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Exploring Tidal Architecture: Amphibious Building Systems for Coastal Communities in Flux

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Abstract

This research employed a mixed-methods approach to investigate amphibious building systems for coastal communities experiencing tidal fluctuations. The study selected three coastal sites through purposive sampling based on tidal range, flooding frequency, and community vulnerability to sea-level variations. Data collection involved structured surveys administered to 120 coastal residents to assess their flooding experiences, existing adaptive strategies, and housing requirements. The researcher conducted systematic observations using a standardized assessment tool to evaluate current building typologies, foundation systems, and flood-resilient features across 80 coastal dwellings. Semi-structured interviews with 25 residents explored their lived experiences with tidal changes, seasonal flooding patterns, and perceptions of amphibious housing solutions. Additionally, the study engaged 8 local boat builders, 6 traditional fishermen, and 4 marine engineers through focus group discussions to understand indigenous water-based construction knowledge and buoyancy principles. Hydrological data collection involved measuring tidal levels, flood depths, and water velocity at selected sites over a six-month period. The researcher analyzed precedent amphibious structures globally through case study documentation to identify successful design strategies and technical mechanisms. Three amphibious building prototypes were developed incorporating floating foundations, vertical guidance systems, and flexible utility connections, then presented to communities for feedback through participatory design charrettes. Quantitative environmental and structural data underwent technical analysis, while qualitative data were thematically coded to extract community needs and design preferences for tidal-responsive architecture.

Keywords: Amphibious Building Systems, Coastal Communities, Tidal Fluctuations, Coastal Sites, Tidal Range, Flooding Frequency, Community Vulnerability.

Introduction

The coastline of Pakistan is about 1050 kilometers along the Arabian Sea, and includes the Sindh and Balochistan provinces. These coastlines areas sustain fishing groups, small scale traders and settlements that rely on marine environment to sustain their lives (Haider, Masood et al. 2025). The growing tidal variability,

sea intrusion in the Indus Delta, cyclonic activity and unpredictable monsoon trends have augmented the possibility of flooding. Districts like Thatta, Badin, Sujawal, coastal areas of Karachi and portions of Gwadar are regularly inundated by tidal water, and this has caused instability in settlements, sanitation networks, and access routes (Ahmad and Khalil 2025). Flooding is not a one-time natural disaster event anymore to many residents since it is a regular environmental phenomenon (Razzak 2022).

The conventional buildings in the coastal strip of Pakistan include mud and thatch buildings (chaunras) to brick masonry and reinforced concrete blocks homes (Arshad, Akram et al. 2025). Certain native typologies in the past adopted the climatic conditions and adapted them with light-weight materials and high platforms, there is now a trend to adopt heavier masonry construction which has made the structuring less adaptable (Akram, Ashraf et al. 2025). Houses are constructed at low ground-level slab foundations thus expose them to the incursion of tidal water in large amounts. Wall deterioration, weakening of foundation, salt crystallization, and reinforcement corrosion are some of the effects of repeated flooding. The financial cost of repeated repairs is disproportionately high to low-income fishing families (Akram, Mubin et al. 2025).

Rise in sea level and decreased supply of freshwater in Indus River have increased the saline intrusion in deltaic areas which have converted agricultural areas into tidal wetland (Aeman, Shu et al. 2023). There is a tendency of communities to respond by increasing the level of plinths by level increments or building temporary embankments with sandbags and rubble (Haq and Milliman 2023). There are reactive measures which are inadequate to long term or escalated flooding. Massive infrastructural plans like embankments and sea walls are costly and hard to sustain especially in isolated coastal communities. Moreover, the natural tidal flows and sediment systems can be interrupted due to the existence of hard barriers (Jamali, Punthakey et al. 2025).

A strategy that can be contrasted with amphibious construction can be proposed that can be more consistent with the changing coastal ecosystem in Pakistan (Ahmad 2024). Amphibious buildings do not need permanent settlements as permanent buildings do, but instead, the building is connected to the ground during normal tidal levels but extends vertically after the floods rise. This system incorporates both the buoyancy foundation underlay and a vertical guidance post to stabilize it during the time of inundation. Elastom with elastics will enable services to be in operation. These systems can be especially suitable in regions where there are predictable tidal courses and average depths of floods, which can be found in most of the Pakistani coastal areas (Jattak, Wu et al. 2023).

Notably, the maritime societies of Pakistan have an extensive indigenous knowledge concerning boat building, water-proofing techniques and buoyancy. Practical knowledge of balance, flotation and longevity in salty areas is evidenced in Wooden fishing boats constructed along the coast of Sindh (Ahmad, Guo et al. 2024). A combination of this art and modern principles of structural engineering can result in cost-effective and culturally sensitive amphibious housing systems. Instead of importing costly external technologies, locally produced buoyant platforms made of ferrocement, closed drums or treated timber can be used to increase this possibility (Ali and Hussain 2023).

In the Pakistani situation, community involvement is essential because land tenure issues, informal communities, and socio-cultural values affect housing choices (Ali and Hussain 2023). The feeling of attachment to ancestral land and fishing routes is commonly given by residents who would rather adapt in-situ than move. Hence, any architectural intrusion should be sensitive towards space culture, gender use of space, and community living (Akram, Mubin et al. 2024).

This study acknowledges resilience as a purely technical issue but also a social process based on local acceptance and ownership. The study examined the amphibious building systems based on the realities of the Pakistani coast through the integration of hydrology monitoring, structural evaluation, and interactive design-build workshops. It aims at offering an architectural answer to tidal variability with evidence based architectural response and providing socio-economic continuity. The study establishes amphibious housing as a climate resilient alternative which can improve safety, dignity and resilience of the vulnerable coastal

communities in Pakistan.

Research Objectives

1. To determine the vulnerability of housing among populations of identified coastal communities in Sindh and Balochistan in regard to their environmental status.
2. To study the technical viability of amphibious building systems in tidal salty conditions of Pakistan.
3. To design culturally relevant and cost-effective amphibious housing models to be applied at Pakistani coastal settlement.

Research Questions

1. Which structural and environmental variables raise housing vulnerability in the coastal areas of Pakistan?
2. Do amphibious building systems have technical and social viability in the Pakistani coast?
3. What role can native maritime building practice play in adaptive housing construction in Pakistan?

Significance of the Study

The research paper will add to climate-resilient housing policies designed in particular to the coastal areas of Pakistan. It provides a counter to moving community and drastic flood defenses with locally based adaptive in-situ amphibious systems based on local craftsmanship and environmental information. The study assists policy makers, planners and architects to come up with a sustainable solution of housing along the coastlines as well as enhancing the community resilience against tidal floods, sea intrusion and other climate threats.

Literature Review

The coast strip region of Pakistan has seen a tremendous change in the environment within the last decades (Kanwal, Ding et al. 2022). Intrusion of sea in the Indus Delta has flooded thousands of hectares of farmland pushing people and changing the settlement pattern (Aeman, Shu et al. 2023). Research on coastal vulnerability of Sindh has pointed to the interaction of weakening river discharge, sea level rise, and cyclonic storm, which together cause a threat (Inam, Clift et al. 2022). The traditional ways of preventing floods like embankments and levees have offered a slight protection, and they breakdown in most cases of extreme incidences (Masood, He et al. 2024).

In Pakistan, traditional coastal housing made lightweight consistency, including timber, bamboo and thatch, could be rebuilt easily after storms. But modernization and permanence have led to use of more of masonry using bricks and concrete blocks. Although these materials are considered durable, they are susceptible to continued salt exposures and dissolution of foundation. Raised plinths are normal but cannot be adequate during large tidal surges (Iqbal, Nazir et al. 2025).

Amphibious housing has been recognized in the world in countries like the Netherlands, Vietnam and Thailand. These structures come with floating foundations, guideposts, and flexible links, making structures to float temporarily (Choorapulakkal, Madandola et al. 2024). Engineering research focuses on the computation of buoyancy, structural stability and anchoring to counteract subsequent water forces laterally. This can be applied to moderate tidal ranges in Pakistan (Akram, Nadeem et al. 2025).

The waterside traditions of indigenous boat-building which are exhibited in Karachi, Ibrahim Hyderi, Keti Bandar, and Gwadar reveal that the locals had a perfect knowledge of flotation and hydrodynamics (Naeem 2022). Construction techniques of wooden hulls and waterproofing methods suggest that the hybrid foundation of housings is possible. Local skills can be incorporated to minimize the construction expenses and enhance ownership by local people (Barış and Gür 2023).

Community participation in disaster risk reduction is emphasized on by socio-economic research in Pakistan. Programs to relocate the people tend to have opposition as people depend on their livelihoods based on

closeness to the coast. Thus, adaptive in-situ housing is becoming a solution that is more acceptable. The scholarly articles indicate that the use of technical innovation and local knowledge in combination with participatory processes can lead to long-term sustainability (Akbar, Ahmad et al. 2024).
Even though the world nowadays has developed amphibious architecture, very little empirical studies have been conducted on the use of amphibious architecture in Pakistan. The current research fills in that gap by incorporating environmental measurements, perception of communities, and prototype testing into a Pakistani coastal model (Ashraf, Ahmad et al. 2023).

Research Methodology

The researchers used mixed methodology in three coastal locations in Sindh and Balochistan that were chosen using criteria of tidal exposure, reoccurrence of floods, and the socio-economic susceptibility. One hundred and twenty households were given structured questionnaires to record the frequency of flooding, damage to houses, and adaptation measures. Observation of 80 dwellings in a systematic manner evaluated materials, types of foundation, levels of plinths, and flood-resistant features. Tidal range, flood depth and water velocity were measured in six months and recorded through measuring gauges and flow meters as hydrological data. The lived experiences of tidal change and sea intrusion were investigated in semi-structured interviews with 25 residents. Indigenous knowledge on buoyancy and material performance in sea-water was investigated in focus group discussions with local boat builders, fishermen, and marine engineers. Environmental data was used to design three amphibious housing prototypes that were shown at participatory community workshops and received the community feedback. Descriptive statistics were used to analyze quantitative data whereas thematic coding was performed on the qualitative data to determine the design preferences and socio-cultural aspects that based on the Pakistani coastal context.

Results and Data Analysis

Quantitative Analysis

Table 1: Flooding Frequency Among Households (n=120)

Flooding Frequency	Number of Households	Percentage (%)
Monthly	42	35.0
Seasonal (Monsoon/Cyclone)	48	40.0
Annual	18	15.0
Rare	12	10.0

Table 1 shows that 75% of households experience flooding either monthly or seasonally, confirming high exposure to tidal and monsoon-related inundation in Sindh and Balochistan coastal districts. Seasonal flooding during monsoon and cyclonic periods is most common (40%), while 35% face monthly tidal intrusion. Only 10% reported rare flooding. These findings demonstrate that water inundation is a recurring environmental condition requiring adaptive architectural strategies rather than emergency-only responses.

Table 2: Existing Foundation Systems in Observed Houses (n=80)

Foundation Type	Number of Houses	Percentage (%)
Concrete Slab on Grade	36	45.0
Raised Plinth (Brick Fill)	24	30.0
Timber / Wooden Piles	10	12.5
Mud Foundation / Improvised	10	12.5

The data indicate that 45% of houses use slab-on-grade foundations, making them highly vulnerable to waterlogging and saline damage. Raised brick plinths account for 30%, reflecting local attempts at elevation-

based adaptation. Only 12.5% use timber piles, primarily in fishing settlements. Mud or improvised foundations remain common in low-income households. The predominance of rigid, ground-bound systems underscores structural vulnerability and limited resilience against tidal variability.

Table 3: Six-Month Hydrological Measurements Across Study Sites

Parameter	Site 1 (Thatta/Sujawal)	Site 2 (Karachi Coast)	Site 3 (Gwadar)
Mean Tidal Range (m)	1.9	2.3	1.6
Maximum Flood Depth (m)	1.3	1.7	1.1
Water Velocity (m/s)	0.7	1.2	0.6

Hydrological monitoring indicates that Karachi's coastal belt experiences the highest tidal range and water velocity, suggesting greater structural demand during peak events. Maximum flood depth reached 1.7m in Site 2, establishing a critical design parameter for amphibious vertical movement. All sites exhibited moderate water velocities below 1.2 m/s, indicating feasibility for guided flotation systems without excessive lateral drift. These measurements confirm technical viability for amphibious systems designed within 2m flotation tolerance.

Table 4: Housing Damage Types Reported by Residents (n=120)

Type of Damage	Households Reporting	Percentage (%)
Wall Cracking / Plaster Loss	68	56.7
Foundation Weakening	52	43.3
Floor Uplift / Settlement	37	30.8
Electrical Damage	49	40.8

The majority of residents reported wall cracking and plaster deterioration (56.7%), largely due to saline water exposure. Foundation weakening affected 43.3% of houses, confirming structural vulnerability. Electrical damage was reported by 40.8%, indicating safety risks during flooding. Floor settlement and uplift further demonstrate instability in slab-based systems. These findings reinforce the need for adaptive foundations capable of temporary flotation rather than resisting water pressure.

Table 5: Community Acceptance of Amphibious Prototypes (n=120)

Response Category	Number	Percentage (%)
Highly Supportive	58	48.3
Supportive	32	26.7
Neutral	18	15.0
Unsupportive	12	10.0

A combined 75% of respondents expressed supportive or highly supportive attitudes toward amphibious housing prototypes. Only 10% were unsupportive, primarily due to cost concerns and unfamiliarity with floating mechanisms. Strong acceptance reflects community preference for in-situ adaptation rather than relocation. Participatory design workshops significantly improved trust and understanding of structural safety mechanisms.

Qualitative Analysis

Theme 1: Normalization of Tidal Inundation

Inhabitants termed tidal flooding as normal especially in the settlements of Indus Delta. The families raise the furniture, build temporary steps using bricks, and during the high tides, they move the belongings. Although a degree of resilience is apparent, the repetition of exposure causes material fatigue and economic stress. The

fact that the flooding is normalized and the call to permanent adaptive housing solutions cannot be overstated.

Theme 2: Structural Fear During Cyclonic Events

The participants of Karachi and Gwadar were found to be fearful of tidal levels soaring quickly at night. One of the concerns was the risk of falling down of the walls, electrical risks, and elderly family members being unable to evacuate. The issue of safety in the event of sudden storm surges was a significant factor of positive reactions to amphibious prototypes.

Theme 3: Indigenous Maritime Knowledge

Ibrahim Hyderi and Gwadar boat builders also provided ideas on the balance of buoyancy, treatment of timber and waterproofing joints. They knew that they could use the materials they could find right here to support floating platforms. The use of maritime craftsmanship in the foundation of houses was considered viable and a custom that was widely accepted by the culture.

Theme 4: Economic Limitations and Financing Needs

The major issue was affordability. Most fishing families have seasonal earnings, so they do not have the capacity to invest. The participants proposed to have a gradual construction, government subsidies, or micro finance support so as to adopt amphibious systems.

Theme 5: Attachment to Coastal Livelihoods

Good emotional and financial connection to fishing did not favor moving. Respondents focused on closeness to boats, jetties, fish markets. The reason why the amphibious housing was the preferred one was that it provided continuity in livelihood, and at the same time enhanced safety.

Theme 6: Value of Community Participation

The citizens liked the participation in prototype discussions. The stair access design, storage space and the location of the veranda were affected by feedback. Engagement made it an ownership and lessened doubts on the new construction technologies.

Discussion

The findings affirm that the coastal communities in Pakistan undergo frequent and structurally devastating tidal flooding especially in the deltaic area of Sindh and the coastal peripheries of Karachi. Hydrological data prove that amphibious systems with the capability of about 2m vertical travel are technically realistic. High community support implies social preparedness of adaptive in-situ solutions. The indigenous maritime knowledge is culturally based with regard to buoyant construction. Nevertheless, economic factors can still be viewed as the primary obstacle, as the policy support, subsidies, and incremental models of implementation should be applied in order to bring the large-scale adoption.

Conclusion

The study has shown that amphibious constructions of buildings provide a technically viable and socially acceptable adaptation approach to the Pakistani communities located along the coast. Repeat tidal inundation, structural susceptibility of slab foundations, and the high costs of repair require the development of alternative ways to build without using statically construction. Hydrological observations support the fact that the mechanisms of vertical flotation are capable of adapting the depth of observed floods. Feasibility and cultural fit are increased through community involvement and integration of local boat-building skills. Even though there are still financial constraints the development of amphibious housing gives an avenue to the development of climate-resilient coastal development in Sindh and Balochistan.

Recommendations

The government bodies need to start pilot amphibious housing in susceptible regions e.g. Thatta and Gwadar. Affordability requires subsidized funding as well as microcredit programs. The technical training programs should be developed which combine the skills of building boats with structural engineering. Adaptive design

standards should be included in the building codes of coastal areas. It is advisable to monitor pilot-prototypes in the long-term to perfect materials, maintenance plans, and scalability in the Pakistani coastal setting.

References

Aeman, H., et al. (2023). "Sinking delta: Quantifying the impacts of saltwater intrusion in the Indus Delta of Pakistan." Science of the Total Environment **880**: 163356.

Ahmad, I., et al. (2024). "Coral reefs of Pakistan: a comprehensive review of anthropogenic threats, climate change, and conservation status." Frontiers in Marine Science **11**: 1466834.

Ahmad, K. and S. Khalil (2025). "Strategic Exploration of Sustainable Socio-Economic Development Initiatives in Pakistan." ASSAJ **4**(02): 558-562.

Ahmad, M. (2024). "An Amphibious Architectural Approach That Dwells On The Problem Of Rising Sea Levels For A Resilient Future For Coastal Settlement." Available at SSRN 5062558.

Akbar, M. S., et al. (2024). "A failure or success?: A qualitative analysis of post-disaster relocation among survivors of 2010 floods in Pakistan." International Journal of Disaster Risk Reduction **100**: 104138.

Akram, N., et al. (2025). "Green Concrete: Enhancing Strength And Workability For Sustainable Construction." Kashf Journal of Multidisciplinary Research **2**(07): 87-120.

Akram, N., et al. (2024). "Decoding the Interplay of Lighting and Spatial Dynamics: A Simulation-Based Case Study Analysis across Diverse Building Orientations." Metallurgical and Materials Engineering **30**(4): 434-458.

Akram, N., et al. (2025). "Beyond Illumination: Stakeholders Perspectives and Preferences on Eco-Friendly Lighting for Sustainable Cities." Metallurgical and Materials Engineering **31**(1): 249-276.

Akram, N., et al. (2025). "OPTIMIZING DAYLIGHT USING PASSIVE STRATEGIES: LIGHT SHELVES AND SOLAR TUBES." Spectrum of Engineering Sciences **3**(6): 474-489.

Ali, S. H. and Z. Hussain (2023). "Impact of climate change on south asia: shifting marine ecosystems in Pakistan." Pakistan Horizon **76**(4): 65-83.

Arshad, W., et al. (2025). "ECO-FRIENDLY CONCRETE: MERGING FLY ASH AND HEMP FOR GREEN BUILDING PRACTICES." Spectrum of Engineering Sciences **3**(4): 1000-1019.

Ashraf, I., et al. (2023). "Community perspectives to improve flood management and socio-economic impacts of floods at Central Indus River, Pakistan." International Journal of Disaster Risk Reduction **92**: 103718.

Barış, R. and N. V. Gür (2023). "Wood-based hybrid construction technology." Journal of Architectural Sciences and Applications **8**(1): 85-99.

Choorapulakkal, A. A., et al. (2024). "The Resilience of the Built Environment to Flooding: The Case of Alappuzha District in the South Indian State of Kerala." Sustainability **16**(12): 5142.

Haider, S., et al. (2025). Understanding Climate Change Impacts on Coastal Communities: Resilience, Adaptation, and Sustainable Development in Sindh, Pakistan. Remote Sensing and GIS Application in Forest Conservation Planning, Springer**:** 391-423.

Haq, B. and J. Milliman (2023). "Perilous future for river deltas." GSA Today **33**(10): 4-12.

Inam, A., et al. (2022). "The geographic, geological, and oceanographic setting of the Indus river–an update." Large Rivers: Geomorphology and Management, Second Edition: 488-520.

Iqbal, A., et al. (2025). "Investigating traditional construction techniques and local knowledge in response to flood vulnerabilities in Sindh, Pakistan." International Planning Studies **30**(1-2): 191-212.

Jamali, S., et al. (2025). "Groundwater Modelling Assessment of a Coastal Agriculture Climate Change Adaptation Strategy Incorporating Green Infrastructure: An Indus Delta Case Study." Groundwater for Sustainable Development: 101484.

Jattak, Z. U., et al. (2023). "Advancing the initiatives of sustainable coastal and marine areas development in Pakistan through marine spatial planning." Science Progress **106**(4): 00368504231218601.

Kanwal, S., et al. (2022). "Vertical ground displacements and its impact on erosion along the Karachi coastline, Pakistan." Remote Sensing **14**(9): 2054.
Masood, M., et al. (2024). "Land use change impacts over the indus delta: A case study of sindh province, Pakistan." Land **13**(7): 1080.
Naeem, A. (2022). A Requiem to the Ailing Landscape of an Ancient Culture: Manchar Lake and the Mohannas in Pakistan. The Routledge Handbook of Cultural Landscape Heritage in The Asia-Pacific, Routledge**:** 495-516.
Razzak, A. (2022). Estimation of Solar Radiation on Coastal Region of Pakistan, University of Karachi, Karachi, Pakistan.