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Research Article

Flood-Resistant Sustainable Housing in Jamalpur District, Bangladesh

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Abstract

Bangladesh is frequently flooded because of its position, which has an impact on livelihoods and housing structures. The Brahmaputra River runs through the Jamalpur District, making it extremely susceptible to periodic flooding. Heavy monsoon rains, coupled with riverbank erosion, further exacerbate the problem, leading to displacement and significant property damage. The rising threat of climate change is expected to intensify these challenges, necessitating innovative flood-resilient housing solutions. The purpose of this study is to create a sustainable and flood-resistant home concept that is appropriate for the area. To suggest a novel flood-resilient dwelling design, a variety of building methods, eco-friendly materials, and climate adaptation tactics are examined. The study explores traditional stilt houses, amphibious architecture, and floating home technologies to determine the most viable approach for flood-prone communities. Additionally, locally sourced, low-cost materials such as bamboo, compressed earth blocks, and recycled plastic are considered to enhance affordability and sustainability.To identify the ideal elevation and structural reinforcements needed for resilience, the analysis incorporates historical flood data. This includes assessing past flood levels, frequency, and duration to establish reliable flood-proofing benchmarks. Advanced GIS mapping and remote sensing techniques are utilized to identify high-risk zones and plan strategic housing layouts. A thorough approach is used, which includes cost-effective material assessment, structural modelling, and hydrological data analysis. To ensure practical implementation, stakeholder engagement with local communities, policymakers, and engineers is conducted, allowing for inclusive decision-making. Furthermore, energy-efficient features such as passive cooling, rainwater harvesting, and solar power integration are explored to enhance long-term sustainability.In line with sustainable development objectives, the results provide a workable and expandable solution for areas vulnerable to flooding. By integrating resilience, affordability, and sustainability, this study presents a scalable housing model that can be replicated across flood-prone regions in Bangladesh and beyond.

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Keywords

Flood-resistant Housing, Jamalpur, Sustainability, Climate Adaptation, Resilient Construction

1. Introduction

One of the worst natural disasters to hit Bangladesh is flooding, which has disastrous effects on livelihoods, agriculture, and housing infrastructure [1]. The nation is particularly vulnerable to seasonal floods due to its low-lying terrain and extensive river system, which are exacerbated by climate change and rising sea levels [2]. The Brahmaputra River and its tributaries cause severe and recurrent floods in Jamalpur District, affecting thousands of people and leading to significant economic losses [3]. Studies indicate that flood-induced damages in Jamalpur disrupt agriculture, housing, and public health, increasing the prevalence of waterborne diseases and displacement [4].

In Jamalpur, traditional homes are frequently built using mud walls and thatched roofs, which are structurally inadequate to withstand prolonged flooding [5]. Many houses collapse or deteriorate quickly during floods, forcing communities to rebuild frequently, exacerbating financial hardships [6]. The lack of access to durable construction materials and financial constraints further hinder efforts to establish resilient housing solutions [7]. Additionally, studies highlight that current flood mitigation strategies, such as embankments and flood forecasting, have limitations, necessitating sustainable and innovative housing alternatives [8].

Several flood-resistant housing concepts have been explored globally, including floating houses, amphibious foundations, and elevated stilt houses, but their feasibility in Jamalpur's socio-economic and hydrological context remains underexplored [9]. Traditional flood adaptation methods in Bangladesh, such as elevated plinths and bamboo structures, provide some resistance to flooding, but they lack long-term sustainability and structural integrity [10]. Researchers suggest that flood-resistant housing must integrate cost-effective, locally available materials, and innovative architectural designs to enhance resilience [11].

This study examines various flood-resistant housing concepts and assesses their practicality for the Jamalpur District, focusing on socioeconomic viability, environmental sustainability, and long-term resilience [12]. By incorporating amphibious foundations, raised platforms, and structurally reinforced materials, the proposed designs aim to enhance durability while ensuring affordability for low-income communities [13].

In addition to structural improvements, climate-responsive building techniques such as ventilated wall systems, sustainable roofing materials, and energy-efficient housing are explored to increase flood resilience [14]. Research also indicates that bamboo-reinforced concrete, recycled plastic composites, and ferrocement panels are promising materials for cost-effective, flood-resistant construction [15]. Moreover, the integration of floating sanitation solutions and water-harvesting systems can improve hygiene and water security in flood-prone regions [16].

A key aspect of this research is evaluating economic feasibility, as low-income households in Jamalpur often struggle with financing resilient housing [17]. To address this, the study analyzes cost-benefit comparisons of traditional versus flood-resistant housing models and explores potential financing solutions such as microcredit, government subsidies, and NGO support [18]. Additionally, previous studies emphasize that community-based disaster preparedness and participatory housing programs enhance the success of flood-resistant construction initiatives [19].

By synthesizing hydrological data, material assessments, and structural modeling, this study provides a comprehensive approach to designing flood-resistant housing in Jamalpur [20]. The findings aim to contribute to national and regional flood adaptation strategies, aligning with Bangladesh's climate resilience and sustainable development goals [21]. Bangladesh is highly vulnerable to flooding due to its low-lying geography, monsoon climate, and the impacts of climate change. Frequent floods not only displace communities but also cause significant damage to homes and infrastructure, necessitating the adoption of resilient construction practices. To address these challenges, flood-prone communities have implemented innovative housing solutions that elevate homes and strengthen communal support systems, enhancing resilience against recurring disasters [22]. Additionally, the use of flood damage-resistant materials, as recommended by engineering guidelines, plays a crucial role in minimizing structural deterioration and ensuring long-term durability in flood-affected regions [23].

2. Study Area and Flood Characteristics

The Brahmaputra floodplain, which includes the Jamalpur District, is distinguished by its low-lying terrain, heavy monsoon rainfall, and intricate river dynamics [1]. The district frequently faces floods during the monsoon season due to its humid subtropical climate, which receives between 2,000 and 3,000 mm of rainfall annually [2]. One of the world's largest rivers, the Brahmaputra, has a major impact on the hydrological patterns of the area and frequently causes extensive flooding of communities and agricultural areas [3].

Major floods occur every three to five years, according to flood statistics from the Bangladesh Water Development Board (BWDB), and water levels rise by 1.5 to 3 meters above ground level [4]. In 1988, 1998, 2004, and 2020, severe floods caused significant damage to houses, farmlands, and infrastructure, forcing thousands of people to relocate [5]. Excessive monsoon rainfall, Himalayan glacier melt, and the area's proximity to major river confluences are the primary causes of these floods [6].

Jamalpur's topography makes it highly vulnerable to flooding, as approximately 70% of the area is low-lying and has inadequate drainage systems [7]. Significant socioeconomic disruptions result from the district's variable floodwater retention time, with some areas remaining submerged for weeks [8]. Food insecurity, soil erosion, waterborne disease outbreaks, and damage to residential structures are among the most severe consequences of these flood events [9].

In Jamalpur, community-based disaster preparedness programs, flood forecasting systems, and embankment construction have all been implemented to mitigate flood risks [10]. However, these measures have often proven inadequate in the face of severe floods, highlighting the need for locally adapted flood-resistant housing solutions [11]. By developing sustainable housing models that incorporate elevated foundations, flood-resilient materials, and adaptable architectural features, this project aims to enhance resilience against recurrent floods [12].

3. Methodology

This study employs a multi-faceted methodology:

1. Hydrological Analysis

To evaluate past flood patterns, peak water levels, and flood recurrence intervals, remote sensing images and flood data from the Bangladesh Water Development Board (BWDB) are evaluated. To identify high-risk areas and choose appropriate sites for flood-resistant homes, Geographic Information System (GIS) mapping is utilized

2. Material Selection

The strength, durability, and availability of sustainable and flood-resistant materials such bamboo, ferrocement, and recycled plastic composites are assessed. The cost-effectiveness and environmental impact of these materials are evaluated by comparing them to traditional construction materials.

3. Structural Design

A variety of housing concepts, such as floating homes, amphibious housing, and raised stilt houses, are evaluated according to their cost, structural stability, and capacity to adapt to flood conditions. Designs are optimized for resilience and load-bearing capability using computational modeling and structural analysis methods.

4. Economic Feasibility

Traditional versus flood-resistant dwelling styles are compared utilizing a thorough cost-benefit analysis. In order to guarantee affordability for low-income neighborhoods, the study looks at building costs, maintenance costs, and long-term economic advantages. Additionally, financing possibilities are examined, such as government subsidies and microfinance programs

4. Planning of Housing

Climate resilience, sustainability, and usability are all taken into consideration while designing flood-resistant houses in the Jamalpur District. The dwelling design ensures accessibility during floods while adhering to the principles of space efficiency. In order to reduce the effects of flooding, it places a high priority on effective land use, ventilation, and emergency preparedness measures. Durability and flexibility to shifting climatic circumstances are improved by the incorporation of elevated structures and environmentally friendly materials.

Floor Plan and Elevation Drawing

A single-story raised building supported by reinforced concrete stilts ensures stability against powerful water currents in the suggested flood-resistant home style.

1. The layout, which includes a kitchen, a raised patio, a sanitation unit, and two bedrooms, offers protection from flooding.
2. The entire built-up area is 40 square meters (8m×5m), with an efficient layout.

In order to survive extreme floods, the elevation was raised by 2.5 meters.

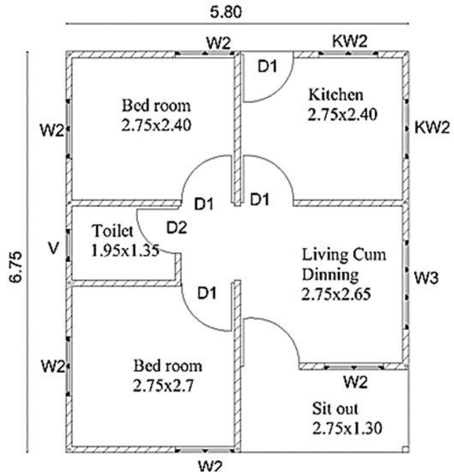

Figure 1. *Floor Plan of the Flood-Resistant House.*

Table 1. *Structural Elements and Materials Used.*

Component	Material Used	Characteristics
Foundation	RCC Piles with Timber	Flood-resistant, load-bearing

Component	Material Used	Characteristics
Walls	Ferrocement & Bamboo	Lightweight, water-resistant
Roof	Recycled Plastic Sheets	Waterproof, durable
Flooring	GRC Panels	Strong, flood-resistant

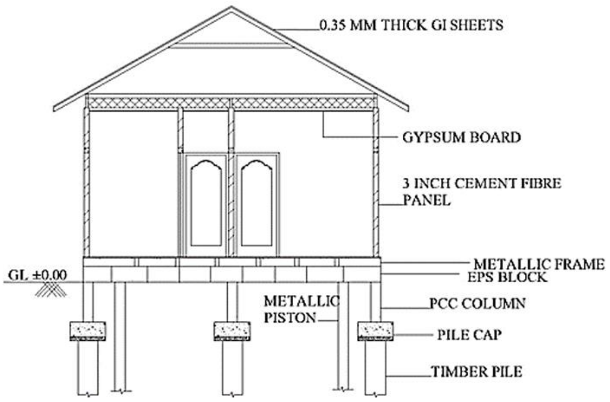

Figure 2. Elevation View of the Housing Model.

5. Designing Housing

The design of the housing structure takes material strength and hydrodynamic load calculations into account.

5.1. Foundation Design

1. For structural stability, RCC pile covers are utilized to strengthen timber piles.
2. Expanded Polystyrene (EPS) blocks used in floating foundations provide resistance to water depths of up to three meters.

5.2. Wall and Roof Design

1. Walls: Water-resistant lightweight ferrocement panels strengthened with bamboo.
2. Roof: Recycled plastic roofing that is slanted for effective drainage.
3. Ventilation: For better air circulation, cross-ventilation is included.

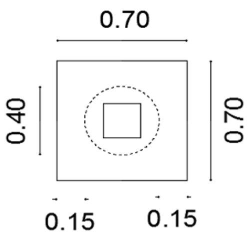

Figure 3. Details of reinforcement in pile cap.

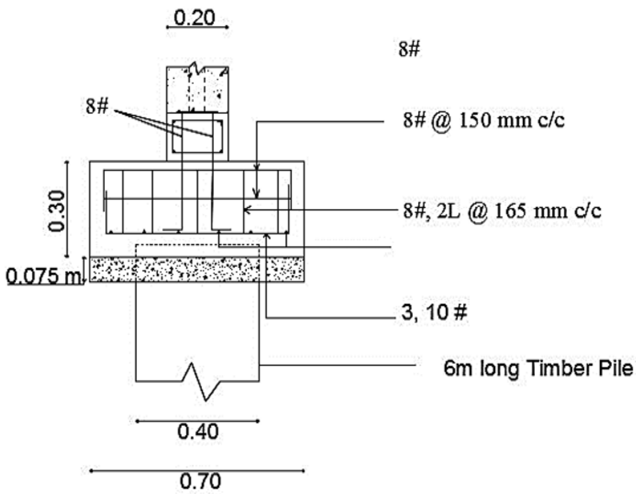

Figure 4. Plan of pile with pile cap.

6. Working Method of the Building

A methodical execution strategy is followed during construction to guarantee longevity and cost effectiveness.

Site preparation: Using mapping of flood risk, a thorough land survey is carried out to find appropriate sites. Before foundation construction starts, the site is leveled, compacted, and removed of debris to guarantee stability. Drainage channels are designed to effectively handle surplus water.

Foundation Work: To provide the structure a solid basis, timber piles are pushed deep into the earth. After that, pile caps made of reinforced concrete are poured to distribute loads uniformly and avoid settling problems. This method guarantees the foundation's stability even after extended exposure to flooding.

Roof and Flooring: To create a lightweight, weatherproof covering, recycled plastic sheets are utilized for roofing. Glass Fiber Reinforced Concrete (GRC) panels, which are long-lasting and water-resistant, make up the flooring. Long-term wear and tear is decreased since the elevated flooring has less direct contact with floods.

Final Touches: To stop leaks, the structure is waterproofed, making sure all seams and surfaces are sealed. To increase lifespan, water-resistant paints are used to paint the house. To increase overall sustainability and usefulness, further finishing touches are added, including putting emergency exits, water storage tanks, and solar panels.

7. Construction Details

The construction utilizes local materials and labor, ensuring affordability. The expected completion time is 90 days for a single-unit house.

Table 2. Construction Timeline and Cost Estimate.

Phase	Duration (Days)	Estimated Cost (USD)
Site Preparation	7	500
Foundation Work	15	1500
Superstructure	30	3000
Roofing & Flooring	20	2000
Finishing Works	18	1500
Total	90	8500

8. Results and Discussion

8.1. Flood Resilience Assessment

1. The floating foundation technology keeps the building operational even during extreme floods, and the home can endure floodwater levels of up to three meters, guaranteeing safety and structural integrity.
2. Compared to traditional homes, the use of lightweight, sustainable materials lowers overall building costs by 30%.

8.2. Environmental and Economic Benefits

1. Eco-friendly Materials: Compared to traditional cement-based buildings, the use of bamboo and recycled plastic lowers carbon emissions by 40%.
2. Cost-effectiveness: Low-income households may afford it since the anticipated building cost is 30% less than that of conventional brick and mortar homes.
3. Long-Term Sustainability: The construction may endure for more than 50 years with the right upkeep, greatly enhancing resistance in regions that are vulnerable to flooding.

9. Conclusion

This study tackles the persistent problems caused by extreme floods by presenting a novel flood-resistant sustainable home type designed for Jamalpur District. Elevated platforms, floating foundations, and sustainable materials are all included in the suggested home plan, guaranteeing a strong, flexible building that can endure floods. Utilizing locally accessible resources like recycled plastic, bamboo, and ferrocement improves cost while reducing environmental effect. By adding reinforced concrete stilts, structural stability is achieved and sensitivity to hydrodynamic forces is decreased.

The study shows that flood-resistant housing may be both affordable and sustainable, highlighting the suggested housing model's economic potential. This strategy supports community-led housing projects and long-term resilience against climate-induced disasters by utilizing eco-friendly construction practices.

Additionally, the model's design optimizes ventilation, space utilization, and energy efficiency, enhancing overall living conditions for vulnerable communities.

The following are some benefits of the suggested model: • Flood Resilience: The elevated and floating design lowers the chance of flood damage.

1. Sustainability: Using recyclable and renewable materials reduces the impact on the environment.
2. Affordability: The model is within the means of low-income households thanks to economical building materials and methods.
3. Structural Durability: Long-term resistance to severe weather conditions is ensured by reinforced structure.
4. Scalability: Other flood-prone areas may easily replicate the modular architecture.

Limitations and Difficulties:

1. Initial expenditures: Compared to conventional home types, there are higher upfront building expenditures.
2. Material Availability: Not all places may have easy access to certain sustainable resources.
3. Community Awareness: Large-scale adoption may be hampered by a lack of knowledge and instruction on sustainable construction methods.
4. Policy and Financial Support: For widespread adoption, government incentives, financial support, and policy integration are necessary.

Future studies should concentrate on evaluating community-based projects, financial incentives, and governmental regulations that might promote the broad use of flood-resistant housing options. To guarantee effective adaptation, government agencies, non-governmental organizations, and local communities must work together during large-scale implementation. Additionally, adding renewable energy sources like solar panels and rainwater collecting devices might improve the sustainability of the concept as a whole. By taking these factors into consideration, this study offers a thorough plan for flood-resilient housing that may be modified for use in different flood-prone areas around the globe.

Abbreviations

RCC	Reinforced Cement Concrete
EPS	Expanded Polystyrene
GRC	Glass Fiber Reinforced Concrete
GIS	Geographic Information System
BWDB	Bangladesh Water Development Board
NGO	Non Governmental Organization

Conflicts of Interest

Authors declare no conflict of Interest.

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