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Designing for Resilience: A Studio-Based Study on Low-Cost Housing for Coastal Communities in Kuakata, Bangladesh

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ABSTRACT

Purpose: This study explores how a studio-based, research-by-design approach can address the urgent need for affordable and cyclone-resilient housing in Kuakata, a disaster-prone coastal region of Bangladesh.

Methods: Conducted in partnership between Southeast University and the Old Rajshahi Cadets Association (ORCA), the project tasked architecture students with designing low-cost, disaster-ready homes for families in ORCA Palli-6. The methodology integrated community engagement, field surveys, and environmental simulations with material prototyping. Residents' input was gathered through interviews and focus groups, informing spatial layouts and priorities. Autodesk Flow Design was used to simulate wind flows and pressures typical of cyclonic conditions, while material testing explored bamboo, compressed earth blocks, ferrocement, and hybrid bamboo-concrete systems. Validation was achieved through feedback loops with residents, expert juries, and comparative design reviews across four student groups.

Findings: Findings highlight that participatory processes combined with a simulation-guided design substantially improve resilience and affordability. Key strategies include clustered courtyards to foster social cohesion and climate regulation, staggered or diagonal sitting to diffuse cyclone winds, raised plinths with integrated drainage and pond swale systems, and hybrid material assemblies that balance cost efficiency with structural safety.

Implications: The project contributes practically by offering a replicable design playbook for NGOs, policymakers, and local organizations working in coastal Bangladesh.

Originality: Theoretically, it advances research-by-design as a method that merges community knowledge with experimental design and simulation to generate transferable insights. By aligning with Sustainable Development Goal 11, the study illustrates how architectural education can bridge pedagogy, practice, and policy to support resilient coastal housing.

1. Introduction

Kuakata, on the southern coast of Bangladesh in the Patuakhali district, is famous for its scenic beaches and rich cultural heritage. Nevertheless, it remains one of the most disaster-prone regions of the country, facing repeated devastation from cyclones, storm surges, and flooding. Events such as Cyclone Sidr in 2007, Aila in 2009, Mohaseen in 2013, and most recently Remal in 2024 have severely impacted the area, particularly its vulnerable communities, who endure cycles of displacement and the destruction of homes and livelihoods (Alam *et al.*, 2018).

Bangladesh's coastal belt is among the most cyclone-prone regions in the world, repeatedly exposed to fast-moving, landfall-intense storms. Between 1960 and 2017, the country experienced more than 30 major cyclonic storms, many striking the Chittagong, Cox's Bazar, and Khulna–Barisal coasts. Wind speeds varied widely, from moderate levels (65–90 km/hr.), as seen in Aila (2009) and Komen (2015), to extremely severe storms (above 220 km/hr.) such as the 1991 cyclone (225 km/hr.) and Sidr (2007, 223 km/hr.). Storm surges have often been devastating, reaching up to 20–22 feet in the 1965–1966 cyclones (BMD, 2020).

The human toll has been immense. The Bhola Cyclone of 1970 remains the deadliest, killing over 300,000 people. Other catastrophic events include the 1991 Chittagong cyclone, which claimed 138,000 lives, and the Urir Char cyclone of 1985, which killed around 11,000. More recent cyclones such as Sidr (2007), Aila (2009), Bulbul (2019), and Amphan (2020) also caused thousands of deaths along with large-scale agricultural and housing losses (Reyha, 2021).

In the aftermath of such disasters, recovery and rebuilding have involved both government agencies and private organizations. While the state has focused on large-scale infrastructure and emergency responses, non-government actors have emphasized community-based needs such as housing, schooling, and livelihood restoration (Mellucci *et al.*, 2014). Among them, organizations like OBHIZATRIK and the Old Rajshahi Cadets Association (ORCA) have played crucial roles in reconstructing schools and homes damaged by cyclones (Hridi & Jami, 2024).

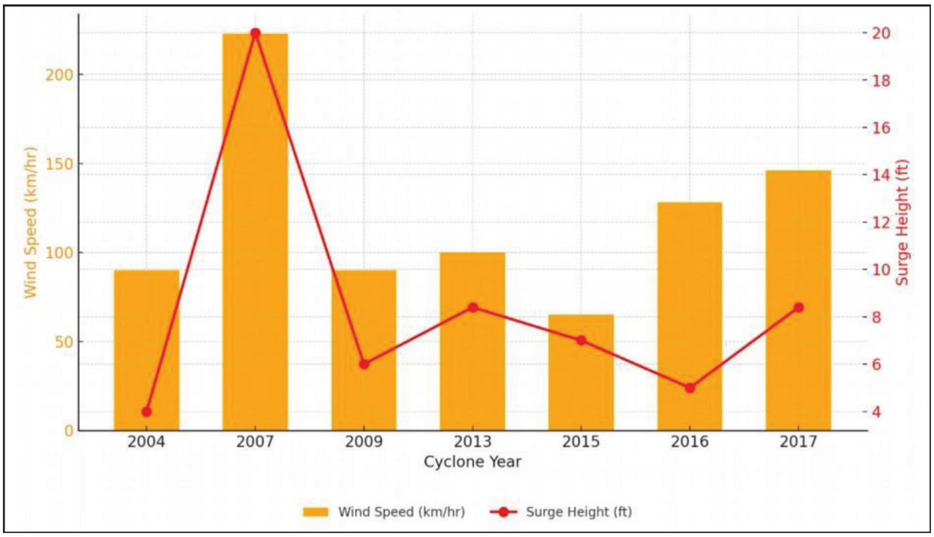

Figure 1: Cyclones in Bangladesh (2004–2017): Wind Speed and Surge Height (BMD, 2020).

After Sidr in 2007, ORCA established ORCA Palli 6 in Khajura village, Kuakata, as a relief settlement for 80 landless families who had lost everything. Over time, however, the initial tin-built shelters deteriorated, worsened by land subsidence and water logging caused by dredging activities nearby, eventually rendering many dwellings uninhabitable (Field Survey, 2025), and over time many households adapted to these built forms (Rashid, 2024). This experience illustrates the urgent need for disaster-resilient and affordable housing in coastal Bangladesh. In this context, affordability is not only an economic question but also a matter of survival and dignity. Durable, elevated housing solutions are essential to protect lives and sustain communities. The urgency aligns with both the Constitution of Bangladesh and the National Housing Policy of 2016, which recognize housing as a fundamental human necessity equal to food and clothing (NHA, 2016). It also resonates with Sustainable Development Goal 11, which emphasizes inclusive, safe, resilient, and sustainable human settlements by ensuring adequate housing for all by 2030 (UN, 2024). There is a paradox that can be found in the National Housing Policy in 1993 and 2016 (Revised); the policy mentioned affordable housing, but it does not define the concept of affordable housing and its implementation (Amin, 2025).

ORCA's continued efforts through the redevelopment of ORCA Palli 6 reflect this vision. Originally a post-disaster response, the project has evolved into a comprehensive community development initiative. The plan envisions 66 new residential units along with guest houses, a mosque, a community center, shops, improved roads, and a complete water supply and drainage system. The ambition is to create a self-sufficient and disaster-ready settlement that can serve as a model for similar coastal communities.

In line with this effort, the architectural design studio "Design IX: Community Architecture II" at Southeast University integrated this challenge into its curriculum. Students visited Kuakata, engaged directly with residents, and examined the environmental and social realities of the site. Their design proposals highlighted cultural sensitivity, community participation, cyclone resistance, water management, and economic sustainability. Through these exercises, students addressed pressing local needs and explored how architectural interventions can advance national housing priorities and contribute to global sustainability agendas, particularly the objectives of SDG 11.

2. Background

The Bengal Delta, shaped by the Ganges and Brahmaputra, is the world's largest delta and the foundation of Bangladesh's landscape. Its shifting land-water boundaries have long influenced settlement patterns, livelihoods, and cultural diversity. This dynamic geography underpins the need for resilient and affordable housing in the coastal belt (Rashid, 2022). Housing is recognized in the Constitution of Bangladesh as a fundamental human need and reaffirmed in the National Housing Policy of 2016, which emphasizes affordability, tenure security, access to services, and disaster protection. These priorities are most urgent in the coastal belt, where cyclones, storm surges, and flooding remain recurring threats. Affordable housing, typically understood as costing no more than thirty percent of household income, must also align with cultural practices and local contexts. In the Bengal Delta, vernacular responses such as elevated plinths, sloped roofs, and drainage systems reflect a long-standing tradition of ecological knowledge and adaptation (Harun-Or-Rashid *et al.*, 2022; Rashid, 2023).

Resilient design has become a central principle in architectural responses to climate change. It entails not only reinforcing buildings against hazards but also anticipating long-term pressures such as rising sea levels and changing weather patterns (Attia *et al.*, 2021; Enderami *et al.*, 2022). For low-income communities, resilience is especially critical: many dwellings are poorly insulated, made from fragile materials, or located in high-risk flood zones (Bezgrebelna *et al.*, 2021). Embedding resilience within affordable housing thus reduces vulnerability, lowers household utility costs, and prevents displacement, positioning resilience as a question of social justice that seeks to guarantee safe shelter for all (Winston, 2021).

Participatory architecture rests on the belief that involving communities in design leads to more meaningful and durable outcomes. This approach integrates local knowledge, skills, and materials while fostering dialogue, reflection, and a sense of collective ownership (Delaqua, 2024). Rooted in traditions such as Pooley's concept of community architecture and Lefebvre's view of space as socially produced, participatory practice emphasizes agency, empowerment, and place attachment ("Strategies and Tactics of Participatory Architecture," 2022; Luck, 2018). Over time, a repertoire of techniques—charrettes, workshops, gaming, and digital simulation—has been developed to ensure that design reflects community priorities and capacities.

Figure 2: Regional Context: Location of ORCA Palli within Barisal Division and Kuakata (left); Satellite View of ORCA Palli 06 Site Boundary (Right)

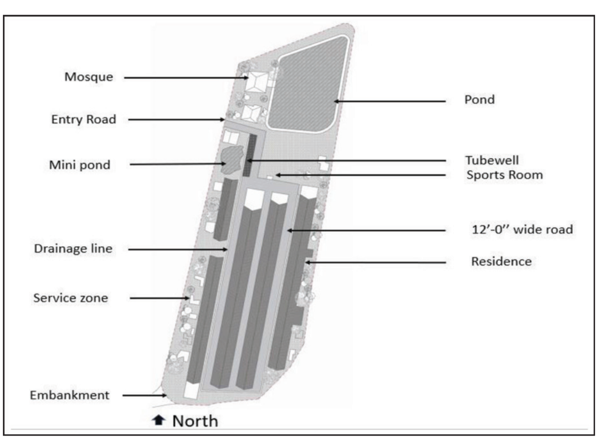

Figure 3: Existing Masterplan; Coastal Proximity and Access Routes to ORCA Palli

Bangladesh's disaster management has evolved from temporary relief after the 1970 cyclone to the institutionalization of cyclone shelters, multipurpose schools, and preparedness programs like the Cyclone Preparedness Programme (CPP). These efforts resonate with the Sendai Framework for Disaster Risk Reduction (2015–2030), which emphasizes reducing disaster losses in lives, assets, and livelihoods (UNDRR, 2017). Similarly, Sustainable Development Goal 11 commits to making human settlements inclusive, safe, resilient, and sustainable, ensuring adequate housing for vulnerable groups by 2030.

Within this policy and theoretical context, research by design has emerged as a valuable methodology, positioning design itself as a means of scholarly inquiry. Originating in Dutch practice at Delft, it demonstrates how iterative design processes produce new insights and alternative futures, validated by expert peer review (Hauberg, 2011). By combining analysis and proposal, this method extends architectural practice beyond problem-solving into critical investigation.

Figure 4: Site Surrounding, ORCA Palli: Water-Adjacent Homestead with Tin Roof and Vegetation Reflection (left); Cluster of Rural Dwellings Surrounded by Tall Palms and Open Path (middle); Dilapidated Corrugated Iron Houses with Visible Structural Damage (Right)

The Old Rajshahi Cadets Association (ORCA), founded in 1972, has long been active in post-disaster rehabilitation through its "ORCA Pallies." After Cyclone Sidr in 2007, ORCAPalli6 in Kuakata provided housing for eighty displaced fishing families. While strategically located near the Bay of Bengal to sustain fishing livelihoods, the site remains highly exposed to flooding and erosion. Sixteen years later, field documentation reveals that much of the settlement has deteriorated due to land subsidence and structural decay.

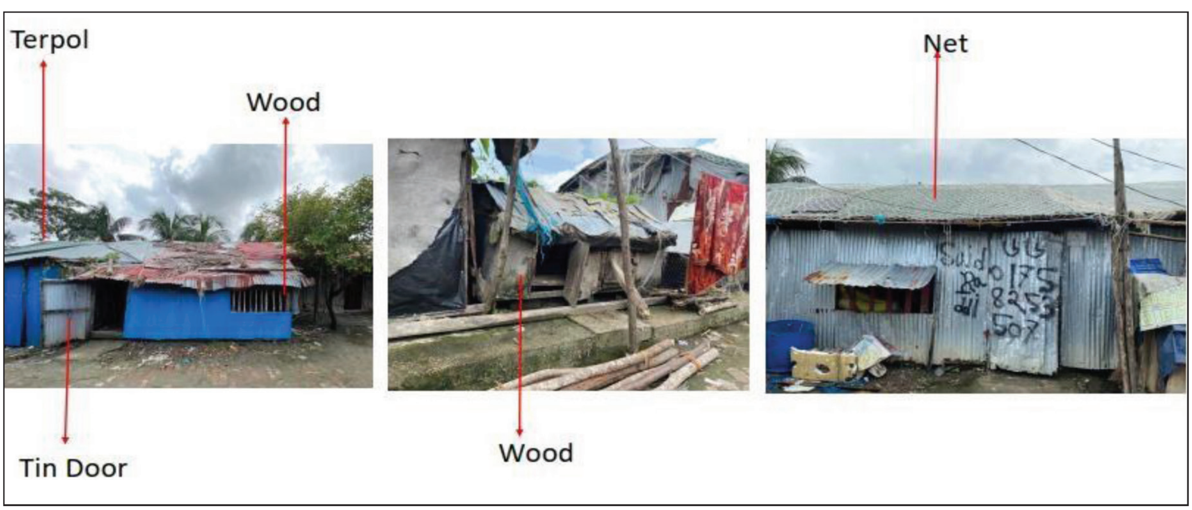

Figure 5: Existing Housing ORCA Palli 6: Tin and Roof with Bright Blue Walls and Tin Door (left); Makeshift Housing Structure with Wooden Framework and Temporary Coverings (middle); Corrugated Sheet House with Fishing Net Used as Faccade Screen (Right)

Figure 6: Existing Housing ORCA Palli 6: Narrow Lane Between Back-to-Back Houses with Overhead Wires (left); Interior Scene Showing Raised Bamboo Platform (Chouki) Over Mud Floor (right)

The existing master plan of ORCA Palli illustrates basic infrastructure, including residences aligned along a central 12-foot-wide road, ponds, drainage lines, a mosque, service zones, and embankments. However, site visits show that many houses rely on temporary and fragile materials: tin doors, coverings, wooden supports, and nets with little durability against heavy rain or storm winds. Roof leakages, poor ventilation, and unsafe foundations are common. Images of the current condition further highlight degraded drainage systems, deteriorating pathways, and makeshift repairs that underscore the settlement's vulnerability.

This scenario demonstrates the limitations of past housing interventions: although ORCA Palli initially provided shelter and restored livelihoods, its long-term sustainability has been compromised by environmental pressures, weak materials, and a a lack of adaptive design. ORCA, in partnership with Southeast University's Department of Architecture, has launched a design studio to revitalize the settlement. The initiative integrates resilient design, participatory architecture, and research by design, aligning local needs with the global commitments of Sustainable Development Goal 11.

3. Research Question, Aim, and Objectives

This research is guided by the central question: How can studio-based architectural design contribute to affordable and disaster-resilient housing solutions for underprivileged communities in coastal Bangladesh, such as Kuakata? The aim is to explore and demonstrate how a research-by-design approach can generate practical and sustainable housing models that directly align with Sustainable Development Goal 11 on sustainable cities and communities.

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To achieve this aim, the study sets out three key objectives. First, it seeks to investigate the environmental, socio-cultural, and economic context of Kuakata, a disaster-prone coastal area where vulnerability to cyclones and flooding is acute. Second, it examines the needs, aspirations, and living conditions of low-income households in ORCA Palli 6 through field surveys and participatory engagement with the community. Finally, it applies the research-by-design method within a student-led studio project to produce affordable and cyclone-resilient housing prototypes tailored to the realities of vulnerable coastal settlements.

3.1. Methodology: Design-Based Research Approach

This architectural design studio employed *a research-by-design approach* (research integrated with the design process) to address real-world housing challenges in Kuakata, a disaster-prone coastal region of Bangladesh. The project was framed within the context of the research-by-design approach, integrating qualitative, quantitative, and experimental methods through a collaborative design process (Lucas, 2016).

3.2. Conceptual Frame: Research by Design

This form of research is produced more directly through practice, as opposed to more conventional academic activities. It is increasingly important in architecture and represents an academic recognition of alternatives to the production and consumption of literature as ways of thinking. The idea is often expressed as 'thinking by doing' (Lucas, 2016). Donald Schön's concept of the 'Reflective Practitioner' is influential here, suggesting that the practitioner constantly critiques their actions, reflects, and changes as appropriate, creating a loop of reflective practice, acting, and thinking as a continuum (Tan, 2020). Characteristics of research by design approach (Lucas, 2016; Groat & Wang, 2001):

- It serves as an academic recognition of different ways of thinking and generating knowledge, often described as "thinking by doing."
- A key concept is reflective practice, where the practitioner continuously critiques their actions, reflecting as they are taken and making appropriate changes ("thinking in action").
- Architectural production in practice-based research should go beyond being merely functional or meeting a brief; it must have "value added" through investigation that contributes to our knowledge of the discipline and the wider world.
- For work to be considered practice-based research, it must demonstrate a unique contribution to knowledge.

In summary, "design-based research," as reflected in the sources' concept of "practice-based research" or "research by design," involves generating knowledge directly through the process of designing and building. It leverages the inherent investigative activities of practice, formalizes them using diverse research methods (qualitative, quantitative, experimental, case studies, simulations, etc.), incorporates reflective practice, and aims to make a documented contribution to knowledge, sometimes through non-textual outputs like built projects or exhibitions.

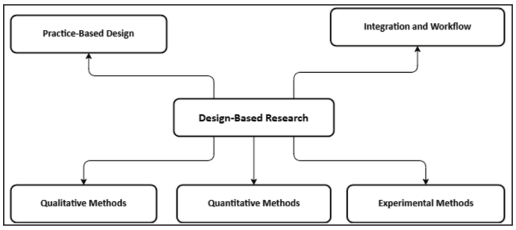

Figure 7: Methodology (Design-Based Research Approach) (Source: Rashid & Amin, 2025)

3.3. Research Approach

The housing studio was conducted in partnership with the Old Rajshahi Cadets Association (ORCA) to propose actionable designs for the reconstruction of ORCA Palli 6 in Kuakata. The project site served as a real-world case study, with four parallel design groups functioning as embedded case studies. This framework enabled comparative analysis of architectural responses to shared environmental, cultural, and socio-economic challenges.

- **Resident Selection and Consultation:** Community engagement was central to the research process. Residents were selected for consultation through purposive sampling, ensuring inclusion of households representing different age groups, occupations (particularly fishing families), and housing conditions within ORCA Palli 6. This approach allowed the studio to capture a spectrum of lived experiences and priorities. Consultations took the form of semi-structured interviews, focus group discussions, and informal conversations during site visits.
- **Input Analysis:** Resident input was grouped into categories such as safety and resilience, spatial needs, material performance, and community services. These were integrated into SWOT analyses and spatial programming exercises, which directly shaped site layouts, clustering strategies, and design prototypes. The qualitative insights were also cross-checked with observational data and photographic documentation, ensuring consistency between residents' narratives and on-site realities.

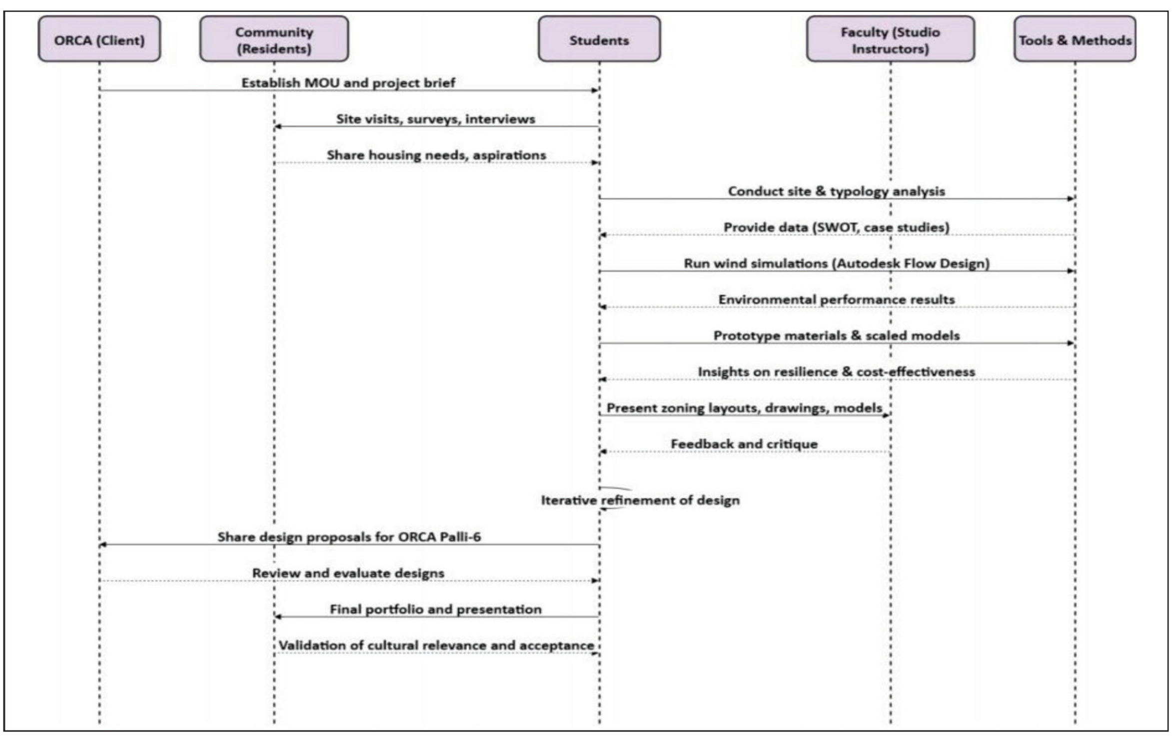

Figure 8: Research by Design Workflow: Kuakata Housing Studio

4. Studio Process and Activities

The Kuakata Housing Studio was designed as an immersive academic initiative that engaged students with the real challenges of designing for disaster-prone coastal communities in Bangladesh. In collaboration with the Old Rajshahi Cadets Association (ORCA), students worked to create sustainable, affordable, and context-sensitive housing solutions for families in ORCA Palli 6. The studio combined fieldwork, participatory learning, and design practice, ensuring proposals were rooted in local realities.

Students began with site visits, surveys, and interviews that documented housing conditions, flooding risks, land levels, and cultural practices. Using these insights, they carried out SWOT analyses, prepared diagrams and maps, and studied case examples of shelter projects from Bangladesh and abroad. This research informed spatial programming, zoning layouts, and clustering strategies tailored to community life and environmental constraints.

In design development, students produced site layouts, building forms, and structural systems using CAD, BIM, and physical models. Wind simulations guided roof and orientation choices, while sustainable local materials such as bamboo and compressed earth blocks were incorporated. Throughout the process, multiple review sessions provided expert feedback, leading to refined proposals presented at mock and final juries.

The studio concluded with individual design portfolios documenting the entire process. These works demonstrated the students' ability to integrate architectural thinking with practical problem-solving, cultural sensitivity, and social responsibility.

5. Community-Centered Analysis and Housing Typologies at Orca Palli

The primary focus of this qualitative investigation was ORCA Palli, a post-cyclone rehabilitation settlement in Kuakata, where 80 vulnerable families were relocated after Cyclone Sidr. This site served as the core design and research ground for the housing studio. However, to gain a broader understanding of the regional context, students also studied other settlements in the vicinity— Rakhaiyen Palli, 80 Ghor, and 18 Ghor—as comparative references. These supplementary site visits allowed the teams to grasp shared challenges, cultural nuances, and environmental conditions prevalent across coastal communities.

5.1. Site and Community Analysis

At ORCA Palli, students conducted direct observation, informal interviews, and community engagement activities. These interactions provided critical insights into:

Table 1: Community Challenges and Living Conditions in ORCA Palli

Issue Area	Observations / Insights
Structural Deterioration	Tin-shed homes, initially emergency shelters, are rusted, broken, and unsafe in bad weather.
Water logging & Flooding	Land subsidence and poor drainage cause flooding during monsoon; homes become unusable.
Lack of Infrastructure	Internal roads are unpaved, no formal drainage; solid waste builds up in open areas.
Limited Services	Limited access to clean water, sanitation, education, and healthcare; tube wells and shared, often unhygienic, latrines are inadequate.
Livelihoods	Income sources mainly fishing and day labor; monthly income ranges from BDT 5,000–9,000.
Household Structure	Average family size is 4–7 people per household.

Source: Field Survey, 2025

Despite these challenges, residents expressed strong aspirations for safe, permanent, and climate- resilient housing. Their desire for ownership, dignity, and community cohesion deeply influenced the studio's design approach.

5.2. Typology Studies

While ORCA Palli remained the design focus, understanding regional housing typologies was critical. Students documented construction methods, spatial arrangements, and material usage across multiple nearby settlements to develop a robust comparative typology.

Table 2: Existing Housing Typologies and Vulnerabilities in Coastal Settlements

Aspect	Observations / Insights
Construction Techniques	Houses used corrugated tin roofs, bamboo/wooden frames, and mud or brick foundations; materials failed due to corrosion, rot, and fatigue.
Layout Patterns	Typically, single-room linear layout; outdoor kitchens and semi-detached toilets; verandas were exposed but multifunctional.
Vulnerability	Lack of elevation made homes vulnerable to storm surges and flooding; poor ventilation caused overheating in summer.
Cultural Features	Included vernacular elements like shaded verandas and alignment along shared community spaces such as roads.
Foundation Issues	Homes lacked stable elevation or proper foundations, increasing flood risk.
Privacy & Comfort	Poor thermal performance and inadequate spatial separation led to a lack of privacy and discomfort.
Material Limitations	Relied heavily on locally sourced but short-lived materials, lacking durability in harsh coastal climates.

Source: Field Survey, 2025

These typological patterns informed the adaptive design principles at ORCA Palli—incorporating modularity, cross-ventilation, shaded verandas, elevated plinths, and climate-sensitive layouts, while respecting local spatial customs.

In summary, ORCA Palli was the central research and design site, but the inclusion of neighboring settlements enriched the students' understanding of coastal housing typologies, enabling a more informed, empathetic, and context-sensitive approach to low-cost, disaster-resilient housing design.

6. Simulation-Based Design for Cyclone-Resilient Coastal Housing

As part of our architectural studio focused on community housing for vulnerable coastal populations, we utilized Autodesk Flow Design to simulate wind behavior and pressure distribution across the proposed housing layout for ORCA Village-6 in Kuakata. This simulation was crucial in understanding how cyclonic wind forces commonly reaching up to 60 m/s (216 km/h) in the region would interact with built forms (Amin, 2019). Through this digital analysis, we identified critical pressure zones and airflow patterns that directly influenced our design strategy. We adjusted the mass orientation, roof geometry, and building placement based on the transient wind flow data.

All four groups used Autodesk Flow Design to simulate wind effects on proposed housing layouts for the coastal community of Kuakata, with wind speeds up to 60 m/s (216 km/h). Their design strategies aimed to reduce wind pressure, turbulence, and uplift risk to make community housing safer and more resilient during cyclones.

Group 01 focused on clustered massing along a winding axis, using staggered building placement, varied roof forms, and tall civic buildings as windbreakers. Their simulation revealed concentrated wind pressures at corners and rooftops, highlighting the need for structural reinforcements like cyclone clips.

Group 02 prioritized climate-responsive layouts with courtyard-based clusters and perimeter tree belts as natural wind barriers. Their findings showed high wind pressures at denser clusters and recommended hip roofs and landscaping to mitigate uplift and channelized wind flows.

Group 03 emphasized hierarchical planning, with green corridors and cluster spacing to manage airflow and pressure. Their simulation indicated that strategically spaced blocks and vegetation reduce wind speed at ground level, and raised plinths and ponds help with flood protection.

Group 04 combined 3D simulation with diagonal building orientation and decentralized clusters, using green belts and water bodies along the perimeter as wind and flood buffers. Their design placed larger structures at the windward edge for protection and open courtyards for pressure relief.

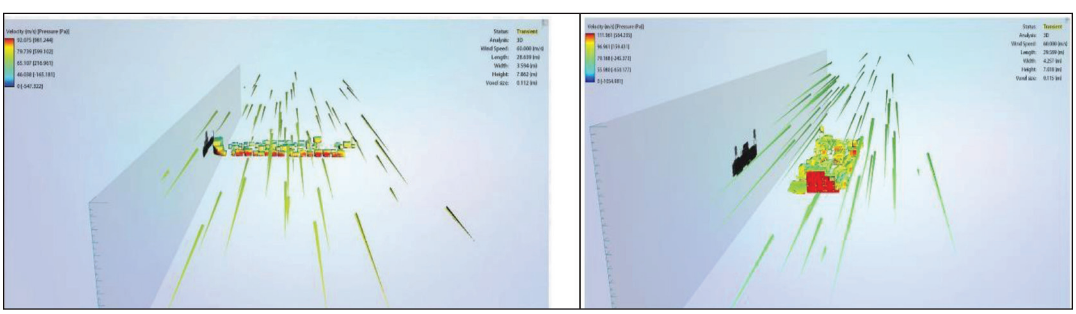

Figure 9: Wind Pressure Analysis at 60 m/s on Clustered Massing(Group 01), Simulation Showing Windstream Behavior Across Modular Grid (Left to Right) (Group 02)

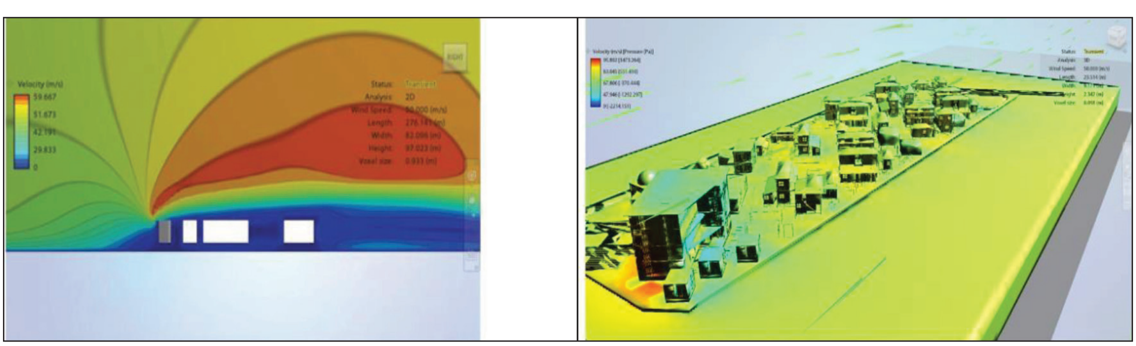

Figure 10: Wind Velocity Contour Over Linear Built Form at 60 m/s (Group 03), Cyclone-Level Stress Analysis at 50 m/s Wind Flow (Left to Right) (Group 04)\

Table 3: Summary of Wind Simulation-Informed Design Approaches by Student Groups

Group	Wind Simulation Analysis	Interpretation & Observation	Key Design Integration Strategies
Group 01	- Max Wind Velocity: 92.075 m/s Pressure: −547.322 to +981.244 Pa Voxel Size: 0.112 m 3D transient analysis	Clustered layout absorbs/dissipates pressure High turbulence at sharp corners & rows Pressure at windward facades/roofs	Meandering central axis- Staggered clusters Community core & green belts Gable/hybrid roofs Tall civic windbreakers Elevated water tank
Group 02	Max Wind Velocity: 111.961 m/s Pressure: 0 to +564.235 Pa Voxel Size: 0.115 m Transient analysis	High pressure in southern dense clusters Roof uplift risk Channelized flow/vortices between units	Courtyard-based clusters Perimeter trees/wind barriers Controlled building spacing Gable & hip roofs Windward landscaping
Group 03	Max Wind Velocity: 59.667 m/s 2D transient analysis Domain: 276x82x97 m Voxel Size: 0.933 m	High turbulence in velocity arcs Effective wind deflection by building mass Reduced wind at ground via buffers	Hierarchical zoning green corridors & cluster spacing Central community functions Raised plinths & pond Perimeter trees/walls
Group 04	Max Wind Velocity: 95.829 m/s Pressure: −2214.151 to +1473.264 Pa Voxel Size: 0.115 m 3D transient	Turbulence/vortices at dense western edge Stress points near large buildings Reinforced roofing needed	Staggered/diagonal buildings Perimeter green belts & water Large windward structures Decentralized clusters Diagonal paths Open courtyards

6.1. Cyclone-Calibrated Design Targets

Evidence from previous cyclone studies, NE / NNE approach path; climatologically common for Bay cyclones. (BMD, 2020). The studio added 6 design targets to deal with the cyclones resilient design. They are:

- Max sustained wind: 110–120 km/h, gusts 130 km/h; lowest central pressure 978 hPa.
- Catalogue peak wind (station/region) recorded for Mora: 146 km/h at landfall corridor.
- Duration/scale: 72 h life, 1,086 km track, ~20.4 km/h translational speed (fast-moving).
- Monitoring & warnings: BMD issued Special Weather Bulletins (3-hourly/6-hourly), with DWR radar support (Khepupara, Cox's Bazar; cone-of-uncertainty graphics) and ECMWF products.
- Rainfall context: WRF/ECMWF simulations used for 10 m wind and 6-hourly rainfall fields during approach/landfall windows.
- Surge benchmarks (for freeboard bands) from national records: Sidr 2007: 15–20 ft, Komen 2015: 5–7 ft, Roanu 2016: 4–5 ft.

6.2. Design Targets and Checks (Tie to Section 6 Simulations)

- Sitting & orientation: Prefer diagonal / staggered settlement patterns and courtyard clusters to break aligned gust corridors along dominant NE/NNE tracks; maintain varied block edges to diffuse pressure zones.
- Envelope & roof: Verify continuous load paths (rafter-to-wall-to-plinth), hurricane straps/tie- downs and edge/corner fastener spacing for ≥146 km/h local maxima; adopt hip or low-pitch gables to reduce uplift.
- Freeboard & safe-zone sitting: Set settlement freeboard bands (and critical facilities) with reference to 15–20 ft severe surge corridors; combine raised plinths with pond–swale storage to keep routes dry.
- Drainage & short-duration rainfall: Size retention ponds, bio swales and courtyard depressions using the event's 6-hourly rainfall simulation envelopes; distribute storage to maintain walkability during 24–48 h peaks.
- Material strategy: Pair treated bamboo / earthen composites with selective precast members for rapid

repair after Mora-class wind/rain loads; specify sacrificial cladding layers for low-cost replacement. (Derived from Section 7 prototypes; calibrated to Mora loads.)

- Early-warning integration: Embed way finding to shelters, roof tarp anchor points, and staging nodes in layouts; align community protocols with BMD's Special Weather Bulletin cadence and local DWR radar coverage.

7. Architectural Strategies

The Kuakata Housing Studio was conceived as an academic design exploration that addressed the real challenges of disaster-prone coastal regions in Bangladesh. Conducted in collaboration with the Old Rajshahi Cadets Association (ORCA) and framed within the principles of community architecture, the studio engaged four student groups in designing sustainable and affordable housing for landless and vulnerable families in ORCA Palli 6. The process combined field-based research, participatory feedback, and experimental design thinking to generate context-sensitive solutions.

Each group approached the task with a distinct design philosophy while addressing shared concerns such as resilience to cyclones, affordability, cultural relevance, and long-term adaptability. The following sections present their design development process, spatial strategies, and architectural responses, all rooted in community engagement and environmental resilience.

7.1. Studio Group 1: Emphasizes the Design's Fluid Spine and Rootedness in Local Culture

7.1.1. Design Philosophy and Concept

The core concept is rooted in mimicking the fluid and organic nature of oceanic curves, drawing inspiration from the nearby Bay of Bengal. This symbolic gesture creates a built environment that:

Respects the coastal context by integrating wave-like, flowing lines into the master plan. Establishes a visual and spatial connection to water, reflecting the cultural and emotional ties of the local community with the ocean. Encourages a natural and intuitive circulation system, guided by the meandering form reminiscent of waves.

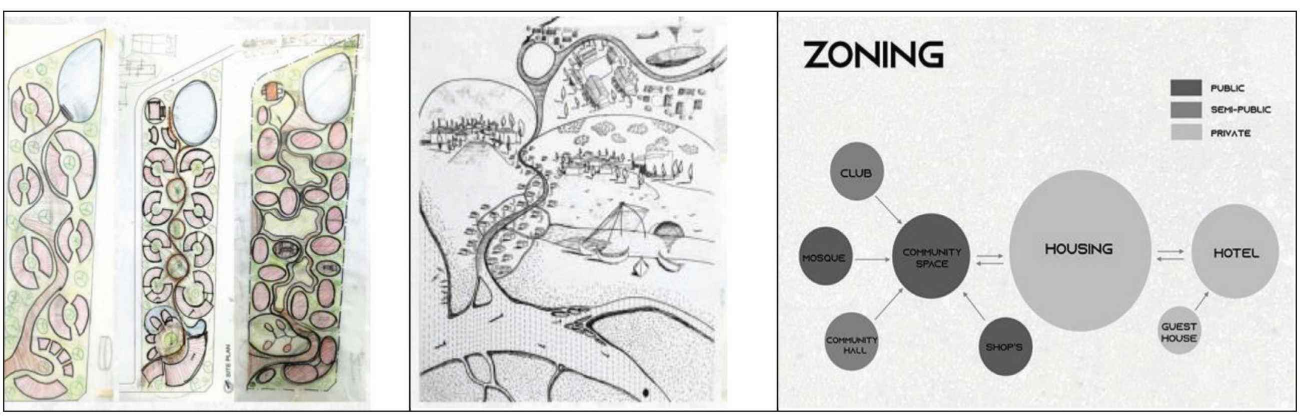

Figure 11: Design Philosophy and Concept; Form Evolution Diagrams (left); Conceptual Community Sketch (middle); Zoning Strategy Diagram (right)

7.1.2. Spatial and Design Features

- **Master Plan & Circulation:** The site is organized along a central curved spine, inspired by oceanic waves. This spine connects two prominent circular hubs one serving as the community center and the other as a community income- generation zone (e.g., ORCA hotel, shops). This organic flow ensures smooth functional zoning and visual continuity across the site.
- **Housing Clusters:** Houses are arranged in a courtyard-based layout, fostering community interaction, passive cooling, and security. Each group of houses shares a courtyard, enhancing social cohesion and encouraging communal activities like cooking, gatherings, and children's play.
- **Connectivity and Accessibility:** Soft pavements link the main spine to all clusters, ensuring pedestrian-friendly access and seamless mobility across the site. Public amenities such as the mosque, community hall, shops, and clinic are strategically located near the main entrance for easy access.
- **Green and Productive Landscape:** Dedicated areas along the curved path are used for vegetable farming, generating income for residents while promoting sustainability and self-reliance. Trees and landscaping elements support shading and improve microclimatic conditions.

- **Programmatic Diversity:** The program includes 64 housing units, 4 guest houses, a hotel, mosque/maktab, imam residence, pharmacy, daily shop, club, community hall, and cattle shed, reflecting the diverse needs of a resilient and self-sufficient community.

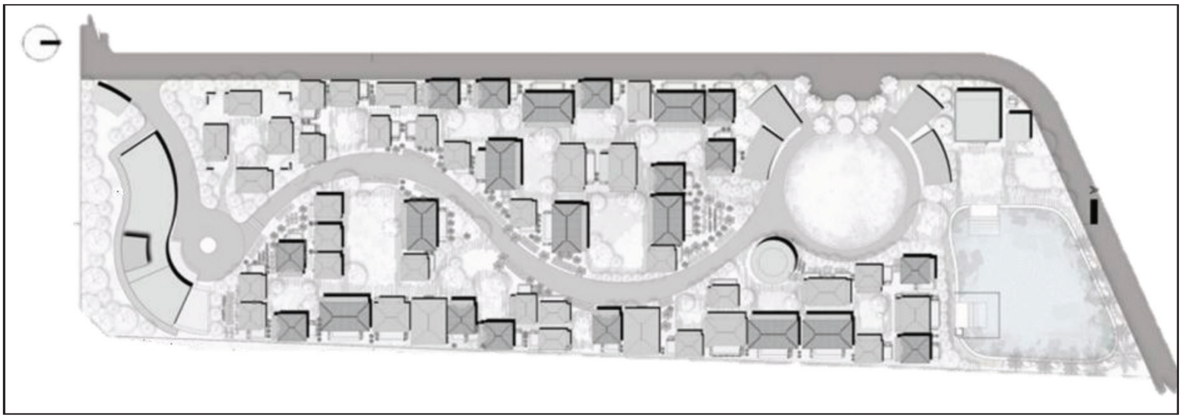

Figure 12: Master Plan (entry, curved residential spine, public space node, pond and services)

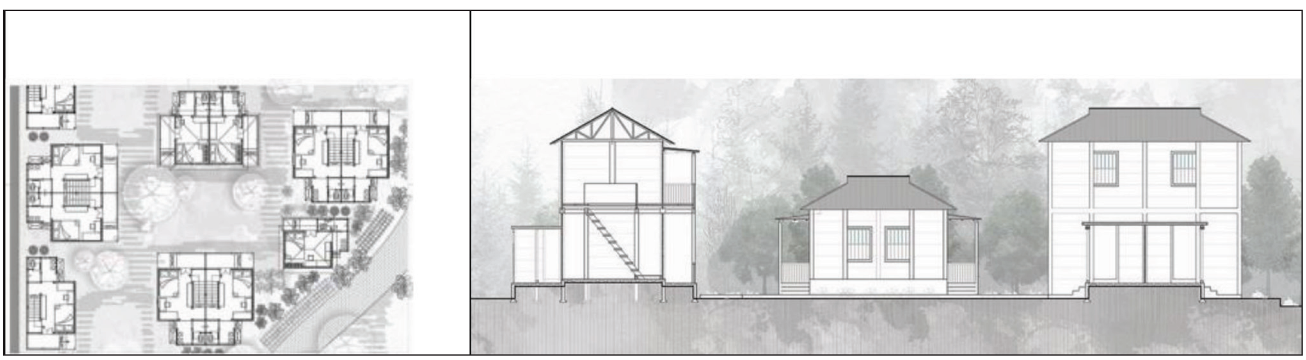

Figure 13: Housing Clusters: Plan and Section (From left to right)

Figure 14: 3D View: Pond and Entry Zone (left); Central Cluster with Pathways (middle); Community Facilities and hotel (right)

7.1.3. Construction and Cultural Integration

- **Structural System:** Use of pre-cast concrete pillars and slabs, enabling modular, time-efficient, and cost-effective construction. Palm wood trusses and cement sheet roofing reflect vernacular practices while using durable materials. Traditional roof forms maintain regional architectural identity and respond to climatic conditions.
- **Material Strategy:** Local and affordable materials: cement sheets, brick plinths, palm wood, MS box.

Prioritizes ease of transport and assembly for remote, disaster-prone areas like Kuakata.

- **Cultural Sensitivity:** Inclusion of a mosque and maktab, imam residence, and community spaces reflects local religious and social values. Planning respects traditional spatial hierarchy, gender norms, and communal living patterns.

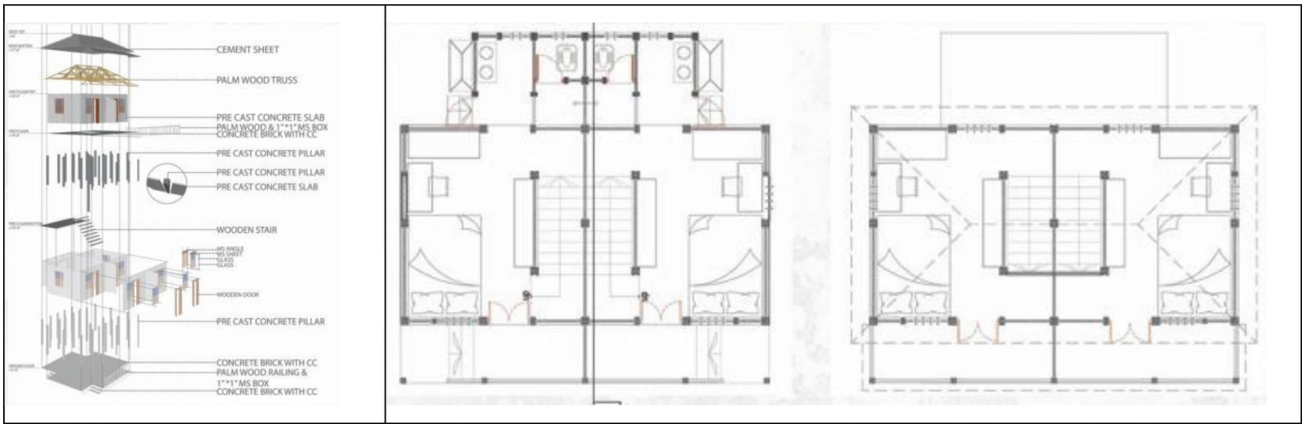

Figure 15: Exploded Unit Structure, Unit Plan (left to right)

7.2. Studio Group 2: Traditional yet Modern: A Courtyard-Centric Coastal Habitat

7.2.1. Design Philosophy and Concept

The guiding concept is "Traditional Yet Modern," where the design aims to revive coastal vernacular living by integrating interconnected courtyards with modern functional strategies. The design promotes a dual ecosystem, courtyards serving as intimate, restful spaces, and the adjacent ocean symbolizing labor and livelihood. This philosophy allows: Cultural continuity through spatial traditions like shared yards and communal nodes. Resilience and livability with modern services like biogas lines and cyclone-resistant roofs.

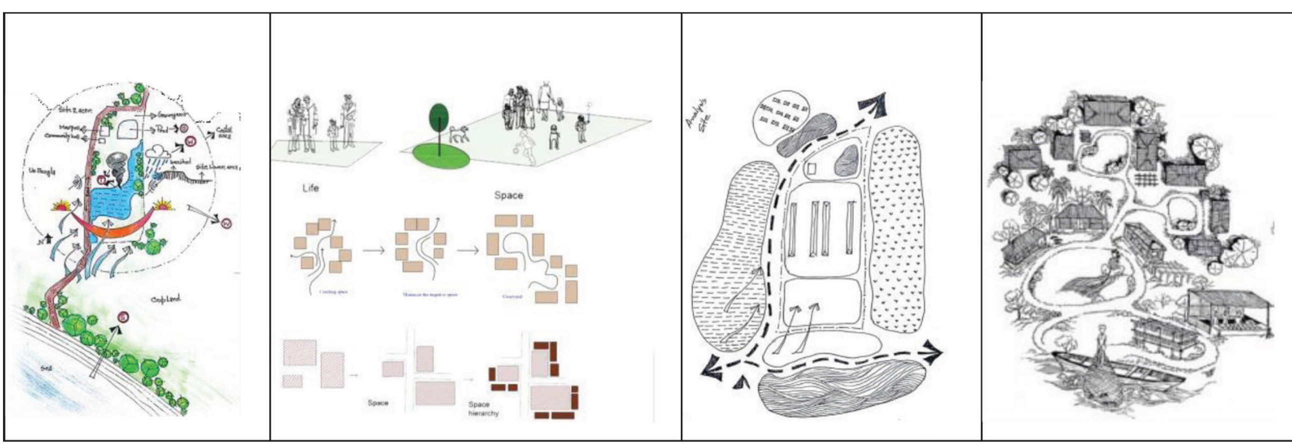

Figure 16: Concept Development: Site Layering Diagram (left); Life and Space Transformation (mid-left); Transition & Flow Logic (mid-right); Conceptual Sketch of Community Living (right)

7.2.2. Spatial and Design Features

- **Zoning and Organization:** The site is organized into distinct but integrated zones: residential, economic, community, and a large central community space. Residences are grouped around open courtyards, reducing negative space and encouraging social interaction.
- **Design Language:** Modular housing blocks surround open green shared courtyard. Design decisions reflect a life-space- structure relationship, prioritizing communal life, minimized voids, and space hierarchy.

- **Infrastructure Integration:** Clearly demarcated utility lines for: Central water distribution; Wastewater disposal; Biogas supply; Cattle waste management; Sustainability is embedded at both household and community scales.
- **Program and Facilities:** Includes mosque, clinic, training center, multipurpose hall, market, hotel, and bio-gas plant, all supporting self-sufficient community living.

Figure 17: Master Plan Showing Integrated Open Spaces, Housing Blocks, Circulation Paths, and Waterbody

Figure 18: Cluster Layout with Courtyard (left); Section of Housing Units (right)

7.2.3. Construction and Cultural Integration

- **Construction Techniques:** Use of ferrocement hollow columns, bamboo roof frames, brick plinths, and mud-pot slabs, making the buildings both cyclone-resistant and affordable. Gable and hip roofs, with wind barrier concepts, enhance storm resilience.

Figure 19: Exploded Structural Assembly (left); Indigenous Trees and Construction Materials Used (right)

Figure 20: Courtyard View from Ground Level (left); Aerial Perspective of Courtyard-Based Housing Cluster (right)

- **Material Palette:** Natural and regional materials such as: Hijol (Indian Oak), Gewa (Milky Mangrove), Supari (Areca Palm), Coconut (Coconut Palm), Siris (Lebbeck Tree), Koroi (White Siris), Bamboo slices, cement sheets, concrete, and mud pots This ensures low embodied energy and local identity.
- **Cultural Sensitivity:** Facilities like female changing rooms, mosque, and community ponds reinforce traditional coastal life. The layout supports gender-sensitive design, livelihood through cattle/farming, and religious practices.

7.3. Studio Group 3: Centralization: Blending Nature, Community, and Growth

7.3.1. Design Philosophy and Concept

Group 03's core concept revolves around "Centralization", emphasizing that community life grows best when centered around shared green spaces and essential services.

The layout encourages; Collective living by integrating residential units with community and economic functions around green cores. A nature-blended settlement, where green spaces, tree clusters, and waterbodies are foundational to spatial organization and resilience.

Figure 21: Sketch of Market: Pond Interface and Gathering Spaces (left); Spatial Layout Alternatives Diagrams (middle); Centralization Concept (right)

7.3.2. Spatial and Design Features

- **Zoning and Evolution:** The zoning and design phases show a thoughtful transformation from conceptual massing to a complex, multi-use layout centered around green community cores. The final master plan reveals well- balanced zones: residential, commercial, civic, and ecological, arranged symmetrically along a central spine.
- **Green Strategy:** Community courtyards are framed by residences, enhancing cross-ventilation, social interaction, and passive cooling. Strategic vegetation zones and waterbodies buffer against climate impacts and provide opportunities for gardening and income generation.
- **Programmatic Features:** Includes community hall, mosque, school, grocery, cattle shade, ponds, resort zone, and training centers, all accessed via a structured road network. The strong spatial hierarchy and clear orientation from public to private zones.

Figure 22: Master Plan Showing Clustered Housing, Central Courtyards, Public Zones, and Integrated Waterbody (Pond) on the East

Figure 23: Unit Plan Layouts (left); Elevations and Sectional Views of Housing Units (middle); Rendered Perspectives of Completed Units (right)

7.3.3. Construction and Cultural Integration

- **Materiality and Structure:** Heavy use of bamboo and timber, with cement sheet roofing, highlights a sustainable, modular, and locally sourced approach. Use of perforated, ventilator, and transparent panels improves lighting and airflow.
- **Structural Strength:** Bamboo-treated systems offer high tensile strength (up to 1000 MPa), surpassing traditional materials in flexibility and disaster response. Integrated storage scaffolds, pre-cast cement pillars, and perforated panels are efficient and culturally familiar.
- **Infrastructure Systems:** Includes a robust network for rainwater harvesting, drainage, and road connectivity. A central water reservoir and ponds supply daily needs and emergency reserves.
- **Cultural Responsiveness:** Facilities like mosque, ablution spaces, school, and market support social norms and everyday needs of coastal Bangladeshi communities. The emphasis on co-living, livestock, and shared resources mirrors traditional village life while upgrading it with modern planning.

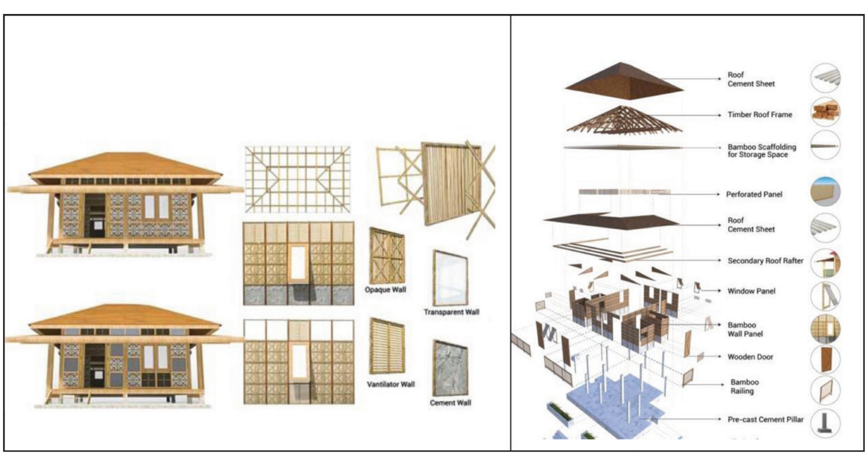

Figure 24: Wall Type Variations and Bamboo Panel Assemblies (left); Exploded Axonometric of Modular Bamboo-Cement Housing Unit (right)

Figure 25: Aerial Perspective of Modular Housing Layout with Green Spine (left); Eye-Level View of Bamboo Housing Cluster with Pathways and Pergolas (right)

7.4. Studio Group 4: Diagonal Living: Optimizing Wind, Space, and Resilience

7.4.1. Design Philosophy and Concept

Group 04's concept is driven by diagonal orientation to maximize spatial efficiency and mitigate wind flow impact. The idea stems from; Strategic disruption of linear wind patterns to create a more comfortable microclimate. Diagonal layout across a limited 2-acre site, enabling better land use and climatic response. Promoting resilience, sustainability, and adaptability through spatial and environmental optimization. The concept combines passive design logic with smart orientation, resulting in a layout that is environmentally responsive and spatially dynamic.

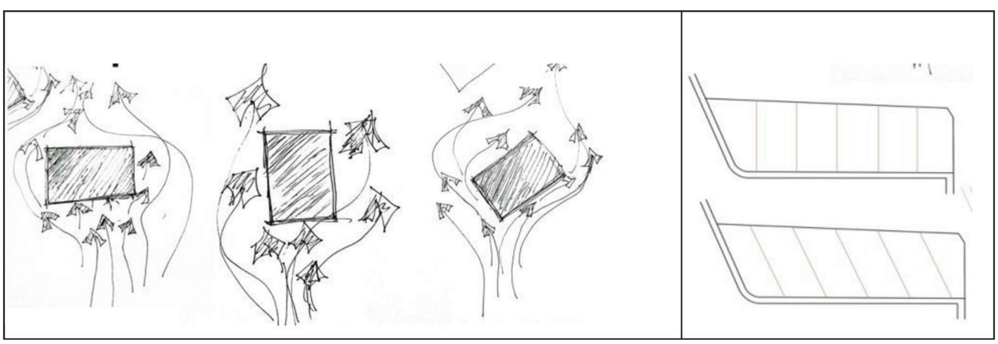

Figure 26: Wind–Built Form Interaction Diagrams (left and middle); Orientation Strategy for Optimal Ventilation and Shading (right)

7.4.2. Spatial and Design Features

- **Diagonal Master Plan:** The entire layout is rotated to follow diagonal zoning, allowing structures to sit at angles that diffuse wind pressure and improve thermal comfort. Circulation and zoning are planned along this diagonal logic to break visual monotony and enhance functionality.

Figure 27: Master Plan Showing Diagonal Grid Housing Blocks, Civic Nodes, and Eastern Pond Integration

- **Programmatic Layout:** Program includes 64 homes, mosque, community center, clinic, pharmacy, store, hotel, and club for youth. Spaces like central gathering nodes, shops, and community zones are aligned with access paths for clarity and accessibility.
- **Green–Open–Drainage Strategy:** A layered infrastructure model ensures effective stormwater drainage, retention ponds, and green buffers. Green areas are preserved around clusters for shade, biodiversity, and communal interaction.

7.4.3. Construction and Cultural Integration

- **Construction Materials and Technique:** Cement sheet roofing; Wooden framing; Bamboo mats and split bamboo for walls; Cement-sand-tush (rice husk) base. This hybrid system ensures thermal comfort, cyclone resistance, and local availability.
- **Cultural Sensitivity and Social Needs:** The design integrates facilities for health, worship, gathering, employment, and gender-sensitive spaces. Units are compact (1 bed, kitchen, toilet), aligning with the goal of affordability and dignity.

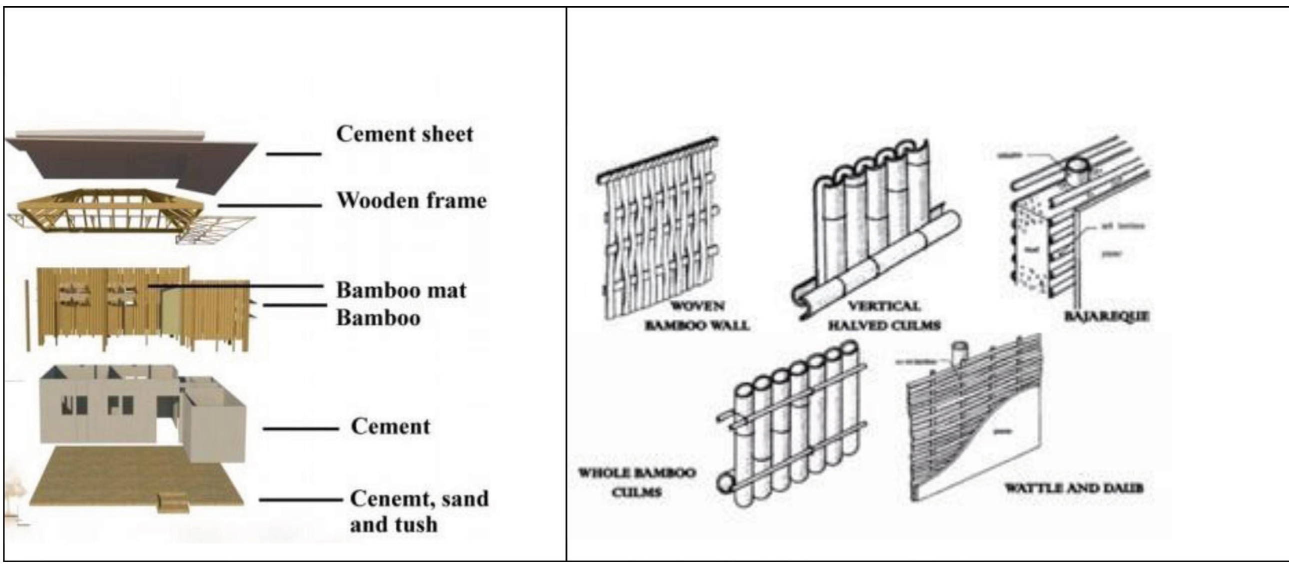

Figure 28: Exploded Axonometric of Wall–Roof Assembly Using Bamboo and Cement (left); Traditional Bamboo Construction Techniques and Joinery Variants (right)

7.5. Comparative Discussion

While each studio group produced distinctive design strategies, a comparative lens highlights shared lessons and viable directions for future housing in disaster-prone coastal Bangladesh.

Table 4: Comparative Approaches to Resilient and Affordable Housing in Kuakata Housing Studio

Aspect	Group 1: Fluid Spine	Group 2: Traditional Yet Modern	Group 3: Centralization	Group 4: Diagonal Living
Spatial Logic	Wave-inspired meandering central spine; staggered clusters linked by hubs (community & economy).	Courtyard-based clusters; modular blocks around shared yards; minimized voids and compact zoning.	Centralized community cores; hierarchical zoning from public → semi- public → private spaces.	Entire site rotated on diagonal; angled sitting disrupts wind flows; avoids monotonous grids.
Wind & Flood Response	Tall civic windbreakers; staggered clusters disperse wind loads; raised plinths, water tank.	Courtyards buffer winds; perimeter tree belts; hip/gable roofs reduce uplift; biogas + drainage links.	Cluster spacing, vegetation belts, ponds; raised plinths mitigate flooding.	Diagonal orientation disperses cyclone winds; layered drainage and retention ponds.

Material Strategies	Precast concrete pillars/ slabs; palm wood trusses; cement sheet roofs.	Bamboo, timber species (Hijol, Gewa, Supari, Coconut); ferrocement columns; mud-pot slabs.	Bamboo & timber with cement sheet roofing; perforated panels; modular & scalable.	Bamboo mats/walls, wooden frames, cement–sand–rice husk bases; low- cost façades (70 BDT/4 sq ft).
Community Integration	Courtyards for shared cooking/play; mosque, clinic, community hall; vegetable farming zones.	Mosque, clinic, training hall, biogas plant, ponds; gender-sensitive spaces; cattle → biogas.	Mosque, school, market, livestock & training zones; communal living rooted in tradition.	Mosque, youth club, clinic, shops; gender-sensitive zoning; compact family units.
Affordability Focus	Modular precast allows phased growth & repairs; farming for self-sufficiency.	Low-cost bamboo/ timber species; cattle waste biogas lowers utility bills.	Passive cooling & rainwater harvesting reduce long-term costs; local bamboo/timber.	Low-cost façades (17.5 BDT/sq ft, 70 BDT/4 sq ft); scalable costed prototypes.
Key Strengths	Strong cultural symbolism (wave spine); scalable modular precast system.	Deep cultural continuity; sustainable, gender-sensitive facilities; eco- cultural balance.	Balanced ecological–social planning; robust water & drainage infrastructure.	Wind-responsive diagonal logic; transparent costing with façade prototypes.
Challenges	Thermal discomfort in cement-heavy units; long-term drainage upkeep.	Durability concerns for mud- pot slabs in monsoon climate.	Bamboo dependence requires regular treatment/maintenance.	Risk of turbulence pockets; bamboo upkeep required.

7.5.1. Common Lessons on Resilience and Affordability

- Courtyards and communal nodes strengthen both social ties and passive climatic regulation.
- Diagonal or staggered orientations diffuse cyclone wind pressure more effectively than linear layouts.
- Raised plinths, ponds, and integrated drainage are non-negotiable for water resilience in coastal settlements.
- Local materials (bamboo, mud, compressed earth), when combined with prefabricated or treated systems, lower costs while enhancing performance.
- Iterative engagement with residents ensures cultural alignment and long-term acceptance, beyond technical resilience.

7.5.2. Most Viable Strategies

From this comparative analysis, the most robust strategies combine:

- Clustered courtyard-based layouts for affordability, social cohesion, and airflow.
- Diagonal or staggered sitting to reduce cyclone wind impacts.
- Hybrid material systems: treated bamboo and mud composites with prefabricated elements, for balancing local affordability and structural safety.
- Integrated infrastructure (drainage, rainwater harvesting, and communal services) as essential resilience backbones.

8. Material Prototyping and Model Making

8.1. Group 01: Material Prototyping and Model Making

Group 01 systematically explored the use of local materials; bamboo, brick, cement, and compressed earth blocks—alongside prefabricated concrete elements to develop prototypes for disaster-prone, low-income communities in Kuakata. Their scaled models incorporated key structural components such as precast concrete slabs and pillars, steel framing, mud oven, and palm wood trusses. The material mix was carefully tested for cyclone resistance, with a roof system using cement sheets and a robust rafter-purlin-truss structure, optimized to withstand high wind loads and reduce vulnerability during extreme weather.

8.1.1. Analysis

- **Structural Resilience:** The use of precast concrete slabs and pillars (ratio 1:1.5:3 for cement, aggregate, and sand) demonstrates a focus on modularity, rapid deployment, and repeatable quality. Elevated and reinforced structural members reduce flood risk and improve stability against cyclones.
- **Cost-Effectiveness:** Locally available materials and modular prefabrication keep costs low while allowing for future scalability or repair. Using traditional mud and bamboo elements further reduces expenses and leverages local construction knowledge.

- **Modularity and Adaptation:** Prefabricated components enable phased construction and easy replacement of damaged elements, crucial for communities exposed to frequent disasters. The integration of mud oven and adaptive wall systems addresses daily living needs and ensures cultural appropriateness.
- **Challenges:** While structural innovation is strong, there are potential criticisms regarding thermal comfort in cement-based units and the long-term durability of mud elements in high rainfall zones unless maintenance protocols are established. Integrating proper drainage and sanitation with modular housing remains critical for health and sustainability.

Figure 29: Pre cast concrete pillar, Pre cast concrete slab, Cement sheet, Brick plinth (upper left to right) (Royal Precast, 2025)

Figure 30: Precast Concrete Pillars and Cyclone Strap Connection in Timber Roof Construction and Roof Section Showing Structural Layers (Cement Sheet, Perlin, Rafter, Palm Wood Truss)

8.2. Group 02: Material Prototyping and Model Making

Group 2's approach to disaster-resilient housing in Kuakata is centered around low-cost, sustainable construction using local materials and context-responsive building methods. Their prototypes showcase a creative blend of bamboo, wood, and composite panels, each serving a specific structural or environmental function.

8.2.1. Use of Local Materials and Traditional Methods

Group 2's disaster-resilient housing strategy centers on using locally available, sustainable materials such as bamboo, mahogany, and teak. The team applied traditional treatment methods water leaching, smoking, and saltwater immersion to enhance the strength and durability of bamboo, making it more suitable for the coastal climate of Kuakata. The incorporation of these indigenous techniques not only leverages local skills but also ensures long-term material resilience.

8.2.2. Composite Wall and Column Systems

The model prototypes demonstrate the effective combination of bamboo frameworks with cement- based plaster and concrete footings. These components form robust yet low-cost columns and walls, ideal for rapid assembly in disaster-prone areas. The integration of wooden frames and the use of sawdust as an infill with cement further improve both thermal insulation and cost-efficiency, making the prototypes viable for low-income communities.

8.2.3. Ventilation and Modular Panel Design

A key feature is the bamboo lattice ventilation panel, designed to allow controlled airflow while maintaining structural integrity. This system addresses the need for thermal comfort in hot and humid coastal conditions. The modular panel approach combining ventilation, framing, and composite infill enables flexible assembly and adaptation to different site contexts, making the design highly replicable.

Figure 31: Bamboo Traditional Methods (Water Leaching, Smoking & Heating, Salt water immersion); (Bamboo U, 2024)

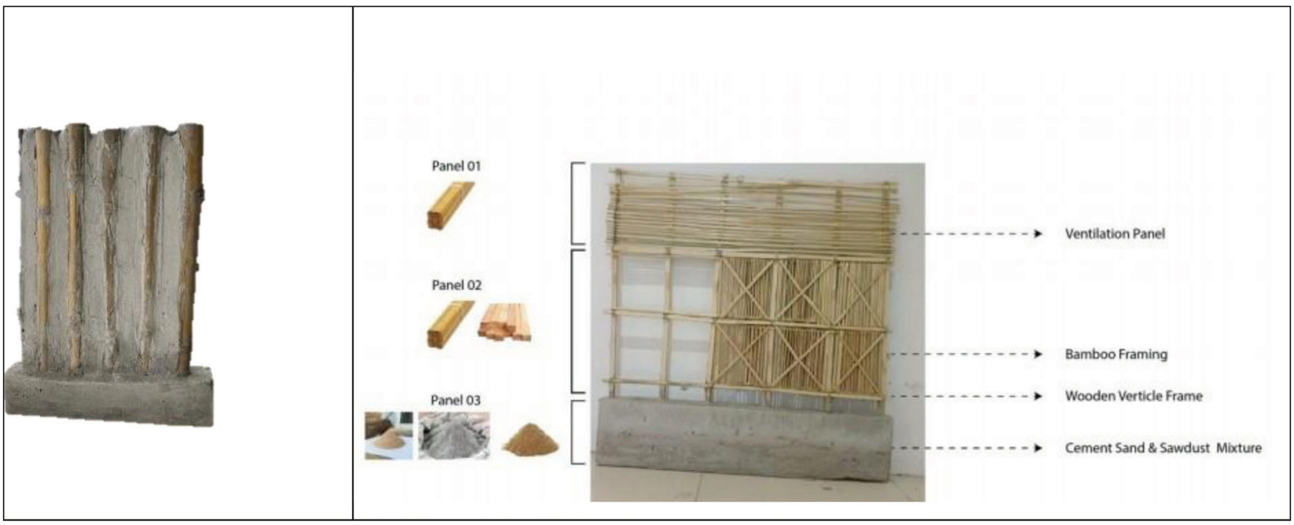

Figure 32: Composite Wall and Column Systems and Ventilation and Modular Panel Design

8.3. Group 03: Material Prototyping and Model Making

Group 3 has innovatively explored locally available materials to develop cost-effective and climate- appropriate building solutions for disaster-prone coastal areas:

8.3.1. Bamboo & Cement Plaster (For Outer Walls)

- **Description:** Bamboo frames are coated with a 2-inch cement plaster to form the outer wall. Advantages are given below:
- **Durable:** Provides good structural integrity against harsh weather.
- **Low Cost:** Significantly cheaper than traditional RCC walls, making it suitable for low-income communities.
- **Heat Resistance:** The bamboo-cement combination offers better thermal performance, helping to keep interiors cool in the hot coastal climate.

8.3.2. Mud Pot and Cement Concrete

- **Description:** Traditional mud pots are embedded within cement concrete walls. Advantages are given below:
- **Durable & Economic:** The use of mud pots reduces material costs and enhances the wall's thermal mass.
- **Heat Resistance:** Mud pots act as insulators, improving the wall's ability to resist heat gain and keep indoor spaces comfortable.

8.4. Group 04: Material Prototyping and Model Making

Group 4 has taken an innovative and context-sensitive approach to architecture by utilizing locally available materials, particularly bamboo, to design cost-effective and climate-resilient structures suitable for disaster-prone coastal regions. Their work demonstrates a deep understanding of vernacular construction methods and integrates both traditional knowledge and modern treatment techniques to enhance the durability and sustainability of materials.

The cost estimation charts reflect a strong focus on affordability, detailing the use of bamboo, cement, sand, and bricks to maintain low construction expenses approximately 70 BDT per 4 sq ft, making the solution accessible for marginalized communities.

Figure 33: Bamboo & Cement Plaster (For Outer Walls), Mud Pot & Cement Concrete

8.4.1. Façade Total Cost

Group 4 has proposed three innovative and cost-effective housing designs tailored for disaster-prone coastal areas like Kuakata, Bangladesh. These designs emphasize the use of locally available materials, particularly bamboo, to create durable and affordable housing solutions for low-income communities. The following breakdown demonstrates a strategic approach to budgeting, ensuring that the designs remain within affordable limits for the target communities.

Table 5: Cost Estimation and Facade Calculation

Item	Quantity	Rate	BDT
Bamboo	1 (50–450 BDT)	100	20
Cement	1.5 kg	15	25
Sand	6 kg (1 cft = 33 BDT)	4–7	47
Brick	2 nos (10 BDT each)	-	20 maxes
Total			**70 BDT (4 sq ft)**

Wood: 1 cft = 700–1500 BDT; Mahogany: 1 cft = 600–1200 BDT

Table 6: Calculates Cost for 3 Building Types (T1, T2, T3) Based on Sq. Ft and Rate (17.5 BDT/Sq. Ft) For 12 Units Each

Type	SQFT	Unit Rate (BDT)	Qty	Total (BDT)
T1	2223	17.5	12	193,500
T2	3042	17.5	12	638,220
T3	5103	17.5	12	1,071,624
Grand Total				**1,904,944**

9. Integrating Research and Design

The ORCA Palli housing project at Kuakata exemplifies a studio-to-research pipeline, where rigorous fieldwork and academic inquiry seamlessly fed into the architectural design process. The workflow began with comprehensive site visits, direct community engagement, and comparative analyses of regional settlements, allowing students to identify the core challenges of structural deterioration, waterlogging, and socio-economic vulnerabilities. Informal interviews, observational studies, and household surveys provided granular data on family structures, livelihood patterns, and resident aspirations.

Insights from this qualitative research directly informed typological studies, in which students documented local construction methods, spatial arrangements, and material practices. By analyzing how existing housing typologies responded to environmental stressors students distilled both the strengths and limitations of vernacular solutions.

Next, this empirical knowledge was fed into iterative design development in the studio. Each design proposal was rigorously tested through simulation-based methods, particularly using Autodesk Flow Design to model wind and pressure behavior under cyclone conditions. The simulation data highlighted critical pressure zones and airflow patterns, guiding adjustments in mass orientation, building layout, and structural details.

Material prototyping and scaled model making then operationalized these findings, as groups experimented with bamboo, earth blocks, prefabricated concrete, and hybrid composite systems, ensuring that their solutions remained affordable, replicable, and locally appropriate.

At each stage, feedback loops between field research, simulation analysis, and material prototyping enabled students to refine their architectural strategies for resilience, cultural relevance, and sustainability. This integrated workflow resulted in context-sensitive, disaster-resilient housing solutions that not only address the technical demands of coastal Bangladesh but also embody the lived experiences and aspirations of the ORCA Palli community.

10. Key Learnings

The Kuakata Housing Studio was a practice-based design initiative that sought to address the urgent needs of disaster-prone coastal communities in Bangladesh. One of the most important lessons from the studio was the value of engaging students directly with real communities, which enriched their understanding of the complex environmental and socio-cultural challenges at stake. This engagement resulted in design solutions that were not only technically resilient but also responsive to the lived experiences and aspirations of local residents.

A central learning outcome was the integration of policy frameworks, particularly the alignment with the National Housing Policy and the United Nations Sustainable Development Goal 11. The project demonstrated how academic initiatives can contribute meaningfully to policy objectives by linking classroom learning, field research, and innovative yet practical design proposals. The use of simulation tools such as Autodesk Flow Design played a vital role, enabling students to test their ideas against cyclone and flood conditions. These simulations informed decisions on building form, site layout, and structural detailing, ensuring that proposed solutions were feasible under real environmental stresses.

Material experimentation also emerged as a key theme. By working with locally available resources such as bamboo, compressed earth blocks, and prefabricated concrete, students showed that sustainable and affordable housing can be achieved through appropriate construction methods. Their designs incorporated elevated plinths, modular layouts, and passive strategies such as cross ventilation and rainwater harvesting, strengthening both resilience and long-term affordability.

The process itself was iterative, characterized by continuous feedback loops between research, design development, simulation, and community engagement. This reflective practice not only enhanced the quality of the final proposals but also instilled in students a strong sense of professional responsibility, adaptability, and commitment to socially responsive architecture.

11. Recommendations

The Kuakata Housing Studio underscores that effective housing for disaster-prone and low-income communities must prioritize community participation, affordability, and resilience. Organizing homes around shared courtyards and integrating infrastructure such as drainage and water supply can enhance both safety and social cohesion. Embedding digital simulation tools within design practice, while drawing on local knowledge, ensures that solutions are scientifically tested yet contextually appropriate.

At the policy level, architectural education and national housing strategies should promote research-driven and community-led approaches. By emphasizing disaster-resilient, modular, and locally sourced construction, supported by ongoing community training, government policies and donor programs can help scale up resilient housing solutions across Bangladesh's coastal settlements.

12. Implementation and Sustainability

Building on the Sendai Framework for Disaster Risk Reduction (2015–2030) and Sustainable Development Goal 11, which call for inclusive, safe, resilient, and sustainable human settlements, the challenge now lies in moving from design exploration to long-term implementation. While the studio produced resilient prototypes, their sustainability depends on a broader set of enabling conditions.

- **Land Tenure:** Secure tenure is a prerequisite for community resilience. Many coastal households remain landless or occupy sites informally, making them vulnerable to displacement.
- **Financing**: Affordability cannot be achieved through design innovation alone. Financing mechanisms must allow low-income families to invest incrementally in safe housing.
- **Policy Support:** The scaling of resilient housing requires alignment with national frameworks such as the National Housing Policy (2016), the Bangladesh Delta Plan 2100, and the Disaster Management Act. Integrating disaster-resilient housing into formal policy instruments strengthens institutional backing.
- **Partnerships with Local Organizations:** Partnerships with NGOs and community-based organizations such as ORCA, BRAC, OBHIZATRIK, and BDRCS are critical for scaling. These organizations provide community trust, logistical capacity, and training infrastructure.
- **Sustainability Outlook:** Resilient housing must be understood not only as a technical intervention but also as a social contract. Combining secure land tenure, accessible finance, enabling policy frameworks, and strong partnerships transforms design prototypes into lived realities. Scaling these approaches across coastal Bangladesh can break cycles of displacement, protect livelihoods, and deliver on the commitments of the Sendai Framework and SDG 11.

13. Limitations of the Research

This study was conducted as a studio-based project with a small number of student groups, which limits the generalizability of its findings to other coastal contexts. Community engagement was constrained by time and resources, resulting in limited survey and interview data. Although simulation tools and material prototyping offered valuable insights, the designs were not built or tested under real disaster conditions, leaving long-term performance unverified. Furthermore, the study focused primarily on architectural and material aspects, giving less attention to broader policy, financial, and land tenure issues that also shape the success of affordable housing initiatives.

14. Conclusion

This study shows that a studio-based, research-by-design approach can deliver affordable and cyclone- resilient housing solutions for coastal Bangladesh while also advancing architectural education and research. On a practical level, the work offers a tested design playbook that combines clustered courtyard layouts, staggered or diagonal orientations to diffuse wind loads, raised plinths with integrated drainage, and hybrid material systems using treated bamboo, earthen composites, and precast elements. These strategies were further validated through wind simulations and material prototyping, resulting in context-sensitive, cost-aware prototypes that can be scaled and maintained by local communities. On a theoretical level, the project demonstrates how participatory inquiry, environmental simulation, and material experimentation can be integrated into research-by-design to generate generalizable knowledge for disaster-resilient housing. It refines coastal housing typologies and contributes to debates on practice-based research by showing how academic studios can act as sites of critical inquiry with direct policy relevance. While the proposals were not field-tested under real cyclone events, the combined insights offer a replicable and adaptable framework that links design innovation to community aspirations, national housing policy, and the global commitments of Sustainable Development Goal 11.

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Authorship Contribution

Masud Ur Rashid: Conceptualization of the study, supervision of the design studio, methodological framing, and critical review of the manuscript.

Abdullah Al Amin: Field survey coordination, supervision of the design studio, data collection and analysis, drafting of the manuscript, and integration of student outputs into the research framework. Both authors jointly contributed to research design, community engagement, and final revisions of the paper.

Ethical Approval

This research was conducted as part of an academic design studio at Southeast University, Dhaka. The study did not involve medical or clinical interventions. Community engagement activities, including interviews and focus group discussions, were carried out with prior informed consent from participants.

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Declarations

Data and materials are available from the authors on reasonable request. All participants gave informed consent; anonymized information may be published.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this study.

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