# Transforming the Existing Households as a Disaster Safehold through Cost-Efficient Architectural Execution Techniques: A Case Study of Assasuni, Shatkhira

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**Abstract.** Due to its geographic location and rapid climate change, Bangladesh has witnessed natural disasters such as floods, cyclones, flash floods, tidal surges, and waterlogging. Natural disasters disturb the lives of those who reside in coastal areas every year as their houses are severely damaged. This devastation of households caused by the disasters brings financial crises for the occupants to rebuild their houses. Shatkhira, being one of the coastal disaster-prone areas, people have been living with natural disasters. Although cyclone shelters offer safety to individuals during disasters, this method of cyclone management has not been successful in minimizing damage to households. The households remain vulnerable to disasters due to outdated construction techniques. Until now, existing built forms lack resilient structural solutions that address future disaster risks. Advanced construction techniques have not yet been introduced to enhance the resilience of existing households. The study aims to analyze the household's structure and specify scopes for improvement. Initially, this study observes the architectural and structural features of the construction in the most practiced one in Pratabnagar, Assassuni in Shatkhina. The study is expected to produce some cost-effective, and comprehensive construction and material selection guidelines to make the traditional structures more resilient, which will allow existing built forms to transform into safe holds during and after disasters.

**Keywords:** Households, Vulnerabilities, Disaster Resilience, Low-cost Construction, Material selection.


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# 1 Introduction

Given its location, funnel-shaped coastline, huge population density, low and flat topography, vast and shallow continental shelf, and high tidal range (Bangladesh 2008, Karim and Mimura 2008) Bangladesh has witnessed a significant number of natural disasters (Eckstein, Künzel et al. 2019) and has ranked eighth on the global climate risk index 2020 (Siddiki, Islam et al. 2012). Bangladesh frequently encounters disasters, including floods, cyclones, tidal surges, landslides, river bank erosion, droughts, and earthquakes (Bangladesh 2008). Tropical cyclones often affect Bangladesh's coastal regions during the pre-monsoon (April-May) or post-monsoon (October-December) periods, causing a severe cyclone to appear at least once every three years (Strategy, Plan et al. 2009). Bangladesh's coastal area can be divided into three separate zones: (i) the south-western coastal zone with mangrove forests, (ii) the central coastal zone with numerous offshore islands, and (iii) the narrow south-eastern coastal zone with a series of hills running parallel to the coast (Ali 1999). This region's land contributes roughly 32% (47201 square kilometres) of Bangladesh's total area. The complete length of the shore is around 710 kilometres. This coastal area of Bangladesh is categorized based on the risk of cyclones as (i) High-Risk Area: it runs alongside the bay and is the most vulnerable area for tidal surge devastation during tropical cyclones where tidal surge height is above 1 meter. (ii) Risk Area: where surge height is under 1 meter. (iii) High Wind Area: mostly affected by high-speed wind (Figure 1)(Strategy, Plan et al. 2009, Islam, Shaw et al. 2013). It comprises 19 of the country's 64 districts and 147 Upazilas, where around 33% of Bangladeshis live (Rahman, Ghosh et al. 2020). In recent years, the increased number of disasters attributed to climate change has imposed additional hardships on the marginalized population of the nation, posing a threat to its overall economic development (Islam, Hossain et al. 2015).

While the Bangladeshi government is prioritizing the enhancement of early warning systems to notify individuals to seek refuge in safer locations, such as cyclone shelters, for life preservation. Still there is a lack of well-structured guidance on protecting properties from these disasters (Davison 2022).

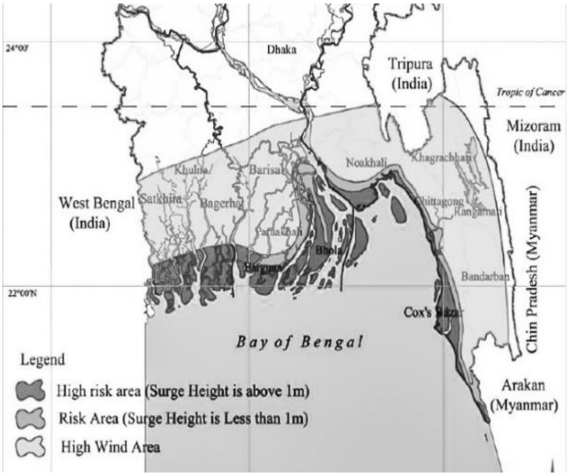


**Fig. 1**: Cyclone affected area of Bangladesh. Source: (Strategy, Plan et al. 2009)

Though it is essential to build cyclone-proof emergency shelters before cyclones hit, it is also worthwhile to make individual houses cyclone resistant (Islam, Hossain et al. 2015). Most of the houses constructed by residents, with the assistance of locally available woodcraft and artisans, are susceptible to damage and lack structural strength to withstand harsh environmental conditions such as cyclones, earthquakes, floods, etc. (Das 1972). That's why lots of houses are damaged due to disasters on a regular basis, which causes the most economic losses during disasters especially cyclones, and wind storms (Bangladesh 2008). Inevitably that will have an adverse impact on development, with those in poverty suffering the most (Rashid 2018). They may not be aware that their houses could be constructed to be both structurally robust and cost-effective, requiring an expenditure similar to that needed for building traditional houses (Alam, Kaish et al. 2017). To mitigate the destruction of houses and economic impact in the coastal zone of Bangladesh during high wind speeds, such as cyclones, it is imperative and urgent to establish rules and guidelines for the construction of non-engineering rural housing (Islam, Paull et al. 2021).

The goal of this study is to analyze the present housing scenario in the south-western region of Bangladesh, one of the worst-affected districts. To develop and carry out a comprehensive, safe, and cost-effective retrofitting concept that will allow people living in poverty to construct inexpensive, stable homes that endure natural disasters. This study seeks affordable and adaptable construction guidelines for making existing houses resilient.

## 2 House as a Disaster Safehold

The majority of houses in coastal regions are susceptible to seismic activity of moderate to high frequency or cyclones (Saunders 2011) or as a result of poor construction practices or the victim's incapacity to build a relatively secure structure (Zisan, Alam et al. 2013). It was observed that people do not want to leave their houses for shelter because of concern for their belongings and livestock. This causes higher casualties during cyclones. People in these disaster-prone areas make their ways of surviving through house-building techniques and settlement patterns (Moles, Caimi et al. 2014). So, if people use the right technical knowledge to build their houses with resilient construction methods in disaster-prone areas of Bangladesh, they can protect their lives and belongings (Sohaana and Rahman 2021). Guidelines are required that are specifically formulated for the strengthening of homes, taking into account a multi-hazard perspective, for coastal communities that have been impacted by cyclones in coastal areas (Alam, Kaish et al. 2017).

The study found that integrating technical knowledge and details can strengthen the structural integrity of a low-cost, non-engineered house against wind forces without raising construction costs compared to retrofitting existing houses (Moles, Islam et al. 2013). Several authors emphasized the need to revise building regulations to include wind-resistant structures for all types of buildings in coastal areas (Aquino, Wilkinson et al. 2018). There is a notable requirement for innovative architectural solutions and construction techniques to mitigate vulnerability to high-speed wind hazards in non-engineered houses, aiming to enhance cyclone resistance (Sohaana and Rahman 2021). Resilient housing solutions need to be innovatively developed, prioritizing cost optimization, rapid implementation through the modification of construction technologies, utilization of alternative materials, and ensuring a maximum lifespan, salinity tolerance, and high yield (Ahmad 2012).

Several researchers have focused on the technical facets of structures resilient to cyclones and the construction techniques of built forms. Pioneers in assessing resilience based on ecosystem services during pre-cyclone, post-cyclone, and recovery phases include Islam, Paull, Griffin, Murshed, and Agarwal (Mayo 1988, Ahmad 2012). Moreover, research has demonstrated that a carefully devised plan for a plantation, suitable layout, and orientation can effectively mitigate the impact of both cyclones and tidal surges (Aquino, Wilkinson et al. 2019). As wind passes over a building, variations in airspeed across and around the building's structures generate non-traditional load paths, exerting an upward force on the house, causing rapid pressurization, which can potentially lead to subsequent destructive events (Karim and Mimura 2008).

However, only a limited number of studies focus on resilient housing construction applicable to coastal areas in Bangladesh (Islam, Hossain et al. 2015). To address this current research gap, we studied vulnerability and developed resilient houses by providing them with the resisting and recovering capacity from the prolonged impacts of disasters. The design draws upon the resilience inherent in the local building culture, incorporating technical advancements to address recognized vulnerabilities (Islam, Hossain et al. 2013).

# 3 Methodology

## 3.1 Selection of Study Area

The Study Area is selected on three criteria. (i) Coastal area, (ii) Community living with disaster, (iii) Native community. Pratabnagar, a union of Assasuni,

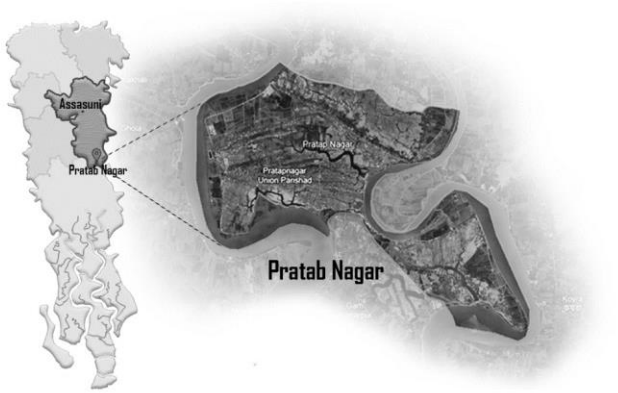


**Fig. 2**: Survey Location

Satkhira was selected as the study area considering the criteria. A thorough investigation was conducted in Assasuni upazila, within the Satkhira coastal belt, to assess the reliance on resources from the Sundarbans mangrove forest. Assasuni is located at 22.5500°N 89.1681°E. It has a total area of 402.36 km2 and 40,735 households.

Marichchap, Kholpetua, Betna, and Kopothakkho are rivers flowing through Assasuni. The district of Satkhira features an elevation ranging from 0 to 7 meters, with a majority residing below sea level. Over the past two decades, the average storm surge height for cyclones has been consistently recorded between 3 and 4.5 meters. As a result, a significant portion of Satkhira's territory faces a notable threat of flooding during cyclonic events.

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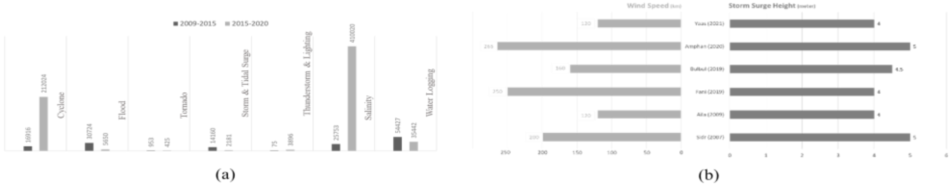


**Fig. 3**: (a) Disaster-affected households in Satkhira (2009-2020) (b) Satkhira affected by disaster (2007-2020)

### 3.2 Methods and Approach

Primary data, obtained through a physical survey and observations, included open-ended questions, questionnaires, and open-ended inquiries. Observations made during the field survey provided information for understanding existing settlement and construction techniques. Secondary data were collected from relevant books, journals, and published reports. Based on the collected information, we analyzed the vulnerability of existing houses in Pratab Nagar, Assasuni. The study recommended resilient, low-cost housing techniques to fortify existing vulnerable houses. The study used both qualitative and quantitative methods to gain a better understanding for looking a system for sustainable resource management and to identify the available and affordable resources that could be spent while building sustainable climate resistant houses by using indigenous knowledge shaped by modern technology and in line with urban design principles.

## 4 Results and Discussion

There was a wide variation in the quality of housing, ranging from permanent housing to temporary or semi-permanent types of housing (Table 1). Statistics for Development Division (2005) classified housing into four categories based on quality: (i) Pucca (permanent quality), (ii) Semi-Pucca, (iii) Kutcha, and (iv) Shanty. These classifications are based on the roof and wall materials used in construction. As the Shanty houses are temporary and number of the houses is negligible, the houses can be categorized into three prominent divisions.

Kutcha house refers to temporary houses built of locally sourced materials and constructed by the dweller himself. The plinth is constructed of mud, and the walls are most likely to be thatched, wooden, or mud. The roof materials are likely to be tali and golpata.

The semi-pucca house’s plinth, wall, and structure are constructed with more permanent modern materials like brick and RCC construction. Most of the materials that are used in building semi-pucca houses are not locally sourced.

Pucca houses are permanent houses where the plinth, wall structure, and roof are constructed of modern materials. Most of the materials are sourced from outside.

**Table 1:** Existing Household Comparison

| Type / Component | Mud House Kutcha House | Semi Pucca/ Thatched House | Brick House/ Pucca | Remark |
|---|---|---|---|---|
| Structure | Thatched Wall, Bamboo Post | Coloum Post | Column & Beam | * Most Costly To Reconstruct |
| Roof Structure | Tin/Tali, Golpata | Tin, Tali, Rcc Sheet | Flat Rcc Slab | *Vulnerable To Strong Wind |
| Plinth / Floor Finish | Mud, Hight (4'-5') | Brick Hight (3'-4') | Brick Hight (3'-4') | *Frequently Damaged By Flood |
| Wall | Thatched Wall, Wooden Wall | Brick Wall | Brick Wall | *Most Affected By Wind |
| Opening & Door | Window: Very Small (2'x3') Door: (2'x3') | Window: Small (3'x3') Door: (2'x3') | Window: Small (3'x3') Door: (2'x3') | *Weak Against The Strong Wind, Can Create Wind Traps Inside The House. |
| Construction | Self Construction, Maintenance | Local Masonry, Self | Mason | *Traditional Construction Techniques |
| Materials Availability | Natural Mostly, Locally Resourced | Locally Resourced | Imported | *Locally Sourced Materials Should Be Used For Cost-Cutting. |
| Damaged | Plinth, Wall, Roof, Structure | Plinth, Roof, Wall | Wall, Roof | |
| Damage Probability By Cyclone, Flood | 50% - 80% | 10% - 40% | 5% - 10% | |

Kutcha houses are most vulnerable to disasters, and almost every disaster affects its structure, wall, or plinth. Despite being the most severely damaged by the cyclone, strengthening a kutcha house is a more affordable and practical possibility that demands the utmost attention. We analyzed the existing houses, considering their components (Table 1). While there are strategies adopted to mitigate cyclone impact, vulnerabilities were identified in locally constructed houses. Accordingly, we recommend construction solutions to address these existing house's vulnerabilities.

## 4.1 Spatial Planning

The spatial arrangement is a response to the villagers' frequent exposure to South-western storms, occurring 2-5 times annually, notably during the Bengali months of

Baishakh-Jaistha (April-May). Traditional houses are typically positioned with a shorter side facing the windward direction of the cyclone. Consequently, the majority of houses face north and east, totaling three-fourths of housing units oriented towards the north and east due to the influence of South-western storms and cyclones in the region.

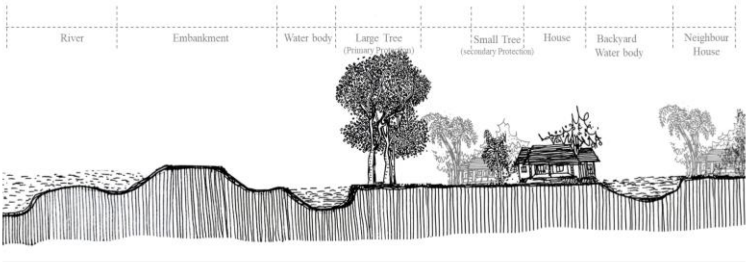


**Fig. 4**: Household Position

Coastal residents strategically plant large vegetation around their homes to mitigate the impact of strong winds associated with cyclones. The peripheral trees positioned to face the prevailing wind act as a primary protective barrier, absorbing and deflecting the force. Notably, many orchards and gardens are situated at the rear of housing units, serving as a secondary defense against the adverse effects of disasters (Fig. 4).

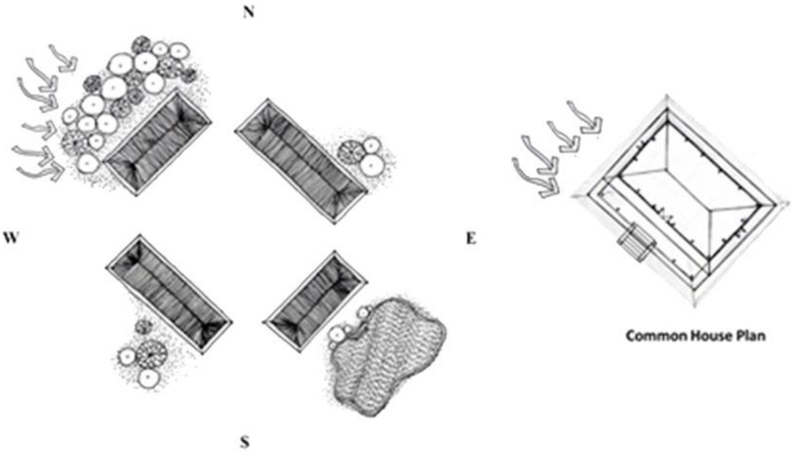


**Fig. 5:** Spatial setting of typical household

If houses are strategically oriented in such a way that the corner section intercepts prevailing storm winds, it enhances the structure's ability to withstand strong wind forces. When the wind strikes this corner, it divides into two, enhancing the house's initial resistance to the force of the wind. This strategic orientation improves the structure's ability to withstand strong wind forces (Fig. 5).

It is not recommended to build a house in an open place. Densely grown strong trees are needed on the south-western periphery. The selection of trees for those edges is made according to their wind resistance capability. Betel nut, palm, and coconut trees are mostly used for this purpose. The recommended distance is determined by the average height of the trees. Consequently, taller trees such as betel nut, palm, and coconut are strategically planted at a safe distance, offering primary protection against strong winds. Respectively smaller trees are then planted closer to the houses, providing secondary protection. Orienting the facades of houses in the opposite direction of cyclones and planting trees on the rear side of the house proves to be a beneficial strategy.

### 4.2 Layout of House

Cyclones and strong winds significantly influence the design of houses in coastal areas. They are often built width-wise to face the wind, favoring a rectangular shape with a length-to-width ratio of around 2:1. This traditional approach helps prevent houses from being overturned by wind forces, showcasing clever adaptation in cyclone-prone regions.

The standard house design includes a "ghar" and a "veranda," which can be positioned on all four sides or both sides of the "ghar." Importantly, the veranda consistently faces the windward direction. To alleviate high pressure on internal wall surfaces, these houses are constructed with minimum numbers of openings on the veranda.

Regardless of the number, the "Varenda" is strategically positioned on the windward side. The veranda wall serves as a barrier, effectively reducing water penetration into the "ghar" during high winds accompanied by rain. The most effective shapes for wind resistance in planning are square or rectangular, though it doesn't mandate all buildings to follow this. If other shapes are preferred, emphasis should be placed on reinforcing the corners. For longer shapes, careful design is necessary to endure wind forces. Typically, houses are rectangular, and an optimal layout is achieved when the length is not more than three times the width.

### 4.3 Plinth

After cyclones or floods, the plinth often stands as the only remaining part of a building. In the surveyed areas, most houses have mud floors, some with natural or pigmented cement. Homes of lower economic status typically have floors near ground level. Woven bamboo mat walls in these houses, buried in the soil to prevent pests, degrade quickly due to moisture, facing issues like fungi, termites, and insects (Fig. 6).

**Fig. 6**: Plinth of existing house

Maintaining a plinth height between 450mm to 600mm above the natural ground level is recommended to safeguard the floor, wall, and structure from most flooding. Reinforcing the sides and corners of the plinth enhances its durability and decreases maintenance costs in the long run. Introducing brick masonry or RCC construction specifically for the sides of the plinth is recommended (Figure 7).


**Fig. 7**: Strengthening Plinth

## 4.4 Wall

For walls in the kutcha houses, they use woven bamboo or timber boards that are attached to vertical posts using goran or bamboo poles. Jute ropes are often used to tie frame elements. Wall sheathing is nailed and screwed to timber board for thatched and timber-boarded walls. Weakly attached walls with vertical posts blown off by cyclones while treating them beforehand would have protected untreated building materials from weather contact.

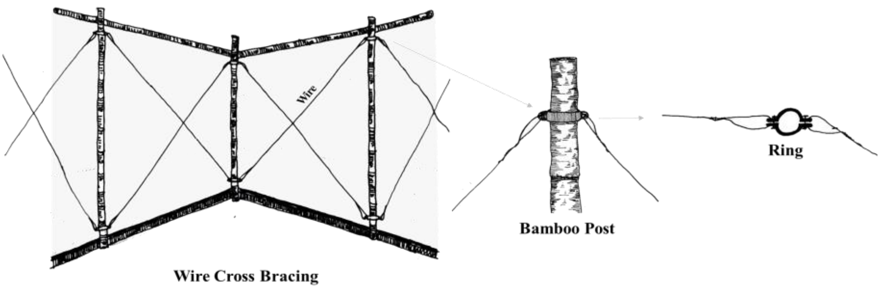


**Fig. 8**: Wall bracing to resist wind pressure

Almost all houses use very low-quality wood bamboo posts unprotected with any approved preservative for this purpose. As a result, they lose moisture and become susceptive to fungus. As for now, it's about quality control of materials and fabrication techniques. Other than this, no intelligent provision for tying and fixing a thatch wall.

In this regard, bamboo and wooden posts would need to be selected based on appearance as well as strength when considering foundations. For bamboo, it is vital to subject it to preservative treatment by either soaking or treating bamboo splits or whole bamboo with preservatives. Bamboo and wood should be immersed in water for 1 day 24 hours and 2-4 days respectively after cutting. They should shade the treated materials for 1 – 2 days and expose them to the sun for 3 – 4 days to prevent attack by insects and rot in the field.

Diagonal bracing on weak walls will help to withstand corner failures in cyclones. One may replace jute rope with galvanized wire to anchor poles much better. GI wire may be used, however, quality of control, proper preparation of the surfaces, and applying the under-coats that are specified are of essential importance in marine as well as salt atmospheres. Furthermore, wooden poles may be replaced by pre-cast columns as a better form of stability (Figure 8).

### 4.5 Openings

Positioning doors, and windows on the windward side of the house might cause storm wind intake, which may create a suction force inside the house. This ultimately leads to the uplift of the roof. So, most houses have no windows on the windward side. Openings are positioned mostly on the outside walls except for one opening for entry to the house.

Positioning the door in the center of the wall with small windows in the rear wall is recommended while keeping the opening size minimal. Openings in timber board sheathing walls can be framed easily by vertical timber posts, and horizontal timber sections. Types of shutters are important for cyclone resistance of houses. Shutters hinged along the top of window frames are preferred as these will not suddenly open and let the wind in, thereby increasing the internal pressure to cause the roof to blow off or the walls to collapse. Pivotal windows can be introduced instead of traditional windows, which are more durable against the wind force.

### 4.6 Roof

In coastal areas, the traditional roof design features a pitched roof over the "ghar" and a low overhang over the veranda, derived from extensive cyclone experience. The roof is typically thatched or covered with burnt mud tally or CGI sheets. Roof failures generally fall into two categories: (i). one involves the roof sheeting getting blown off, often due to faulty fixing details of roof members with the wall and column, improper joining of roof sheeting with the roof purlin, and imbalances in large facade openings. (ii) The other type of failure is caused by an overextended roof overhang and faulty foundation of the wall and column with the ground.

Studies indicate that houses with hip roofs inclined at 30 to 40 degrees show better resistance than general pitched roofs. Separating the roofs of the veranda and inner house with minimal veranda overhang enhances safety. Tying down the bamboo roof strengthens it. To reduce the risk of house damage, ensure a secure attachment of the strong roof skeleton to vertical posts and tightly fasten roof claddings. Sturdy purlins, well-seasoned and pressure-treated, should bear the load of the roof cladding. Strengthen fixing purlins to rafters with metal straps or bolts at ridges and eaves. Use gauge galvanized metal straps, nails, nuts, bolts, and nylon ropes for joint tightening (Figure 9).

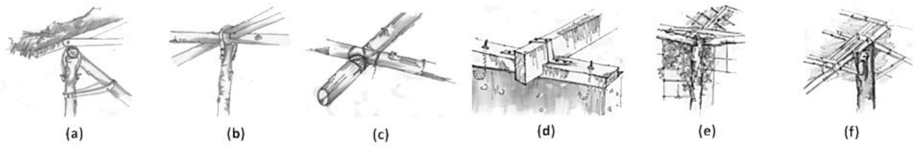


**Fig. 9:** Stronger Joints with nylon rope, metal strip, nails

## 4.7 Footing

In the surveyed areas, houses are supported by wood, bamboo, and pre-cast concrete posts. It has been observed that vertically anchored foundations, when weakly anchored and directly buried into the ground, lose durability rapidly due to weather contact. The supports are not appropriately grounded based on the height of the houses, leading to outcomes such as houses being lifted, turned over, or blown away by strong cyclone winds.

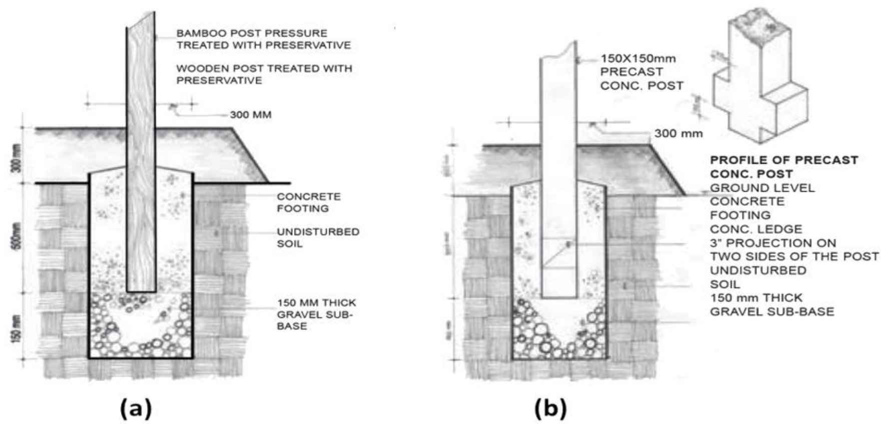


**Fig. 10.** (a) Typical footing for timber and bamboo posts, (b) Typical Footing for precast concrete post

Bamboo selection should prioritize both strength and appearance, with pressure treatment using preservatives recommended. The bamboo post section should not be less than 125 mm in diameter, and for corner posts, a higher diameter is preferable.

Timber posts should be chosen based on strength and appearance, and they should be well-seasoned and treated with preservatives. Sawn lumber size for the posts should be around 100x100, and for log-form, it should be approximately 150 mm in diameter. Corner posts are recommended to have larger sections for added strength. Foundation following the details in Pre-cast concrete posts should be fabricated with quality control of o materials and proper shuttering, fastener, ties, etc. During fabrication, provisions for ledges should be embedded in the pre-cast concrete post (Figure 10).

## 5 Conclusion

Bangladesh's deltaic area is frequently hit by cyclones, which seriously impair both the economy and the welfare of those living there. The locals are finding it difficult to deal with the problem using the present building materials and construction techniques. The majority of the houses constructed in Bangladesh's coastal regions were non-engineered homes, which are single-story hipped structures made of mud, bamboo, straws, tiles, wood, jute sticks, bricks, CGI sheets, etc. According to an analysis of field data gathered about the housing situation in these areas. It is advised that those impacted by cyclones build or repair their homes according to the guidelines for building sturdy, stable structures. They ought to take certain precautions as well to shield their homes from powerful winds.

In summary, cautious design of the communities according to their geographic locations should come after spatial configuration and house construction. Additionally, a cyclone-resistant house is achievable if a community-oriented plan for tree planting is implemented concurrently, all building materials are preserved, and technological input recommendations for construction techniques, structural details, and components are followed. Research and demonstration programs should support design considerations for creating resilient structures for future disasters that can withstand cyclones. Houses shall be designed prioritizing locally accessible resources and cutting-edge technology to enhance their ability to withstand cyclones.

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