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Article

Shelter for people in extreme weather: Exploring the options in the coastal areas of Bangladesh

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ABSTRACT

Bangladesh's coast is affected by tropical cyclones, which are now exacerbated by climate change in terms of intensity and frequency. Though the death toll from cyclones has decreased significantly through the implementation of the CPP (Cyclone Preparedness Programme), initiated by the Bangladesh Government, the event still disrupts the lives and resources of coastal communities. The primary sector destroyed during a cyclone is coastal communities' housing, settlements, and livelihoods. During a cyclone, coastal residents must evacuate their homes to a cyclone shelter for temporary refuge, whereas many do not intend to leave their homes and properties. Several initiatives have been undertaken in Bangladesh to provide shelter during cyclones. The common practice of sheltering people is building a "Multipurpose Cyclone Shelter". Some "Killas" were also constructed to shelter the livestock. After the cyclones of 1970, 1991, SIDR, and Aila, the Bangladesh Government and some NGOs also provided houses to affected people in coastal areas. However, most initiatives in coastal shelter design were not successful enough to provide sustainable shelters, considering both durability and maintenance. Architects in Bangladesh are still searching for the most effective and sustainable solution to provide shelter to the coastal community, considering the devastating cyclone. This paper examines shelter design initiatives by studying existing shelters and proposes alternative solutions to provide shelter to people on the coast of Bangladesh. For the study, examples of shelter design and construction following the devastating cyclones of 1970, 1991, SIDR, and Aila have been analyzed through a literature review and physical survey. A physical survey of some affected areas has been conducted to understand their inherent and indigenous survival mechanism. Based on this study, the research proposes a sustainable solution for sheltering coastal communities.

KEYWORDS

Cyclone; multipurpose cyclone shelter; disaster resilient house; shelter design; and indigenous knowledge.

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1. Introduction

The Bay of Bengal is the ideal breeding ground for tropical cyclones. In the Bay of Bengal, approximately 10% of the ‘ ‘world’s total cyclones have been generated, with about 17% affecting the coast of Bangladesh (Choudhury, Jamilur R., 1994). The entire coastal belt of Bangladesh is vulnerable to destructive cyclones, storm surges, and tidal floods. The severity of this catastrophe in our country is due to its geographical position. A tropical cyclone forms over the ocean surface, where the water is warm, maintaining a consistent surface temperature of 26-27°C. This creates a low-pressure zone, and the Coriolis effect occurs, resulting in the formation of a cyclone. The Bay of Bengal is particularly conducive to cyclone formation, offering a favorable environment with warm sea surface temperatures. The cyclone, which is generated in the deep sea, passes through the large shallow continental shelf and gains energy on its way to the coast. Bangladesh’s funnel-shaped coastline creates a path to the country’s shore and a landfall. The cyclone in Bangladesh is associated with storm and tidal surges, which may rise to 10m above the tide, and may reach 10m above mean sea level, accompanied by cyclone wind speeds of approximately 225km/h (Battling the Storm).

1.1. History of the Deadliest Cyclone in Bangladesh

From the historical evidence, it is found that each year Bangladesh is severely affected by devastating cyclones, which leave a trail of deaths, injuries, and property damage. As the country experiences frequent cyclones, it is likely to witness many such natural calamities that place a burden on human lives and infrastructure along the country’s coast.

Figure 1. Cyclone-prone coastal belt of Bangladesh (Photo: Author)

During the last 40 years, cyclones, the most devastating one was in 1970, which had a 224 km/hr wind speed, carrying a sea surge of 33 feet in height, causing a death toll of around 500,000 people. In 1985, a devastating cyclone occurred, which fiercely blew over Urirchar, Noakhali, with 200km/hr wind force and 20’-0”” “” “”””” surge height, where 20,000 people died. Another severe cyclone made landfall on the coast of Chattogram and ‘ ‘Cox’s Bazar, causing a Death toll of around 1.5 million, destruction of houses at approximately 1.63 million, and property losses of roughly 7 thousand crores. In 2007, Cyclone SIDR crossed the southwestern coastal zones, where ,wind speeds reached 223km/hr and storm surges were 15-20 feet high. Coastal zones of Bangladesh with a wind speed of 223 km/hr, and the height of the sea surge reached up to 15-20 feet. SIDR caused the death of 3,363 people and full damage to 563,887 houses and partial damage to 955,065 houses.

Cyclone Aila, on May 25 2009, hit 15 districts in the southwestern part of Bangladesh offshore, with wind speeds of 120 km/h. About 150 people were killed and 200,000 houses were damaged in the storm. Cyclone Mahasen made landfall near Chittagong on May 16 2013, with a wind speed of 85 km/h. It caused the deaths of 17 people. Roanu made landfall near Chittagong on May 21 2016, killing 26 people. Around 40,000 houses were damaged in the storm. Fani on May 4 2019 and Bulbul on November 9 2019 hit the coastal areas of Bangladesh, affecting numerous resources. Cyclone Am-

phan, an extremely severe cyclonic storm, took the lives of at least 31 people and destroyed at least 1,76,007 hectares of agricultural land in 17 coastal districts on May 20 2020. It also damaged 83,560 establishments, either partially or completely, in Khulna. Cyclone Yaas battered Bangladesh, leaving tens of thousands of people homeless and destroying roads, crops, and fish farms in 23 districts, mainly along the coastline, on May 26 2021. Cyclone Sitrang on October 24 2022 claimed the lives of at least 24 people and left millions without power after it struck Bangladesh, forcing the evacuation of about a million people. Cyclone Mocha hit the coast between ' 'Cox's Bazar in Bangladesh and Kyaukpyu township in Myanmar, with sustained winds of 250 km/h and wind gusts up to 305 km/h on May 14 2023. Three fatalities were reported in Bangladesh at the time. Cyclone Midhili, on November 17 2023, left seven people dead in Bangladesh. A total of 19,655 hectares of crops were damaged in six districts under the Barisal Division, resulting in losses of approximately Tk182 crore.

The table below presents a comparative analysis of casualties caused by cyclones in 1970, 1991, and 2007.

Table 1. Comparative analysis of devastating Cyclones that occurred in 1970, 1991, and 2007

Year of the Incident	No. of affected people	Total death	Damaged Houses
1970	4,700,000	300,000	400,000
1991	10,721,707	140,161	1,630,543
2007	8,923,259	4,234	563,877 (fully damaged) 955,065 (partially damaged)

Source: Cyclone Damage in Bangladesh, UNCDR, Nagoya, Japan, December 1991 (Further added by author)

1.2. Impact of Cyclone on the coastal community in Bangladesh

The impacts of Tropical cyclones in Bangladesh are devastating. It causes not only the death of the people but also disrupts the life and livelihood of the coastal community through the destruction of resources. The Cyclone Preparedness Programme (CPP), initiated by the government, reduces the death toll by constructing cyclone shelters and improving Early Warning Systems. However, cyclones still put a burden on coastal people. The cyclone in Bangladesh causes loss of life and injuries, damages infrastructure, disrupts the environment, agriculture, and fishing, creates a food crisis, and has a significant impact on the economy. This study aims to explore various sheltering options to ensure the safety of the coastal community in Bangladesh.

Figure 3. Damage to houses after Cyclone SIDR (Photo: Author)

This study aims to explore various shelter options for protecting the coastal community during cyclonic storms in Bangladesh. It also analyzes existing options and, through the study, prepares a guideline for building sustainable shelters in the ' 'country's coastal areas.

2. Background of the study

Providing shelter to the coastal community during a cyclone is one of the most challenging tasks, which can sometimes be done effectively. The Bangladesh government initiated a programme in 1972, named the CPP (Cyclone Preparedness Programme), following the devastating cyclone of 1970, in collaboration with the Bangladesh Red Cross Society, now known as the Bangladesh Red Crescent Society (BDRCS). CPP works with the early warning system, evacuation, and rescue of community members during a cyclone. It also ensures that people are sheltered in safer places and helps with post-disaster recovery and resettlement programs. The government then initiated the Coastal Area Rehabilitation and Cyclone Protection Project (CARCPP), under which several cyclone shelters were built in coastal areas. After that, many National and International organizations came forward and constructed a significant number of shelters in the aftermath of disasters. Some organizations also built Killas, a type of earthen mound raised on stilts that provided protection for livestock during cyclones.

In ' 'Bangladesh's coastal areas, many cyclone shelters have become useless because of poor construction and maintenance. Some have been ruined, whereas others are abandoned due to a lack of occupancy. Although cyclone shelters are constructed in coastal areas, some community members do not want to relocate to them, leaving all their belongings behind and staying in their houses. In the conventional cyclone shelter, there is no place for accommodating livestock, poultry, and other belongings of the people. Some cyclone shelters are built far from the community, as finding land is difficult near the community. Most cyclone shelters have shared facilities for men and women, which discourages conservative communities in coastal areas. Lack of security at the cyclone shelter is another reason people avoid going there during a cyclone.

Studying the most severe cyclones that have occurred previously, the sectors most significantly disrupted were the housing and livelihoods of the coastal community. Many houses in Bangladesh's coastal zones and coastal settlements are vulnerable to tropical cyclones due to their weak construction and location in high-risk areas. The coastal regions of Bangladesh are mostly undeveloped and rural. Approximately 40% of the total population lives above the poverty line, with most (81%) residing in rural areas (BBS, 2005). These scenarios are common along the coastal belt of Bangladesh, as they 'can't build resilient houses. Even when they stay at home during cyclones, there is a risk of significant casualties.

Given the frequency of cyclones, it is now essential to provide safe shelter for the coastal community. Cyclone shelters save lives; however, the security of resources and houses is also essential for the sustainable growth of the coastal community to align with national development. The study will explore sustainable shelter options by providing Disaster Resilient Houses that serve as shelters, are cost-effective, and offer extensive accessibility to the community.

Therefore, it is necessary to seek a sustainable solution to provide suitable shelter during cyclones and in the aftermath of disasters. Architects who deal with sheltering the community are continually experimenting with this solution. This paper will explore the existing sheltering options in the cyclone-prone coastal belt to understand the scope and constraints of providing shelter. The paper will also explore sustainable solutions to accommodate coastal populations during and after disasters by identifying the most effective shelter design.

3. Aims and objectives

The research aims to explore sustainable options for sheltering people by examining the existing shelter situation in ' 'Bangladesh's coastal areas. Furthermore, it seeks to understand ' 'people's perceptions of the design process for cyclone-resistant shelters and gather information about the building techniques used in individual shelters in coastal communities that can withstand cyclones.

The objectives of the research are:

- To explore the existing options for providing shelter for the coastal people during and after the cyclone.
- To analyze the scope, merits, and demerits of existing sheltering options.
- To prepare a guideline for designing sustainable sheltering options for the coastal community.

4. Aims and objectives

Both qualitative and quantitative methods are used in combination for the research. A reconnaissance survey of some coastal areas was conducted to gather information for a detailed survey and analysis. A literature review, Household Questionnaire Surveys, and Focus Group Discussions were conducted in the selected areas.

To achieve the ' 'study's first objective, a physical survey of various types of shelters in coastal areas, including multipurpose cyclone shelters, individual houses designated as shelters, and other Disaster-Resilient Houses, was conducted. Architectural and structural drawings of those cyclone shelters and homes have been studied thoroughly. For the second objective, a needs assessment survey on the requirements of the coastal community for shelter was conducted using a questionnaire and FGD. After that, a comparative analysis of the requirements and existing facilities was conducted to identify the gap between the supplied shelter and the ' 'community's needs. And finally, for the last objective, the perceptions and requirements of the general public, existing resources, and community capacity have been analyzed to prepare a guideline for the best possible solution for providing sustainable shelters.

The research design consists of two elements: a field-based inquiry (using interviews, observations, and documentation of settlements) and a secondary analysis of policy documents, scientific literature, and disaster reports. For case study four, vulnerable coastal areas were selected, those are: Urir Char, the south-western coastal districts such as Khulna, Satkhira, Borguna, and the south-eastern island Moheshkhali, etc. Cases were chosen using purposive sampling and were based on four criteria. They are; High exposure to climate-induced hazards, Ecological diversity, Variation in livelihood patterns, and Presence or absence of resilience interventions. Data was gathered using semi-structured interviews and field observation of housing, settlements, and local adaptation practices. 150 households were interviewed in the sites of choice. The respondents were men and women of various ages.

5. Initiatives Taken in Providing Shelter

In Bangladesh's coastal areas, the government, NGOs, and other organizations have initiated various solutions to provide shelter for the coastal community. The Cyclone shelter is the most common and predominant in coastal areas. It is designed and constructed for temporary refuge during a cyclone. There are other options, such as KILLAS (an Elevated earthen mound), to accommodate livestock. Following this, a considerable number of cyclone-resilient houses were constructed along the coastal belt to withstand extreme weather events through various projects and initiatives. The provision of cyclone-resistant houses has increased significantly following the 2007 SIDR. Below, the existing sheltering options for coastal people are discussed. The study of the previous project will help explore existing options for providing shelter for coastal people during and after the cyclone, as mentioned in objective 01.

5.1. Multipurpose Cyclone Shelter

In Bangladesh, a significant number of multipurpose cyclone shelters have been constructed following the devastating 1970 cyclone. A substantial response to cyclones has been the construction

of multipurpose cyclone shelters. Besides providing shelter during cyclones and tidal surges, these buildings are used during regular times as schools, community centres, and training centres. Most cyclone shelters are located in high-risk zones where wind speeds reach up to 250 km per hour, accompanied by water surges ranging from 6 to 15 feet above sea level. The structural design of these shelters must consider wind forces. Considering the tidal water surge factor, the buildings must also be supported by columns. These buildings also have a strong physical presence in the localities, providing local people with a sense of protection and security. Giving these buildings an aesthetically pleasing form also creates a sense of pride among local people. Providing safety during cyclones is the main objective of multipurpose cyclone shelters. As a preventive measure to mitigate the devastation caused by cyclones, various agencies have constructed cyclone shelters in Bangladesh's coastal areas. Here are some examples of Multipurpose Cyclone Shelter.

The main concept of constructing a cyclone shelter is to provide emergency shelter to the community and to save their life and livestock. The construction cost of this type of shelter is .05 million USD on average. The shelters were well accessible and had multiple uses.

5.1.1. PRISM

Projects in Agriculture, Rural Industry, Science, and Medicine (PRISM) responded quickly after the 1991 cyclone. They supplied three Cyclone Shelter cum Community Development Centres at three different locations within the high-risk zone of ' 'Cox's Bazar from 1992 to 1994. The structures are located at Chakaria, Maheshkhali, and Kutubdia, three island thanas in ' 'Cox's Bazar district of Bangladesh. They are exposed to the Bay of Bengal and are prone to cyclones. The 'villagers' occupation is mainly dependent on natural resources, with a focus on farming, fishing, and salt extraction. Most of the houses in these areas are made of fragile materials and are vulnerable to cyclones and storm surges. Therefore, the shelters work like sanctuaries for the local community. The focal point of these shelters is the ramp leading to the first floor, which enables people with disabilities to access the ' 'shelter's first floor and remain safe during tidal surges. The shelters also have provisions for sheltering the 'villagers' livestock. During regular times, these shelters serve as PRISM's office and are also used by community members involved in various development programs, including income-generating activities and informal education. The ground floor of the shelter is often used as a community gathering space and for various village events.

Figure 4. Cyclone Shelter PRISM (Photo: Bashirul Haq and Associates)

These Shelters were designed for 1,500 people, including their livestock, who lived within a 1.5-kilometre radius. The shelter is a 3-story building with a hollow ground floor above a 60-centimetre-high plinth. The ground floor of the shelter is 4.6 meters high, and the first floor is designed to accommodate livestock, which is accessible via a ramp. The total area of the shelter is 725 square meters. Considering 0.46 sqm of space per person, which allows people to stay there comfortably during a storm. The hollow ground floor, the roof, and the two floors in between can be used for different purposes simultaneously without disturbance, thanks to the staircase being placed on one side. Unlike other such projects, these Cyclone Shelters have toilets and water taps on each floor, which are designed to accommodate men and women on separate floors.

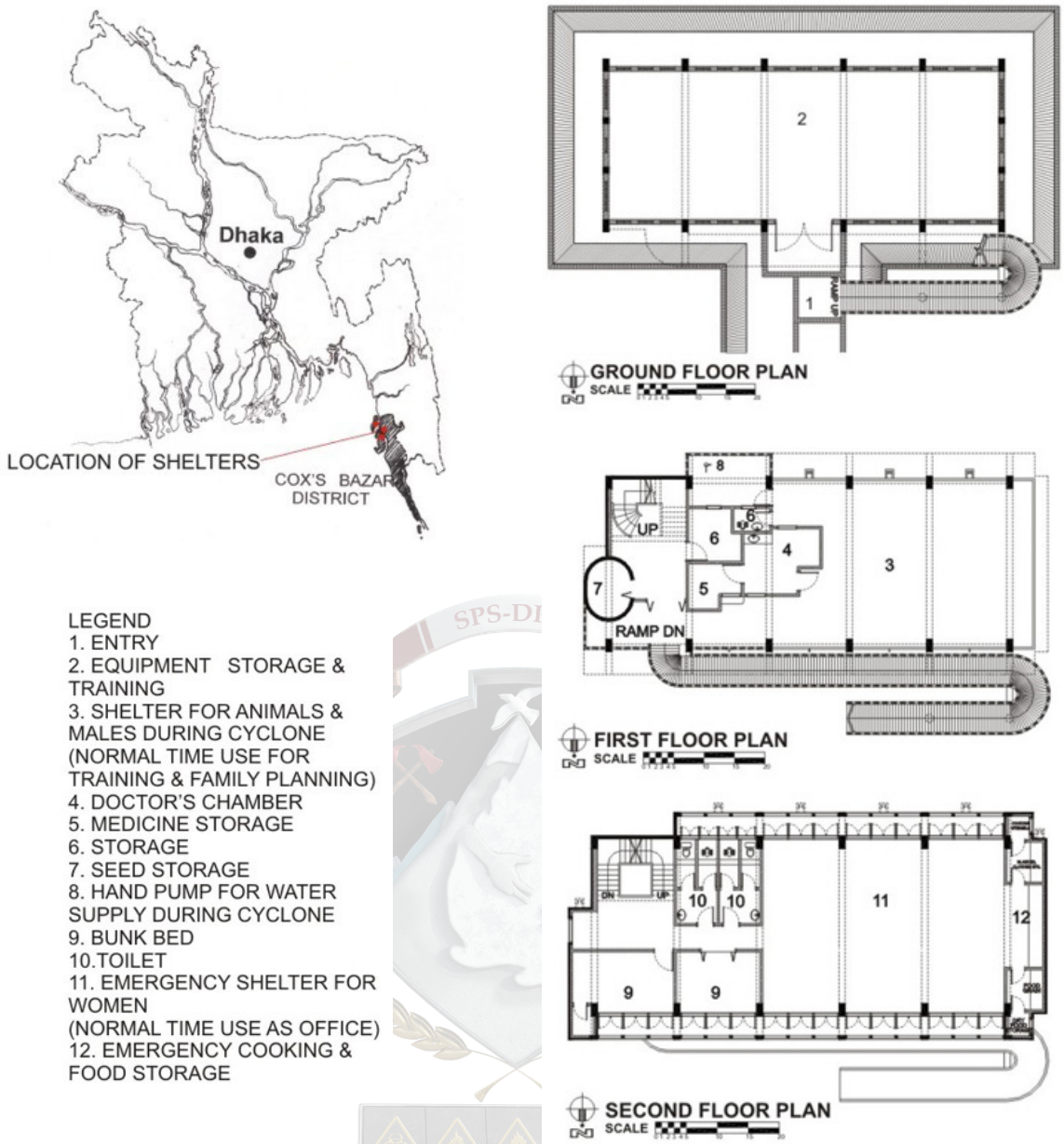

Figure 5. *Cyclone Shelter PRISM (Source: Bashirul Haq and Associates)*

The Cyclone Shelters are reinforced concrete structures designed to withstand cyclonic winds with speeds of up to 260 kilometres per hour. The ground-floor columns are braced to minimize bending caused by lateral wind forces. The raised ground floor allows the tidal surge to pass through the shelter without damaging the occupants. Once the concrete is finished, the buildings require little to no maintenance. Chemical hardeners have been used in the concrete mix to achieve a minimum porosity, thereby minimizing water absorption. The partition walls dividing the internal spaces are 1.25 centimetres thick and of exposed brick. Doors and windows are of wood. There is no glass in the windows to avoid accidents; instead, wooden louvres are used, and these can be adjusted to control light and air.

5.1.2. The Community-Based Multipurpose Cyclone Shelter (CMCS) by DASCOH:

The Development Association for Self-reliance, Communication, and Health (DASCOH) is a Swiss international NGO established on June 15 1994 and supported by the Swiss Red Cross. It started work in Bangladesh on May 17 1995. DASCOH took a unique approach to building CMCS, involving community members in the construction process. The Community-Based Multipurpose

Cyclone Shelter (CMCS) was built to support disaster management for cyclonic storms and tidal surges. CMCS provides shelter during cyclones and tidal surges and is utilized as community facilities, such as schools, community centres, and training centres, during regular times. The building was handed over to the users of locations at Kachubunia, Khonkar Para, and Moheskhalia Para of Teknaf, ' 'Cox's Bazar, in January 1999. The Swiss & French Red Cross financed the project.

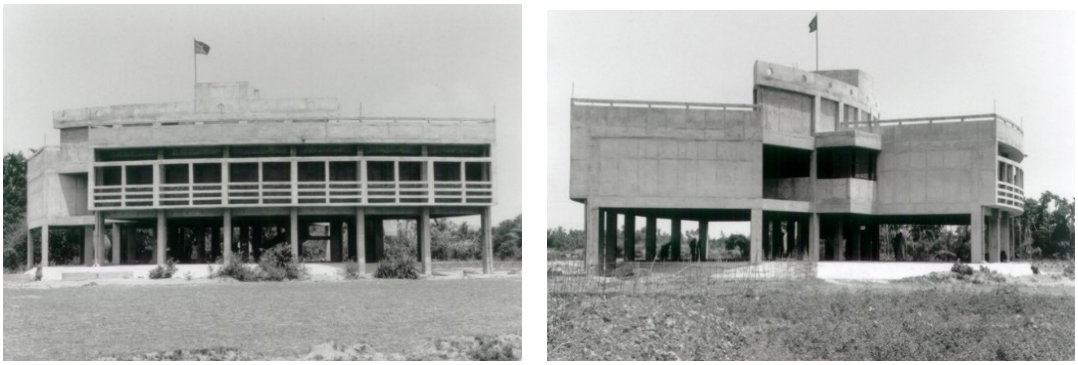

Figure 6. Cyclone Shelter DASCOH (Photo: Bashirul Haq and Associates)

The response of the Development Association for Self-reliance, Communication and Health (DASCOH) was unique in that DASCOH involved the people of the locality in the process of building the shelters. Distinctive features included site selection, the multiple use of the building, and approval of the basic concept plan, among others. The architect, DASCOH, and the contractor were closely associated with the local community. After completion of the building project, DASCOH handed over the management of the building activities to the local committees. These buildings are comparatively maintenance-free.

The building's form and the careful use of materials have had an impact on the locality, making it immediately acceptable to the people. Further, it was felt that the shelter location should be within a 1-kilometre radius of the village. The budget was a limiting factor. Criteria which considered during design and construction phases are the building form and aesthetics, availability of drinking water and toilet facilities inside the building that can be used during cyclones, heat and ventilation control during normal time as well as during cyclones, low maintenance finish, performance during normal time as a primary school and during cyclones as a shelter and separation of spaces inside the shelters for men and women.

Most cyclone Shelters are located in high-risk zones, where wind speeds can reach up to 250 km per hour and water surges can reach 6 to 15 feet above sea level. A significant design challenge was to find a robust structural solution that could withstand the combined forces of wind and tidal surge. The solution, a hollow ground floor raised on stilts, gives the hovering form and impression of lightness. As symbols of hope and protection against natural disasters, these shelters have a strong physical presence in their locations. Inspired by the local boat-building industry, the form was based on the image of a boat, with the core area of the shelter accommodating it. The two sails projecting out of the ' 'boat's shape core area, forming two wings, visually separate the ' 'men's and ' 'women's sections, which is a cultural necessity. The core area accommodates the staircase, drinking area, toilets, and a hand pump. The windows are positioned approximately four feet behind the rhythmic repetition of louvres, providing climatic protection and creating a dialogue with nature. A round plinth area defines the ground floor, which can be used for community activities at regular times. The first floor has five classrooms, a ' 'teacher's room, and a community development office. The covered area of the core at roof level is designed to store dry food and provide temporary cooking facilities during cyclones.

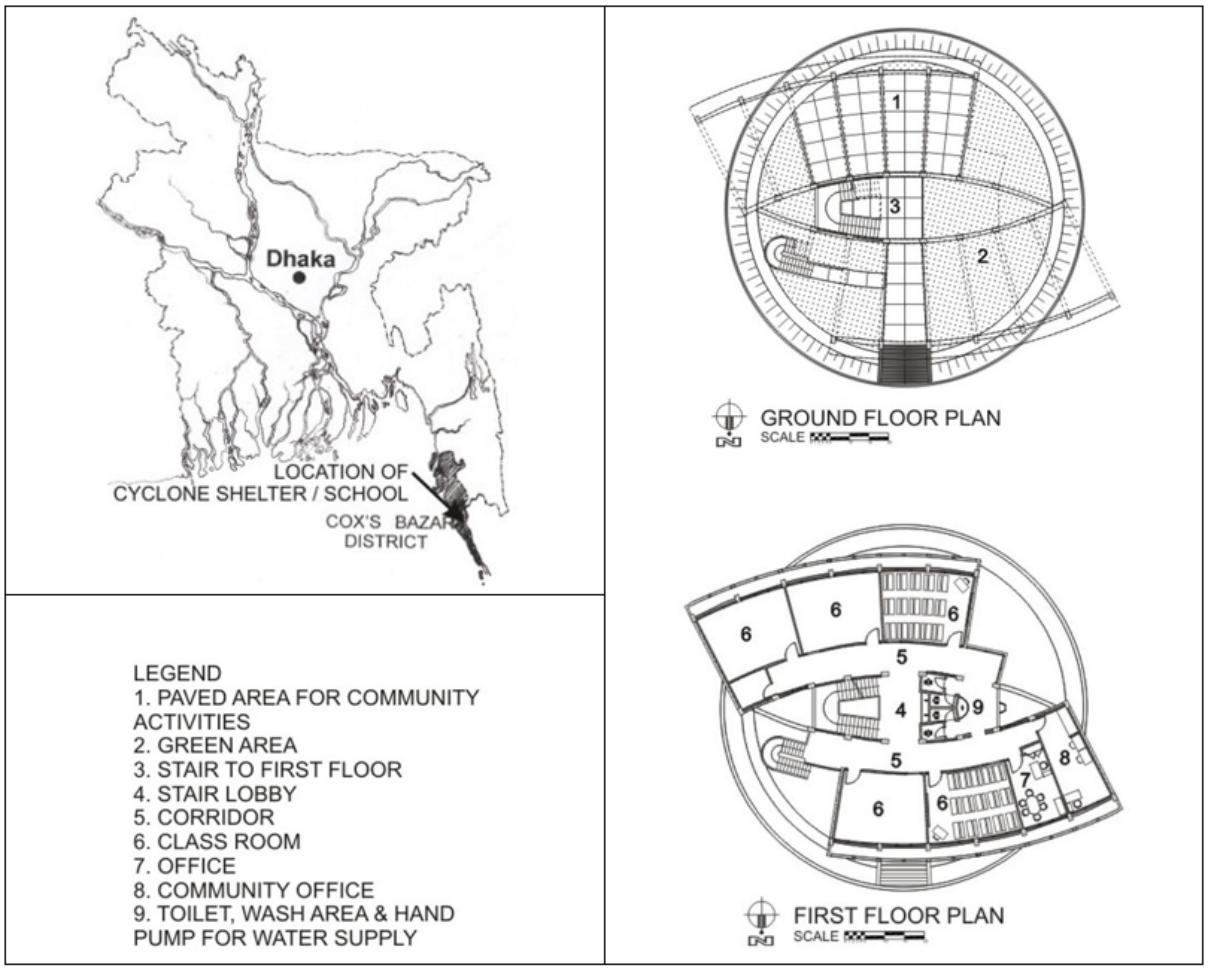

Figure 7. *Cyclone Shelter DASCOH (Source: Bashirul Haq and Associates)*

5.2. Disaster Resilient Houses (DRH)

The Disaster Resilient House (DRH) is a housing concept that involves building individual houses for households to reduce their vulnerabilities. It is designed and constructed in such a way that the house can withstand natural hazards, including cyclones, floods, and tidal surges, allowing for minimal damage over a long period and ensuring the safety of life during and after a disaster. DRH also provides livelihood opportunities and acts as a social infrastructure. In Bangladesh, DRH is an effective and popular option in providing shelter in disaster-prone areas. Many national and international organizations supplied a significant number of DRHs throughout the coastal belt, where all stakeholders attempted to construct sustainable and resilient homes.

The main concept of constructing a DRH is to provide individual houses at a minimum cost. This house provides shelter and safety to a moderate level of cyclone. It gives protection to the resources of the community. Here, the livestock are accommodated easily. The cost of this type of DRH was 5,000 USD.

Here are some examples for DRH:

5.2.1. Urir Char Project 1985

Urir Char, a river Island under Sandwip Upazilla of Chattagram, was severely affected by the devastating cyclone on May 24 1985. It caused the death of 20,000 people and massive property damage. Following that cyclone, the government initiated the construction of a resilient settlement in Urir Char. The project had several components that could be used in various combinations to

achieve different hierarchical levels of protection and could be spread over a time frame to gradually strengthen and reach the desired level of a balanced environment.

The settlement was designed with a dyke around it, and the houses were constructed within it following the nucleated dyke settlement concept. The houses were built as a cluster village with provisions for the growth of the individual houses. Each cluster had a pond in its center with sufficient land to accommodate 15 to 20 individual houses. The settlement was designed to include a shelter, a school, a market, a mosque, and other infrastructure facilities. All the typical facility buildings were intended to act as a cyclone shelter.

Twenty individual houses were built around a core house on R.C.C. stilts, forming a cluster locally known as a village, situated near the pond. The protective dyke, lined with plants, acted like a shield, protecting the houses in the cluster. Each household was allotted one bigha of land, and five bighas of agricultural land were allotted to each cluster.

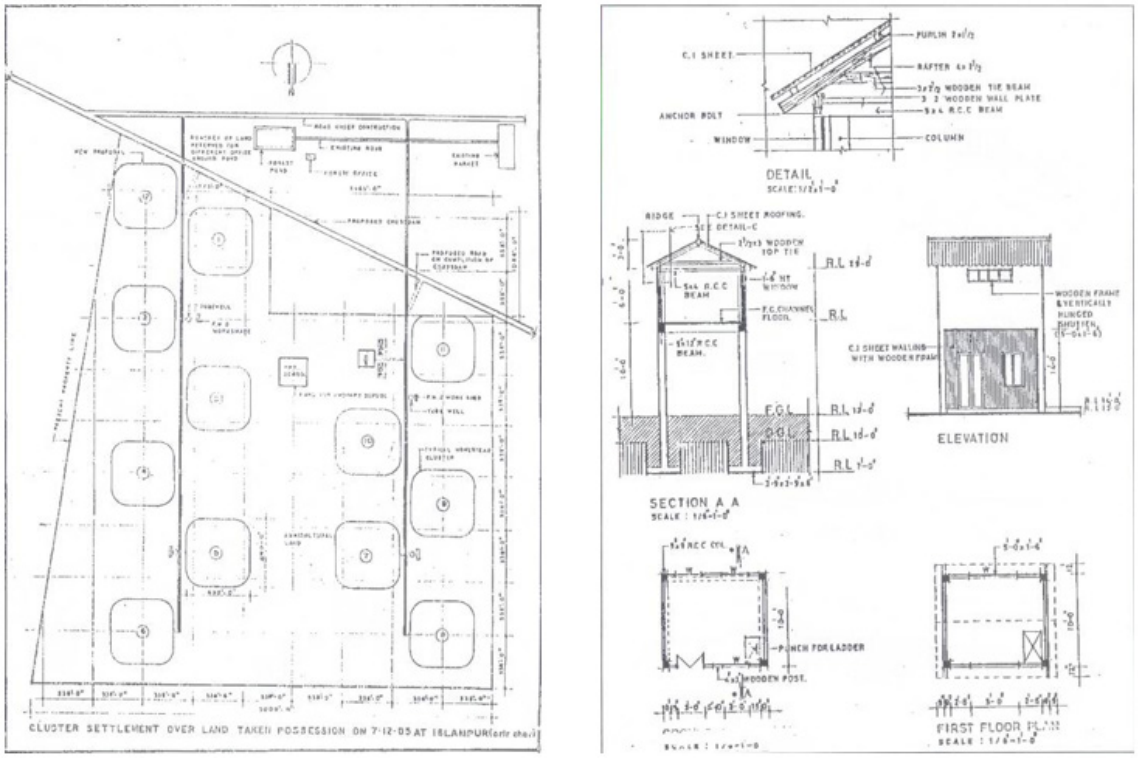

Figure 8. *Settlement at Urir Char the Cyclone on May 24 1985. (Source: Zahiruddin et al, 1991)*

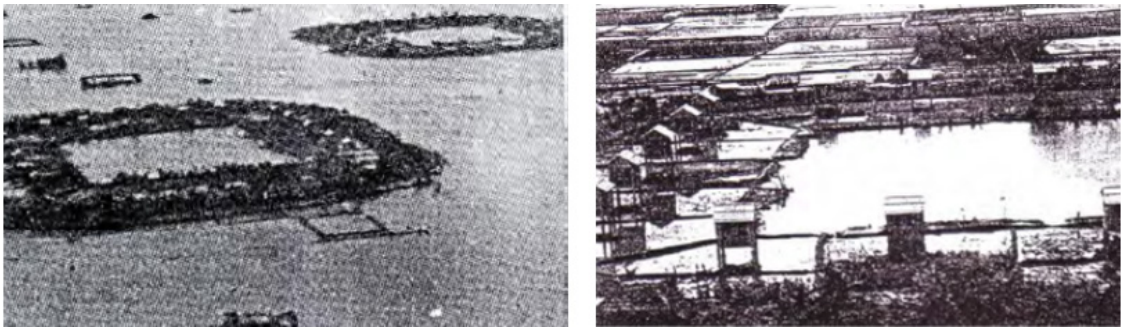

Figure 9. Settlement of Urir Char after the cyclonic surge of 1991. (Source: Zahiruddin et al, 1991)

5.2.2. Example of houses constructed by different NGOs in the SIDR-affected areas

Development and humanitarian agencies, in coordination with the Bangladesh Government, formed the Shelter Coordination Group or the Shelter Cluster to supply DRH after the Super Cyclone SIDR. The group built Transitional and Core Shelters and assisted in repairing houses. For

the study purposes of this research, the shelter projects of UNDP, BRAC, CARE, CRS, Caritas, and BDRCS have been analyzed.

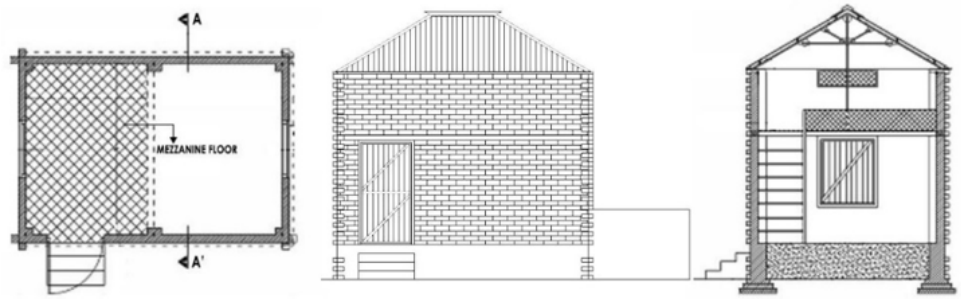

Figure 10. Plan, Elevation, and section of shelter projects implemented by UNDP (Source: Shelter Cluster)

BRAC

Figure 11. *Plan and Elevation of BRAC Shelter (Source: Shelter Cluster)*

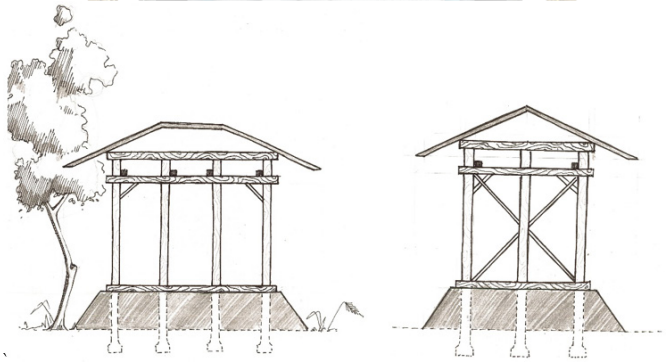

Figure 12. *Sections of BRAC Shelter (Source: Shelter Cluster)*

CRS and Caritas

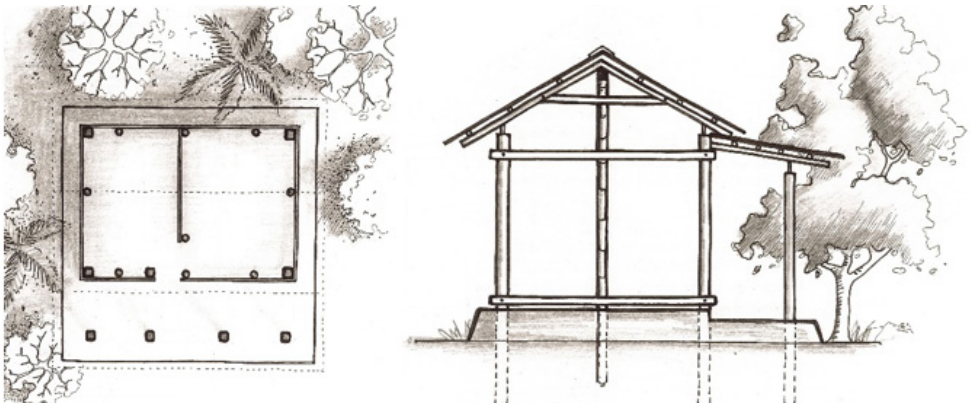

Figure 13. *Plan and Section of CRS and Caritas Shelter (Source: Shelter Cluster)*

BDRCS

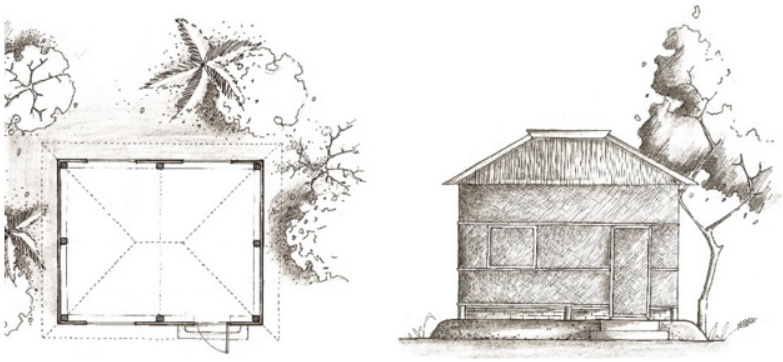

Figure 14. Plan and Elevation of Shelter projects implemented by BDRCS (Source: Shelter Cluster)

5.2.3. Cyclone Resilient Houses (CRH) by BRAC

BRAC, an International Development Organisation in Bangladesh, constructed 35 houses under its Climate Change Programme with assistance from other organisations. These climate-resilient houses are two-story buildings with a. In regular times, it serves as a typical house, and during cyclones and floods, it acts like a shelter. The features of the house is: it built on an elevated plinth with loft ground floor to allow tidal surge to pass through; it designed following the BNBC (Bangladesh National Building Code) 2021considering area specific wind speed; on the first floor there are two rooms with balcony; the ground floor is almost open to accommodate livestock and poultry; hygiene toilet, rain water harvesting, energy saving cooking facility are placed in ground floor; solar panels are placed on roof to supply electricity.

Figure 15. A Cyclone Resilient House by BRAC (Photo: Ashraful Haque)

The house is allotted to a single family; however, during a cyclone, 35 to 40 people, mainly from the neighbourhood, can stay there. During the allotment of the house, the owner agrees with BRAC regarding this issue. This climate-resilient house is more effective than a typical cyclone shelter in both financial and social terms. Recently, BRAC has been seeking to engage the Government of Bangladesh and the United Nations Environment Programme (UNEP) in this project to provide additional housing in disaster-prone areas. They are also conducting experiments to enhance the design, providing more features at a reduced cost.

The main concept of constructing a CRH is to provide individual houses tthat will act like a mini cyclone shelter at a moderate cost. This house provides shelter and safety from a cyclone not only for the owner but also for the neighbours around. It gives protection to the resources of the community. Here, the livestock are accommodated easily. The cost of this type of CRH is about 12,000 USD.

6. Existing condition of Shelters

Experts have explored several options to provide shelter during the emergency period in Bangladesh. Among them, Cyclone Shelter and DRH are the most practised options, which are constructed

to reduce the risk to life for coastal people during cyclones. Cyclone shelters are a vital disaster risk reduction option in Bangladesh, resulting in a significant reduction in the death toll from storms and tidal surges. Following the 1970 cyclone, many cyclone shelters were constructed in ' 'Bangladesh's coastal areas; however, not all of them function properly as emergency shelters. Among the 3,976 constructed shelters, approximately 1,576 were unusable or damaged. Faulty design, poor construction, and low maintenance are the primary reasons for the non-function of these shelters. Wrong location of the shelter, poor accessibility to shelter, lack of security, lack of privacy, and inaccessibility for the elderly, disabled, and pregnant women also made some shelters ineffective. Through the analysis of the existing conditions of houses and shelters, the second object of the study, the scope, merits, and demerits of existing sheltering options can be understood.

6.1. Existing condition of PRISM and DASCOH shelters

The PRISM cyclone shelters were constructed in 1994, and since then, they have been used by the community people for different purposes. Currently, the shelters are being utilized as community schools and community office spaces. Now, all the responsibilities regarding the shelter are carried out by the local community. However, the community lacks sufficient knowledge and resources to maintain the shelter, resulting in its prolonged neglect. Spontaneous use of the shelter is reduced, and only a few people use it during regular hours.

During the visit to the Mohashkhali PRISM cyclone shelter, it was found to be in poor condition. Though the ' 'shelter's R.C.C. structure is still firm, some portions of it have been damaged due to the lack of maintenance. Most of the windows on the floor are damaged, and those that remain are not in a suitable position to operate. Brick partition walls are partially damaged and are supplemented with a bamboo mat. The sanitation system is inactive with no provision for drinking water, which was provided during the construction of the shelter. The outer surface of the concrete walls is lichened, making the surface colour very ugly. The building has provisions for access by persons with disabilities; however, the approach road to the shelter, which runs through the field from the main road, is not adequately maintained after construction and has become inaccessible to older people and persons with disabilities.

Figure 16a. Existing condition of PRISM Cyclone Shelter (Photo: Author)

Figure 16b. Existing condition of PRISM Cyclone Shelter (Photo: Author)

Another shelter, constructed by DASCOH in January 1999 at three locations in Teknaf, was found unoccupied during a visit to the shelters. A primary school has one, but it is not in use and is in poor condition. The shelter is kept locked during regular times. DASCOH reduced its activities in the area, and the community people took over the responsibilities of the shelters. However, they are not using the shelters and have left them abandoned.

The ' 'shelter's structure is in good condition, except for some minor damage and colour deformation of the R.C.C. wall. Many of the doors and windows have been removed, and the rest are mostly damaged. The brick walls are affected by salinity and are partially damaged. The sanitation and water supply systems are eliminated. As a whole, two of the shelters cannot be used without major rectification, not even during an emergency period. The other one also needs to be adequately maintained and should be used regularly.

Figure 17a. Existing condition of DASCOH Cyclone Shelter (Photo: Author)

Figure 17b. Existing condition of DASCOH Cyclone Shelter (Photo: Author)

6.2. Evaluation of the impact of the 1991 Cyclone on the Urir Char Project

The settlement of Urir Char, which was developed after the 1985 cyclone, withstood the 1991 super cyclone and protected the lives and property of its inhabitants efficiently. Qazi Azizul Mowla, a planner and architect involved in the development and implementation phase of the project, observed that the houses and the neighborhood were expanded in accordance with the concept and philosophy of the survival process as conceived by the designer. The project proved its efficiency and sustainability, which Grameen Bank later adopted, and they established a nucleus settlement as part of their sustainable development process (Mowla, 1998).

6.3. Good Practices and Common Construction Problems of Shelter provided after Cyclone SIDR

'Shelter technical working group coordination mechanism' determined a standard to construct a core shelter after the cyclone SIDR, which the Bangladesh government permitted. Experts from the group surveyed and thoroughly analysed the houses to identify their strengths and weaknesses. The

team identified some good practices in the houses and pinpointed fundamental problems that made them vulnerable.

The effective improvisation of local techniques and past experiences:

1. The local house pattern influenced the morphology of the built houses.
2. Use of locally available materials, like timber, bamboo, ropes, etc.
3. Providing bracing at the corners of the houses in the horizontal timber frame.
4. Providing a cross to tie the walls and columns to the floors and foundations to make it more durable.
5. Adequate storage spaces were integrated in shelter design through the provision of attic space.

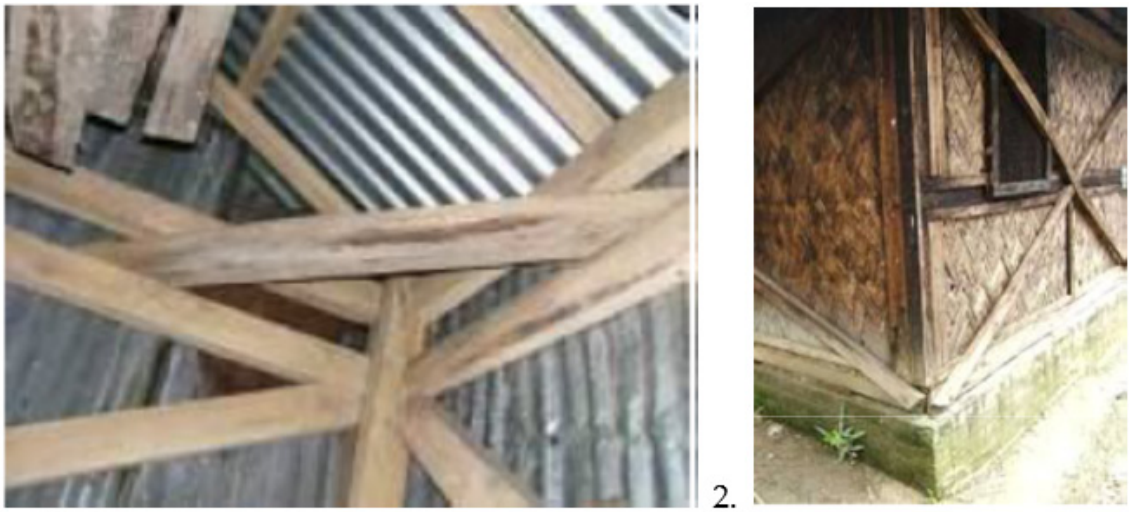

Figure 18a. 1 & 3 *Structural details(Source: Shelter Cluster)*

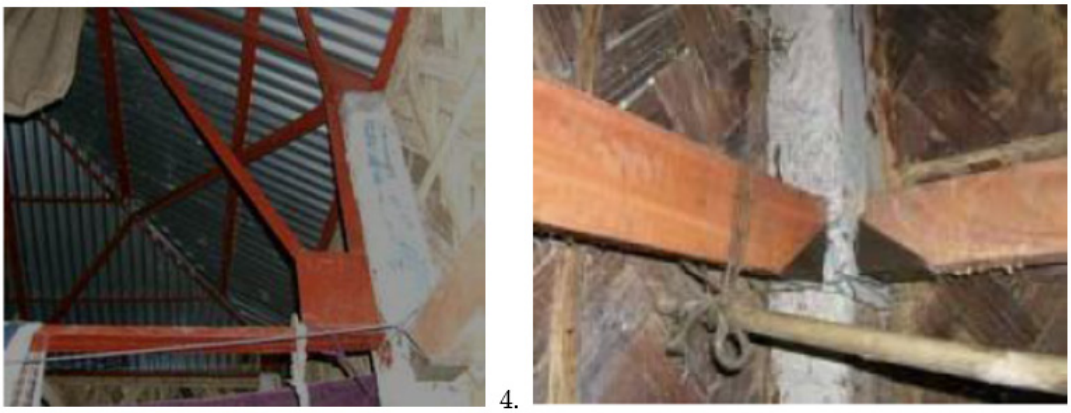

Figure 18. *3 & 4 Improved connections of R.C.C. pillars with steel roof (Source: Shelter Cluster)*

Major fault in the construction of the shelter supplied by the different organizations:

Houses that are constructed incorrectly or are made of poor materials cannot sustain a cyclone. These types of houses were vulnerable to natural disasters and could not withstand prolonged periods without support. During the survey, it was found that some houses had poor joinery details that were severely damaged, even under moderate wind forces during a cyclone. The use of a poor-quality CI sheet on the roof and metal truss also made the roof structure fragile, as both materials could not withstand the coastal environment'ssalinity.

From the study of houses constructed after SIDR, there are some methods and materials that should not be used for the sustainability of the houses. These are:

- Use of untreated wood or bamboo
- Use of a steel plate without precaution

- Low height plinth.
- Earthen floor
- Low-cost CI sheet on the roof.

And for sustainability, these methods should be followed:

- Use of a high-quality Industrial Bond Sheet on the roof.
- All materials should be checked and treated to save from the salinity and storm surges.
- Plastered flooring to protect against erosion. Etc.

Figure 19. A Loose connection of timber with R.C.C. pillar makes the structure vulnerable, and using nuts and bolts frequently makes the post less intense. (Source: Shelter Cluster).

6.4. BRAC Cyclone Resilient Houses

The concept of the BRAC climate-resilient house is to provide a shelter that will withstand cyclones. In comparison to a conventional cyclone shelter, these houses are more cost-effective. The construction cost of a cyclone shelter is around Tk. 2 to 3 crore, whereas the construction cost of a house is about Tk. 6lakh. So, at the cost of a cyclone shelter, 32 shelter cum individual houses can be constructed. In a cyclone shelter, on average, 1200 people can take shelter. On the other hand, 32 climate-resilient houses can serve as shelters for a minimum of 1,300 people during a cyclone. Therefore, more people can be accommodated in climate-resilient houses than in a cyclone shelter with limited budgetary constraints. As the houses are built within the community, people would not feel hesitant to move there and will get a private, safe, and secure environment.

7. Recommendations

The number of cyclone shelters is insufficient, resulting in a shortage nationwide. Bangladesh prioritizes this sector and has a plan to provide 100% of the required shelter to ensure the safety of coastal communities. Given the resources and changing trends in cyclone activity due to climate change, the government and other organizations need to implement practical approaches to providing shelters by improving their design, including services and accessibility. Not only the cyclone shelter, but they also need to explore the alternatives to typical shelters that are sustainable, considering the ‘ ‘country’s socioeconomic conditions. Here are some recommendations that will help to prepare a guideline for designing sustainable sheltering options for the coastal community:

7.1. Sustainable Options for Cyclone Shelter

Cyclone shelter is an essential DRR approach for the safety of life and providing shelter during a cyclone in the coastal areas of Bangladesh. However, the efficiency of the shelter depends

on its construction and execution, particularly in terms of universal accessibility. A cyclone shelter should meet the needs of all users, including those of women, children, people with disabilities, older adults, and pregnant women. Considering the safety, security, and privacy, a cyclone shelter should have separate facilities for men and women. The inclusiveness of these cyclone shelters is enhanced by special features, including provisions for breastfeeding, education for children, and managing menstrual hygiene, as well as designated safe areas for nursing mothers. The cyclone shelter should have a multipurpose use and be adequately maintained. Alternative uses of shelters keep them ready to use during an emergency.

Bashirul Haq and Associates explored some sustainable solutions for providing cyclone shelters after the devastating cyclones of SIDR and Aila. The solutions were submitted as a proposal during the design competition of cyclone shelters funded by the Saudi philanthropist Fael Khair. In the solutions for providing sustainable cyclone shelters, BHA proposed two shelter designs, focusing on the active multipurpose uses of the shelters. Below, the design solution of Fael ' 'Khair's cyclone shelter is discussed.

Faelkhair School/ Shelter Program:

An appropriate, less costly, and more workable shelter-cum-school design was the opinion of BHA, which was dictated by the site location. These are:

- Height of site from sea level.
- Surge height at the site during a cyclone will dictate whether livestock should be at first floor level (above surge level) by providing a ramp to the first floor or whether livestock can be sheltered by raising the ground floor to 5'0" " " " """ (±) above the surrounding land area.

Earlier studies in 1991 have shown that some people died while trying to save their livestock, and in the process, they got swept away by the surge. This fact is crucial to consider when designing the shelter. There is also the problem of the availability of large parcels of land for the construction of killas, as these require additional land for landfill. Considering severe land shortage, the idea of building a killa does not appear very attractive. Instead, it is essential to include a ramp in the design to make the shelter more user-friendly, particularly for the elderly, the sick, pregnant women, and people with disabilities. This ramp will also help the safety of livestock. The design should blend with the natural surroundings and be sympathetic to local building typology. For ease of vertical transportation, it is better to provide multiple options (stairs, ramps, etc.). Regarding the site, two types of sustainable design solutions have been explored.

Type-1: Raise the ground floor above surge height for sheltering livestock. In the design, it is recommended that the raised area be protected to minimize maintenance problems. This type of design solution will include five classrooms, the ' 'principal's office, storage, and other facilities at regular times. The design features two wings, providing separate shelters for men and women with children, intended for use as a shelter during a cyclonic storm.

Type- 2: Raise the ground floor plinth high enough to keep the first floor above the surge level. The plinth will be protected to minimize maintenance problems. This type of design solution will feature three classrooms, a ' 'principal's office, and storage space during regular hours, with the remaining area available for socio-cultural activities. The design features two wings, similar to Type 1, with one wing for sheltering men with their animals, belongings, etc., and the other for women and children during cyclonic storms.

Use of building materials:

The structure, except for the roofing, is built with R.C.C. column-beams and slab. R.C.C. members will have a 2 "clear cover due to salinity. R.C.C. columns and brick wall on the first floor are used to support wooden rafters, purlins, marine-grade plywood, and sheet metal roofing. Non-load-bearing R.C.C. sections will be used for railings. Openings will feature wooden frames, wooden styles for doors and windows, and operable wooden louvres in doors and windows for ventilation.

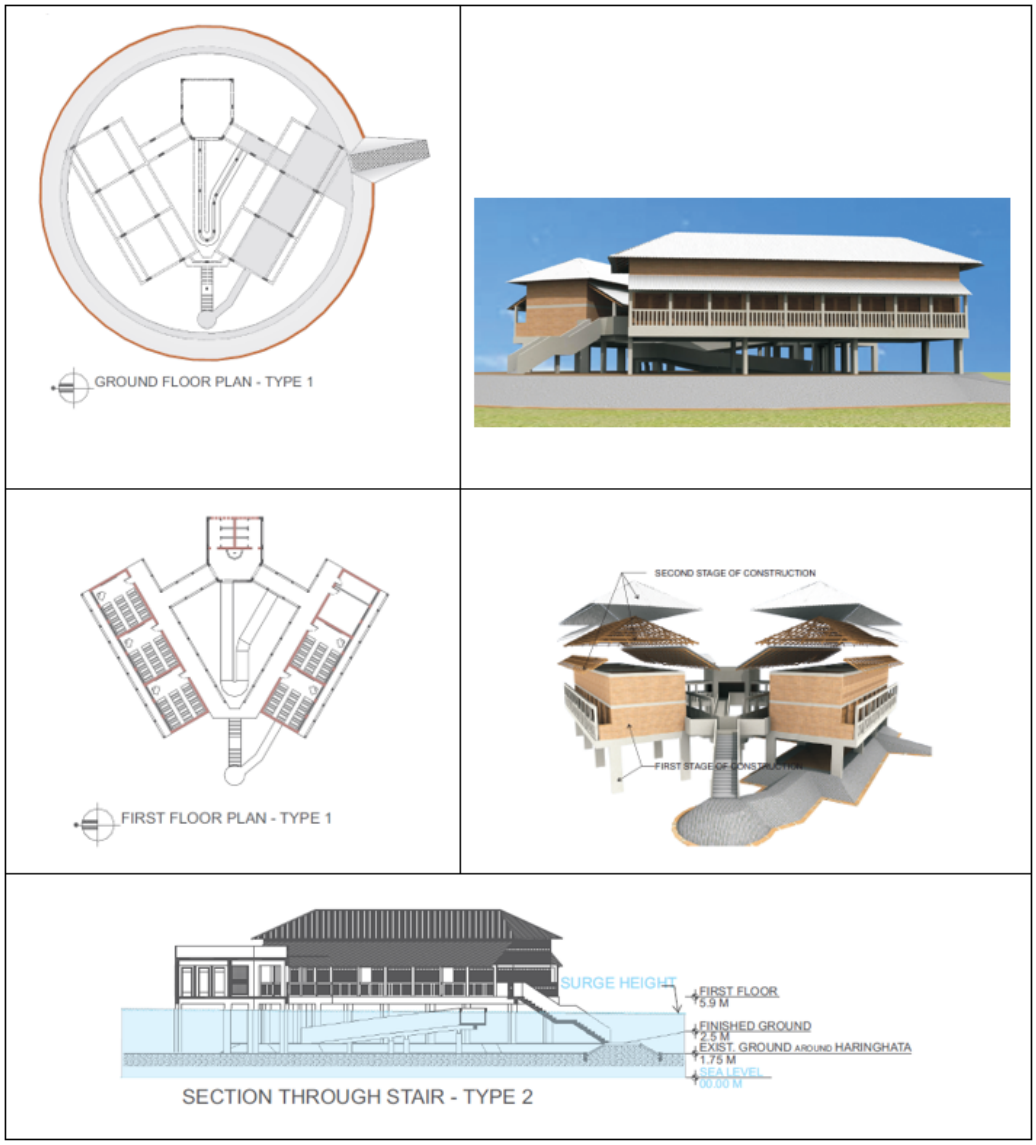

Figure 20. *The conceptual design of a Multipurpose Cyclone Shelter, considering an indigenous Disaster Resilient House proposed by Bashirul Haq and Associates. (Source: Bashjirul Haq and Associates)*

In the design, glazing is avoided to minimize cuts & bruises from broken glass. The use of steel or any other metal is minimized due to the presence of salinity in the atmosphere. However, steel can be used provided the sections are properly undercoated and factory finished. The appropriate type and quality of wood are used for different purposes. The wooden members will be seasoned, treated, and applied with proper preventive treatment. Joints in the roof structure of wooden joists and purlins will be carefully detailed to withstand the strong upward force of the cyclone. When installing corrugated GI sheet roofing, it is essential to space the purlins so that the sheet joints align with them. It is also recommended to use bolts and screws, including J-hooks, to make the roofing cyclone-resistant.

The building is carefully designed and detailed, allowing for construction to be completed in two stages. The first stage involves building the R.C.C. foundation, columns, beams, first-floor slab, brick wall, toilets, and other components. This part of the construction is to be undertaken by a general contractor. The second stage involves fabricating joists and purlins, as well as installing marine-grade plywood and sheet roofing, which will be constructed by a local subcontractor. The idea is to use locally available building materials and local technology, thereby fostering local economic development. Architectural practice should be closely linked with local people, enabling them to participate in project formulation, the design process, and construction, thereby transforming communities.

7.2. Disaster Resilient Houses vs Cyclone Shelter

A cyclone shelter is essential for saving lives during devastating cyclones, and a significant budget is allocated for its construction and maintenance. But people in the coastal areas are not always eager to go there because they have to leave all their assets behind at home. Cyclone shelters could not protect their belongings, livestock, stored grain, and poultry, as cyclone shelters have no option to accommodate them. Lack of privacy, accessibility, security, and an unhygienic environment also deter people from visiting cyclone shelters. So, people go to the shelter at the very last moment during a severe cyclone, which increases the risk to their lives.

Figure 21. an indigenous Disaster Resilient House in a coastal area. (Source: Bashjirul Haq and Associates)

Compared to the cyclone shelter, a Disaster Resilient House (DRH) is more effective in terms of cost and usage, as it can withstand disasters. DRH can easily withstand moderate wind forces and tidal surges, and if the quality of design, materials, and construction is maintained correctly, then it can sustain even in severe cyclones. In the physical survey following the 1991 super cyclone in the areas most affected, Ar. Bashirul Haq and his team discovered some local houses constructed using indigenous technology that had survived even after the massive devastation in the area. The design of the DRH should consider the BNBC code 2021, area-specific wind forces, a 100-year return period for severe cyclones, and predictions of sea level rise in 2050. If a DRH is built using this design method with proper materials and correct construction technology, it will provide a sustainable solution for sheltering people.

To provide a sustainable sheltering option, the entire settlement, including the DRH, should be disaster-resilient. DRH and DRS combined can provide shelter for coastal communities during extreme weather. To build a DRS (Disaster Resilient Settlement), the following components need to be incorporated:

- Houses should be built on a raised platform with a high plinth level.
- Plantation of different heights around the house with a safer distance should be implemented.
- Coastal afforestation is necessary along the coastline, serving as a shield and wind barrier during cyclones.
- Each settlement should have at least one PSF pond with a raised dyke to supply pure drinking water.
- An earthen embankment should be built along the shore, providing a proper slope with sluice gates to avoid waterlogging in the inner land.
- Scope for alternative and supplementary livelihood approaches should be incorporated within the settlement.

7.3. Using Indigenous Knowledge for Strengthening the Houses

In coastal areas of Bangladesh, people have their own mechanisms for sustaining themselves in the face of disasters, as they have lived there from the very beginning. They inherently learn how to survive and construct houses using their local technologies. Ar. Bashirul Haq gave examples of Disaster Resilient Houses in the book 'Battling the Storm – Study on Cyclone Resilient Housing', which were built using indigenous technologies and survived the super cyclone of 1991. He also discovered some indigenous details in building construction

technology, which strengthened the houses. In the book, he mentioned how the strength and longevity of local construction materials could be increased with proper treatment. He suggested blending indigenous knowledge with modern technology to build resilient houses and settlements.

7.4. Sustainable Solution for Sheltering Coastal Communities

This study explored three major options for sheltering coastal communities commonly practised in Bangladesh: Cyclone Shelters, individual houses supplied by different organizations after Cyclone SIDR, and Disaster-Resilient Houses. All these options have some limitations. Cyclone Shelters cannot provide all the facilities needed to ensure the safety of resources, and they are costly. Individual houses are not sustainable for the long term. Additionally, DRH is an effective solution, but it may not be feasible for large groups of people across coastal areas. Therefore, we should reconsider the sheltering options for individuals, ensuring the safety of lives, homes, livelihood opportunities, and other essential resources. A cyclone shelter will be there; in fact, all public buildings will act as a Cyclone Shelter. However, with these Cyclone Shelters, every ndividual's house should be able to withstand a cyclone up to a certain level, which will serve as an Individual Family Shelter.

This type of sheltering option should be designed and constructed with consideration for the local context, climate, available skills, construction materials, and cultural traditions of the area. The traditional houses that survived previous cyclones may offer guidance in this regard. The indigenous knowledge of local communities should be improved in the construction of houses by integrating modern technology. A disaster-resilient house is a preferable solution for an individual family in coastal areas because it protects their belongings, ensures safety, provides security, maintains privacy, and makes them comfortable, as they can keep their livestock and poultry in a safe place nearby.

7.5. Limitation of the study

The limitation of the study is that most of the components suggested for the DRH have not been tested in a lab to prove that the materials are suitable for the cyclone. In most cases, the DRH may not fulfil the requirement of the community, as traditionally, the household members in the family in the coastal zone are larger than the average. Sometimes the prototype house doesn't cope culturally with the community. Scarcity of land and ownership of land are other problems in building DRH.

8. Conclusion

Providing shelter during a cyclone is a fundamental requirement of disaster risk reduction. Shelter ensures the safety of life from storm surges in the coastal areas of Bangladesh. With the Cyclone Shelter, Disaster Resilient Houses are also a practical option for providing shelter to coastal communities. However, both solutions are designed specifically to save lives, which cannot protect individual houses and resources. Considering the financial aspects, neither of these . However, to build a resilient coastal community, people's capacity needs to be strengthened by stabilizing their socioeconomic conditions. And the stability of the coastal people is reflected in their housing conditions. So, in general, the individual houses in the coastal areas should also be strong enough to withstand a cyclone up to a certain level. For this, indigenous knowledge and modern technologies should be blended. In the construction of a house, the use of local materials and local skilled labour must be ensured, alongside the advancement of technology. Not only the individual houses but also the whole settlement must be resilient, including the embankment, mangrove forest, and other DRR components. To build a resilient coastal community, the safety of life is a must, but the houses, resources, and livelihood opportunities should also be ensured.

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