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Shelter Research Unit
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(p1) FOREWORD

Thousands of shelters are built throughout the world every year in response to disasters. Records are mostly kept per project, per operation or per organization. This means there is little inventory of shelters that covers a specific country across time and implementing agencies. Shelter teams miss out on extensive experience in and knowledge of building techniques, traditional shelters, or common shelter models used before in a specific region.

The IFRC SRU is collecting shelter knowledge in a global database of tried and tested 'Shelter Solutions' of some particularly vulnerable countries in the world. Using a standardized method of information collection, explained further on under 'Theoretical Construct', the different solutions become comparable and easily debatable by those in charge and executing new sheltering interventions. The burden of deciding remains with the implementing team but essential time can be saved by using the technical, material and design knowledge extracted from previous shelter interventions. The database, and this report, offers a country specific starting point to sheltering, focusing on the actual inhabited construct rather than on the largely agency driven implementation rational.

This report focuses on the south of Bangladesh. The world's largest delta is hit regularly by cyclones and tropical storms causing loss of homes. There are issues with sheltering in the north as well, but this report is limited by the information that could be collected about the south. The response to cyclone Sidr, that hit Bangladesh in December of 2007, led to the construction and repair of thousands of shelters. It was also the first time that the Shelter Cluster was activated in the country. A lot of the information in this report stems from this operation. Secondly, this report is based on a mapping field study carried out by an IFRC SRU consultant in December 2011. The 17 shelters presented in the 'Bangladesh 17 Shelters' are a direct outcome of this mission. They are referred to regularly in this document, through coded pictures.

For the reader, it is important to regard the issues highlighted in this report as essential issues to be taken into account when implementing sheltering in the south of Bangladesh. Attention is drawn to technical considerations such as cross-bracing, or design issues such as site organisation, but the list is nor exhaustive nor are the issues developed into all of their detail. Some issues are included that, in our opinion, do not yet receive the attention they deserve. This document is at the same time thus a 'repository', also leading to various other specialised resources regarding shelter in Bangladesh.

Foremost, we thank the people living in the shelters for allowing us to visit and document their homes. We also thank ACF, Action Aid, the Arab Emirates, the Bangladesh Government, the Bangladesh Red Cross, the British Red Cross, Care, Caritas, Cordaid, the IFRC, the Indian Government, Islamic Relief, Muslim Aid, the Swiss Red Cross and the Spanish Red Cross for allowing us to document their shelter projects in the field. Lastly, we thank the many people who have supported the publication of this report, and, not least, the people who have offered their technical feed-back.

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Bangladesh - 17 Shelters



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(p3) BASICS ABOUT BANGLADESH

General Information*

Part of British India until 1947 when it broke away as a part of Pakistan. Seceded from Pakistan in 1972 to become the People's Republic of Bangladesh.

On the Bay of Bengal, neighboured by India and, on its south-eastern border, Myanmar.

Large part, the south, is river delta. Tropical climate, June – October is monsoon season.

Demography*

Population: 154,7 million (2012, Worldbank), Population Density: very high, 1142 people/km², Population Growth Rate: 1.58%.

98% ethnic Bengali, remainder mainly Bahari and tribal groups.
89.5% Muslim, 9.6% Hindu.

Official language: Bengali. English used as well, in middle and upper class, in higher education and legal systems.

Economy*

Low-income economy, high population density and a vulnerable government structure; however the economy has grown 5,8% per year since 1996.

45% of the population works in agriculture, rice is the main crop. 30% works in industry and 25% in services.

31.5% of the population (over 50 million) is below the poverty line.



Floods and Storms*

Bangladesh is considered the 6th most vulnerable country to flooding in the world. Every 4 to 5 years, a severe flood affects over 60% of the country. One third of the country floods during the annual rainy season.

It is considered the 3rd most vulnerable country to cyclones; every 3 or so years it is hit with a severe tropical storm.

The many homeless are left on flood-prone lands. Waterborne diseases and water contamination are myriad.



*For further information:

www.moef.gov.bd/moef.pdf

www.emdat.be

www.worldbank.org/

www.cia.gov/library/publications/the-world-factbook/

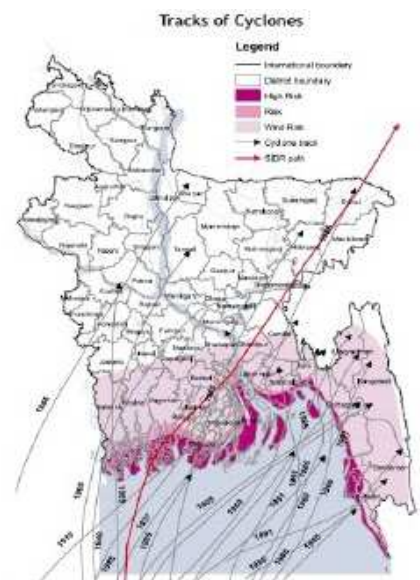
Recent Natural Disasters – 2007 to Aug 2013*

In the International Disaster Database EM-DAT, a total of 34 natural disasters have been recorded for this period. 15 of these were tropical storms and cyclones, 11 general and flash floods, 5 extreme temperatures (cold), 3 landslides, 2 epidemics and 1 drought.

The four that affected the highest number of people are:

- July 2007 floods, affecting close to 14 million people, killing 1110
- Cyclone Sidr in November 2007, affecting close to 9 million, killing 4234
- Cyclone Aila in May 2009, affecting close to 4 million people, killing 190
- July 2012 floods, affecting over 5 million, killing 131

Bangladesh is also at risk for earthquakes and fires. It is an extremely vulnerable country, because of its population density, geographical location and landscape, its weak governance (regulations, support systems, corruption etc) and extreme poverty.



Other Disasters*

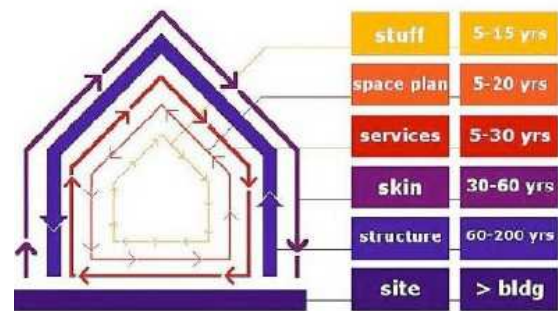
The country suffers regular technological disasters as well, mostly in industry and transport. The collapse of a factory killed 1125 people as recently as April 2013.

Bangladesh has known periods of violence, criminal, political or religiously inspired, but is rather calm today.

(p4) THEORETICAL CONSTRUCT OF SHELTER ANALYSIS

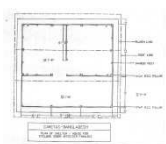
To systematically analyse a shelter solution, the IFRC SRU adopted a model from Stuart Brand* that defines buildings in six layers: site, structure, skin, services, space plan and stuff. He states that these layers change at different rates; the structure may not change that often while stuff generally does. This hierarchy is not static; layers lower in the hierarchy, such as site and structure can also change more rapidly than layers higher up such as stuff.

Apart from changing at different speeds, each layer performs a different function in the house. The site locates the building in its place, the structure keeps the building upright, the skin protects against the weather and the services make the internal environment comfortable. The space plan divides into separate spaces and stuff supports activities in the house such as eating, sleeping and cooking or is merely decorative.



Stuff:

Stuff consists of the furniture in the house and all other objects that can be easily moved around such as chairs, beds, tables etc.



Space Plan:

The space plan determines the interior lay-out of a building. These are the partition walls with the floors and the internal floors and ceilings.



Services:

Services are the working parts of the building such as the plumbing (water and sewerage), electricity and communication wiring, heating, ventilation, and air-conditioning.



Skin:

The skin stands for what separates the interior of the building from the exterior including its openings such as doors and windows; it keeps out the wind, rain, sun, heat and cold.



Structure:

The structure includes the foundations and its load bearing elements, and the roof structure, that together keep the building upright.



Site:

This is the geographical setting, the location and the legally defined lot where the building is built on.

A shelter response by agencies is always partial; families appropriate the shelter and change it into a home. Change needs to be built into shelter planning; with this layer system that change can be qualified more clearly. Limited response budgets force agencies to make choices, invest more or less in some or other layers. This layer system links those choices more clearly to the different functions and the durability of the shelter. Some layers may also be more crucial in some contexts than in others. This layer system makes it easier to compare shelters in that sense; which shelters respond most effectively to those aspects of a shelter that needed our biggest attention? These layers were used to structure the mapping and presentation of the individual shelters in 'Bangladesh – 17 Shelters', to compare them and to structure this report.

*See: HOW BUILDINGS LEARN. What happens after they're built. *Steward Brand*. Penguin Books 1995

(p5) RURAL VERNACULAR HOUSING

KUTCHA, SEMI-PUCCA AND PUCCA

KUTCHA AND SEMI-PUCCA HOUSING

The great majority of rural housing in Bangladesh can be labelled '*kutcha*' or '*semi-pucca*'. *Kutcha* stands for *temporary*, whereas *semi-pucca* stands for *semi-permanent* and *pucca* for *permanent**. It is a classification that focuses on the durability of the house. Both kutcha and semi-pucca houses require regular maintenance and replacement of parts (such as foundations, roof covering etc.) that have withered with time and in the climate. Providing that this maintenance is done, both types can offer very qualitative living environments.

KUTCHA HOUSING is made entirely out of organic material. For the walls materials like jute stick, catkin grass, straw, bamboo, mud etc are used. Partitions are mostly made using bamboo frames. In some areas earth is used, though rarely in the delta in the south. The roof covering is out of thatch from different materials, wheat or maize straw, catkin grass etc, on a split bamboo supporting structure. Around 70% of houses damaged by cyclone Sidr were kutcha**.



SEMI-PUCCA HOUSING is made of a mix of organic and inorganic materials. The structure may be of wood, concrete posts, earth or partial or full masonry. The wall cladding is most often bamboo mats, CI sheets or wood panelling. Sometimes earth or bricks are used. Foundations are mostly rammed earthen plinths, possibly reinforced with a brick perimeter wall. The roof is mostly covered with CI sheets on a timber or bamboo framing. Around 30% of the houses damaged by cyclone Sidr were semi-pucca**.



PUCCA HOUSING

Amongst the population there is a preference for houses out of concrete columns and a metal roof truss or brick-built houses. They are considered to be more disaster resistant. The materials are more expensive, and the techniques not well-known. These houses are most found in semi-urban and urban areas, in rural areas they are quite rare.



TEMPORARY HOUSING

There are some travelling communities in Bangladesh living in self-built temporary structures.

***TRADITIONAL HOUSE OF BANGLADESH : TYPOLOGY OF HOUSE ACCORDING TO MATERIALS AND LOCATION. Rumana Rashid.** University of Technology Malaysia, Hohor Bharu, Malaysia

****POST-CYCLONE SIDR FAMILY SHELTER CONSTRUCTION IN BANGLADESH. Documentation of Plans and processes, Rumana Kabir.** Shelter Working Group Bangladesh 2007-2009

(p6) RURAL VERNACULAR HOUSING

PANELLING

Many rural vernacular houses of the more affluent families with a large plot of land exhibit panel structures and facades. Out of timber a rectangular frame is put together, often with double nailing, and bolted to a mostly timber structure, or the timber structure itself is panelled. The panels are filled in with wooden or iron sheets. The panels or timber structure are often fixed to a tree trunk sunk into the ground that serves as foundation. The timber of the façade itself rests on clay disks on the mud plinth. In the absence of cross-bracing techniques, this panelled structure attached firmly to the structure of the house, provides wind resistance to the house. Though we didn't find statistical information to confirm it, these houses seem to resist wind forces better.

These houses are quite costly to construct. They require, for the context, a large amount of qualitative construction materials such as timber and bolts and a lot of hours of skilled labour. Often this type of houses is larger, has a higher roof over the central part and is surrounded with lower rooms and verandas all around. These are comfortable houses. Though people say to prefer RCC or brick structures, this type of house is still the 'good standard' in the rural areas.



This type of house is out of reach for the poorer families in the countryside who do not have the means to pay for the materials and labour, and don't have building plots large enough to sustain this architecture. Though there are solutions to provide cross-bracing with fewer materials, and in a different way, these are seldom practiced.

After disaster, there is a high need for materials and often a lesser supply. The higher quality timber used for this type of architecture was, for example, after cyclone Sidr as good as unavailable. Many people resorted to recuperation of timber from damaged houses and recovering entire panelled facades flown off houses.



For more detailed descriptions of rural vernacular housing types, please consult, amongst others:

BATTLING THE STORM. STUDY ON CYCLONE RESISTANT HOUSING. *Bashirul Haq*. Bangladesh Red Crescent Society and German Red Cross. December 1999.

(p7) RURAL VERNACULAR HOUSING

MUD PLINTHS, FOUNDATIONS AND ROOFS

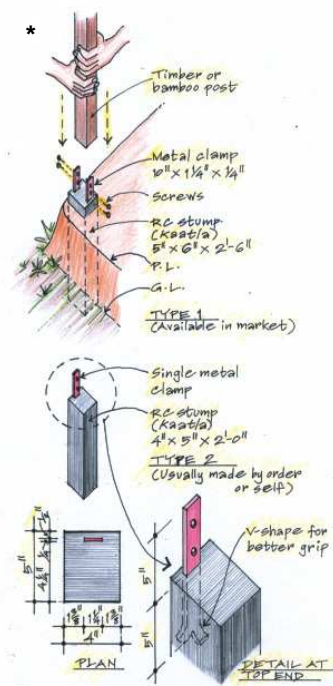
MUD PLINTHS

Almost all houses in the southern delta of Bangladesh are built on a single or double mud-plinth. Made out of clayish earth dug out next to the housing plot, leaving a pond, they provide extra height against flooding and a quite stable basis for the house. There are several techniques to reinforce the plinth: by adding hay in the mixture, covering it with a cement mixture, covering the edges with bags or tiles, adding gutters to the roof, increasing the overhang of the roof etc. The mud plinth requires regular maintenance, which is often done by the women.



FOUNDATIONS

Most of the stronger houses in the delta have pieces of tree trunk or thick branches stuck into the mud plinth as foundations. To these stumps the wooden upper structure is nailed or bolted. The stumps are regularly replaced and this can thus be done without compromising the entire structure. Sometimes these stumps are made in reinforced concrete, see the drawing* on the right.



For a more complete overview and detailed descriptions of rural vernacular housing technologies, please consult:

***HANDBOOK ON DESIGN AND CONSTRUCTION OF HOUSING FOR FLOOD-PRONE AREAS OF BANGLADESH. Dr. K. Iftekhar Ahmed.**
ADPC. Bangkok.
January 2005.

ROOFS

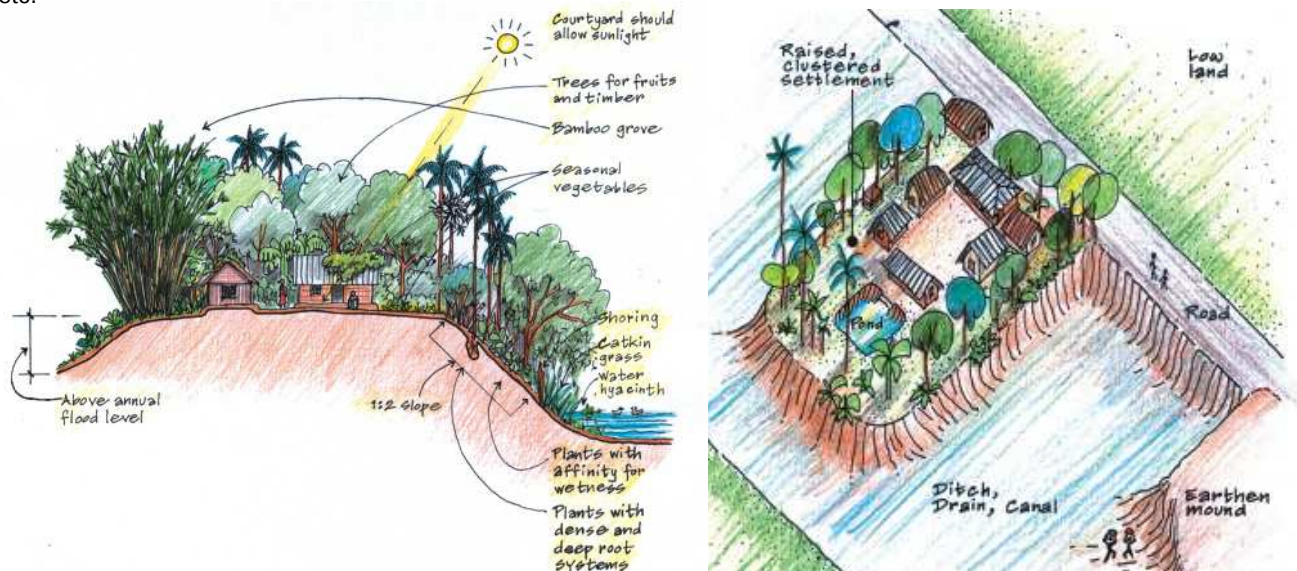
Most houses have a wooden roof structure, though bamboo, where it is available, and steel, for who can pay it, are used as well. In terms of structural integrity the quality differs a lot. Many roof structures miss essential cross bracings, have weak tie down of the roof coverage material to the structure, and of the roof to the wall structure. People that can afford it have overlapping joints and double pinning. Of many other houses the joints often pose a problem.



(p8) RURAL VERNACULAR HOUSING

SITE ORGANISATION

Most houses in the delta are grouped in clusters or along roads or waterways in a type of ribbon development. The entirety of the cluster or ribbon is on higher ground, easily 2 or more meters above the level of the surrounding rice fields. It is a sort of 'communal plinth' that protects the houses from flooding. This communal plinth is mostly fully overgrown with vegetation such as shrubs and fruit trees. This vegetation protects the plinth itself and the houses on the plinth from wind. The choice of plants and trees is not random: plants and trees that prefer a wetter environment are chosen for the edges of the plinth etc. Also the root system is important; deeper and denser root systems are preferred in a storm prone context. Except for protecting the house, this type of site organisation reflects the way the people live; the plinth supports daily life; grow food and construction materials, manage agricultural produce, discard of waste, wash, organise family life etc.



The above drawings are taken from:
HANDBOOK ON DESIGN AND CONSTRUCTION OF HOUSING FOR FLOOD-PRONE AREAS OF BANGLADESH. Dr. K. Iftekhar Ahmed. ADPC. Bangkok. January 2005.

Houses that are built in this kind of setting have shown to be less vulnerable to impact from storms, both from the wind as from flooding and flash flooding. Many families however don't live in such a setting and are much more exposed to the elements.



Left: a typical residential ribbon developed above the level of the surrounding fields. Right: also the houses that are not included in a cluster or ribbon will protect themselves as they can by organising carefully the plot they build on.



Left: a house built on its own double mud plinth, constructed on top of the communal plinth. Two pictures above: the edges of the communal plinth. The plinth rises above the level of the surrounding fields.

(p9) **IMPACT FROM A CYCLONE**

The death toll of cyclones in Bangladesh has been diminishing over the last decades. Extensive early warning systems and risk reduction efforts contributed to this (UNDP Bangladesh). Cyclone Sidr cost the lives of 4.234 (EMDAT database, CRED, <http://www.emdat.be/result-country-profile>). The destruction overall however remains enormous. Working towards more factual and evidence based sheltering, it is useful to look at how exactly cyclones bring damage to housing. Below are all pictures from after cyclone Sidr.

LANDSCAPE



Homestead vegetation flattened from wind force and rain, crops flattened in the field, trees losing foliage. Longer flooding can pollute ground and water sources. Though vegetation around the house breaks the force of wind and water, the type of tree and its root system can be inappropriate causing trees to fall on housing.

HOUSES

Generally, a difference is made between 'catastrophic failure' and 'component' failure; the first term pointing at total destruction of the house, the second to partial damage to parts of the house. Compounded, component failure can cause total destruction of the house as well.

Cyclones build up the pressure in the house, what causes strong up-lift forces. Certainly for light constructions, the foundations are often not heavy enough to withstand this or the tie down of the house to the foundation is weak. A second major cause is weak connections in steel and wood structures: inappropriate bolting, nailing, welding, reducing the rigidity of the structure. If the roof is not tied down for example, the roof will fly off entirely. Lateral wind forces tend to flatten houses which can be resisted by bracing the structure. The combination of up-lifting forces of pressure building up in the house and lateral wind pressures cause houses to be lifted up, toppling over, be torn apart and collapsing.

Storm surges caused by cyclones are particularly destructive, sweeping houses off their footing. Short and prolonged flooding can cause the soil to saturate and loose its carrying capacity. Sufficient anchorage or depth of foundations is key to prevent this.



Many mud plinths are swept clear of the house entirely. If flooding is not too severe, the mud plinth can remain rather intact, depending on the impact of torrential rains and storm surges.



Many houses are not anchored well enough in the soil. The foundations were not deep enough, not anchored well or too light. These houses are picked up and put down meters further sometimes furthermore still quite intact.



Houses are flattened by the push and pull of wind forces. Again the foundation, or connection to, is too weak. This damage is also caused by insufficient bracing of the structure; because of lack of cross-bracing or weak jointing.



Roofing material is blown off the house. In case of CI sheets this is caused by inadequate fastening to the structure of the roof and/or inappropriate frequency of the fasteners, in relation to their weight.

For more information:

GUIDELINES FOR CYCLONE RESISTANT CONSTRUCTION OF BUILDINGS IN GUJARAT. *Gujarat State Disaster Management Authority, Government of Gujarat.* Gujarat, India. December 2001.

(p10) EMERGENCY SHELTERING

The poverty of the housing stock, **the type of materials and structures used and the type of disasters affecting the south of Bangladesh allow for recuperation of materials after disaster to construct emergency shelters.** These materials are not always of good quality, but mainly good building technology for emergency sheltering is lacking. Adopting construction models and techniques practiced in 'normal' times is not adequate (see also page Rural Vernacular Housing – Panelling); they require too much time, skill and qualitative material. Emergency shelters need to be built quickly, with lesser materials and skills. Thereto, **different construction technologies are needed, that guarantee a minimum of resistance to wind forces and rains with lesser materials and skills.** These may be adopted in longer term construction as well, for people with smaller plots or less financial resources.

SELF-BUILT

Below are examples of what people put up within hours after a cyclone has passed. People recover materials from their old house, search for new materials and combine these to build an immediate emergency shelter. This will in many cases transition over time into a larger and stronger structure. Many families don't succeed however to add qualitative materials and apply strengthening techniques to these structures; they remain in these structures that have the value of a temporary shelter for months.



AGENCY SUPPORTED: MATERIAL DISTRIBUTION

Many agencies include shelter NFI's into emergency distributions immediately after disaster. These items should be chosen to help build and improve the structures the people start to build themselves. Plastic sheeting for example is a quick and easy solution to cover structures and keep spaces dry. Tin sheets can be less advisable since most self-built temporary shelters do not have adequate structural materials and strength to fix the sheets properly. In a context of frequent storms, this poses a safety hazard. Including connection elements and some basic training (manual or volunteers) into toolkits may be beneficial.



AGENCY SUPPORTED: MATERIAL DISTRIBUTION + TECHNICAL ASSISTANCE

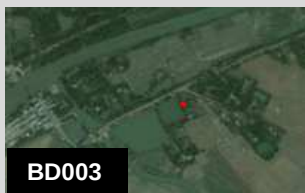
Below are pictures of an agency's temporary shelter intervention where shelters were built with material and technical support. This substantially increased the durability of the shelter and the comfort in the shelter. Built on the coast line, these temporary shelters allow for some storms and rainfall before a more long term sheltering solution can be provided.



(p11) LAYER ANALYSIS - SITE

Most of the documented shelters have been rebuilt on the same plot where the family's house was standing on before the disaster hit. These families are generally owner of the land. The vegetation around the house is thus mostly what it was before the cyclone hit, except for some trees that fell over or lost foliage. Still, there is a difference between the sites. Some are protected well, located in the inner of a residential cluster or ribbon, generously surrounded by vegetation and on a high communal plinth. Others are more exposed to their surroundings. None of the projects documented focused on the development of the site, because funding for housing was already scarce. In most cases it is neither advisable nor possible to change the site. Nonetheless, planning of the plot and the surroundings could impact positively on the resistance of the housing stock in the south of Bangladesh and should, in some way, be included in programming.

In this respect, look at: IFRC and BRC developed Participatory Approach to Safe Shelter Awareness (PASSA): tool to work together with vulnerable populations to increase the resilience of their shelter and settlement. It was tested in Bangladesh. <http://www.youtube.com/watch?v=ivC9Dr-FXyE>



LESS WELL PROTECTED SITES

Left to right: shelter in an open plain; shelter whose plot is well protected but directly surrounded by rice fields; site with little vegetation to break wind or flood forces.



WELL PROTECTED SITES

On the right: an example of a site that is located centrally in a residential cluster, where the shelter is protected by full grown thick vegetation.



NEWLY CLAIMED LAND

Three shelters documented are built on relocation sites. All three were built for families that were previously landless. Newly occupied land most of the time was previously used for agriculture or is new sediment because of shifting river beds. This land is not yet organised to give the shelters any type of natural protection and therefore the issue of site planning is even more important.

On the right: two shelters on land newly occupied for housing. The landscape is to be built from scratch.



Also BD015 is built on newly claimed land. It is, for the area, a high density relocation site. Of the projects documented, this one spent most attention to the organisation of the site, internally however mostly. Functions that usually happen on the land surrounding the shelter, such as cooking and toilet, are organised inside of each individual shelter. Water sources are provided in small, paved, alleys. The limited raising above the surrounding landscape of the entirety of the site, the lack of surrounding vegetation and the lack of rainwater collection may however pose problems.



(p12) LAYER ANALYSIS - STRUCTURE

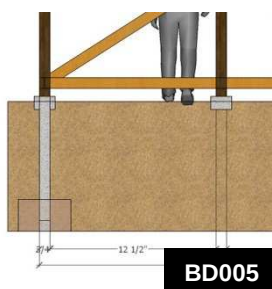
MUD PLINTH AND FOUNDATIONS

All of the 17 documented shelters are raised above plot level; most are built on a mud plinth. A good mud plinth is crucial for the stability of the shelter. It is however easily damaged by rainfall and, during storms, by floods, surges and receding water. Good maintenance of the mud plinth can compensate for rain impact. For resisting storms a reinforced plinth is better. On the pictures below, from left to right: a mud plinth eroded by rainwater, a mud plinth protected from rainwater by covering with plastic bags, a plastered mud plinth, a brick perimeter wall protecting the mud plinth, and a mud plinth protected by long roof eaves. (This last picture is from a traditional house; agency-built shelters have short eaves to reduce impact of uplifting powers on the shelter.) Cementing the mud plinth or building it up with a couple of layers of masonry are preferred options.



POLE FOUNDATION

Most of the documented shelters have reinforced concrete poles as foundation. In 2 cases, the poles reach up to plinth level, where a metal anchor allows the fixing of a wooden frame structure.



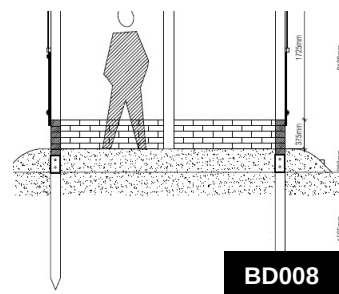
Most shelters have poles reaching all the way from the foundation up to the roof level. Some have a T-footing to improve anchorage in the soil. Others have a brick perimeter wall at plinth level tying the poles together.



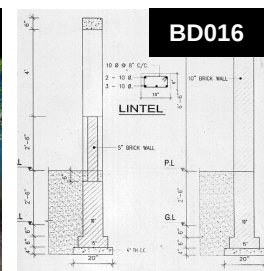
Another shelter was inspired by the local technique of 'kaatla' and has concrete poles reaching about 1/3 the height of the walls. This way, the wooden frame structure is less vulnerable to humidity. This type of pole is lighter and easier to transport than full length poles. It is also easier to produce, thus easier to guarantee quality.



Since the use of RCC is not common in Bangladesh it is difficult to guarantee qualitative work. Some actors set up their own production units for prefabricating poles; others ordered them prefabricated from urban centres where RCC techniques are better known. Unfortunately not all projects attained the desired level of quality. It is crucial that this part of the construction is supervised well.



STRIP FOUNDATION



The above shelters have a strip foundation as their superstructure is out of brick and concrete. The last one has a pier foundation. This last type is vulnerable to buckling; proper reinforcement is crucial. Corner bracing could be added, whereas full length diagonal bracing could form an obstacle for debris dragged along in strong flooding.

(p13) LAYER ANALYSIS - STRUCTURE

SUPERSTRUCTURE

TIMBER

Shelters BD005 and BD006 are timber frame constructions from top to bottom. Though locally timber is the most used material, the structural designs of these shelters are different to what people are used to build. The shelters resist lateral wind forces through cross-bracing rather than with panelling. In BD001, the timber joints are strengthened with metal plates. Supply of good quality timber is important; some agencies struggled to find well-dried timber and therefore shifted to materials.



Local



Local



BD006



BD001

REINFORCED CONCRETE COLUMNS

Many of the shelters are built with reinforced concrete columns. Though this is certainly a viable technique, and preferred by most people, there are some risks involved. Firstly the saline environment is not mild on concrete and any reinforcement bars that are exposed. Secondly, the materials to produce good quality RCC are not easily available. Water is often saline or not free of organic material. Sand and other aggregate is possibly abundant in the delta, but is often neither pure nor strong enough. Since the people are not used to this material the execution can also be problematic; the positioning of the reinforcement bars should allow for enough coverage, the mixture needs to have the right and an even consistency, the concrete needs to be compacted properly. Most villages lack electricity, so the tools that can be used are limited.



BD010



BD014

Lastly, transport of heavy columns is possible but not easy. Some projects included women headed households who struggled to organise transport of these columns to their plot. **In conclusion, using RCC is one of the options preferred by agencies, but close attention should be paid to quality throughout the whole construction process.**

Extreme left: uncovered reinforcement bar; left: concrete column suffering from environment.

REINFORCED CONCRETE / MASONRY STRUCTURES

Some agencies have opted for an entirely different structural concept and built shelters using a mix of masonry and concrete. Bricks are produced in Bangladesh, in the dry season, but not often used in rural areas. Issues with quality of masonry exist similarly to issues with reinforced concrete as mentioned above.

In terms of structural strength, in light of both storm and earthquake risk, considerations to be made with this type of structure are different. The heaviness of this structure makes it in principle more resistant to storms. Still, precautions are necessary and bracing of the structure crucial since storms can bring strong flash floods. Good earthquake resistance techniques should be applied as well.



BD003



BD004



BD011



BD016

(p14) LAYER ANALYSIS - STRUCTURE

ROOF

Except for BD003, BD004 (concrete roofs) and BD017 (thatch roof), all shelters have either a timber frame roof structure or a steel angle roof structure. Some frames are very minimal and miss elements crucial for withstanding high wind forces. These can only be considered temporary or transitional structures as they cannot, in their current form, offer safe shelter for a longer term in this context. Others are much sturdier and have applied wind resistance techniques.

The other major distinction is between hipped and gable roofs. A hipped shape roof allows wind to move more easily around the shelter and therefore performs better in areas vulnerable to storms. Still, gable roofs can also be designed and executed to withstand heavy wind forces.

TIMBER GABLE



BD007



BD005



BD001

Top left: a light purlin and rafter structure in small sections without reinforcement measures. Top right: same, but with addition of a king post. Side left: timber truss with cross bracing in horizontal and roof planes, joints reinforced with metal plates.

TIMBER HIPPED



BD011



BD017

STEEL GABLE



BD014



BD013

Left: a quite light steel angle truss, though with cross bracing in the horizontal plane and in the vertical trusses, bolted together. Right: a heavier steel angle truss structure where the connections are formed with metal plates.



BD002



BD006

STEEL HIPPED



BD008

Only one shelter has a hipped roof in steel angle. This roof was purposely designed to offer extra height in the house for storage, safe area and allowing construction of lower surrounding verandas as is the local practice. Trusses were pre-fabricated, welded, and bolted together on site.

From top to bottom: a simple hipped roof structure with good connections; a local roof with plentiful structural elements partially compensating for the lack of cross-bracing; a hipped roof with collar ties added; another hipped roof with collar ties and ridge beam.

(p15) LAYER ANALYSIS - STRUCTURE

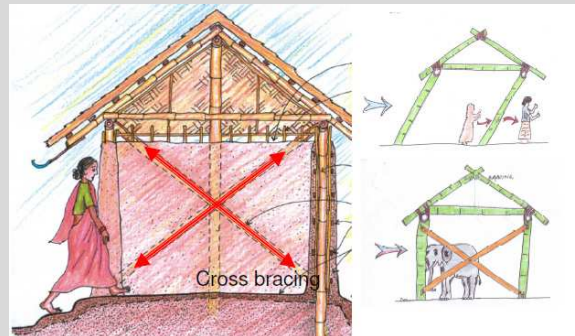
BRACING AND TIE DOWN

The two main structural principles to respect in areas subject to tropical storms and cyclones, in terms of wind resistance, are bracing and tie down. Measures to ensure both work together to provide wind resistance to the structure. In a simplified manner, bracing renders the structure rigid to withstand lateral wind forces whereas tie down keeps the structure down and thus protects the shelter against the up-lift forces involved in storms. For shelters seeking longer term durability both these principles need to be respected in the structure.

BRACING

Taking into account prevailing wind directions has a limited meaning in tropical storms as micro features of the landscape can make wind shift direction locally or cause swirls. The shelter thus needs to be designed to withstand lateral winds impacting from all directions.

The scheme on the right hand shows what bracing should prevent: the falling over of the shelter under lateral wind forces. In many of the shelters this has been done by adding diagonals to the structure, as in the drawing. In all the planes of the structure this needs to be done, also in the roof. It can however also be done in other ways, such as the traditional construction technique of panelling. Also strong, stiff connections between structurally sound elements can be sufficient.



TIE DOWN

Tie down needs to be considered from the bottom to the top. If the lower parts are tied down better than the upper parts, only the upper parts will fly away. If the upper parts are well tied down but the entire shelter is not fixed well to the foundations, the entire shelter may fly away. This happens to many of the houses in Bangladesh: because of weak foundations the entire house is lifted up by wind and deposited meters further.



Firstly the foundations need to be anchored well into the soil. Heavy rains and flooding can solidify the soil; that requires foundations of sufficient depth. Secondly, the superstructure needs to be well connected to the foundations. In many of the documented shelters, the RC columns extend into the soil to perform as well as foundation. The third crucial point in the structure is the connection of the roof structure to the vertical structure. Lastly, the upper part of the roof needs to be well-connected together and powers transferred to the rest of the roof structure.

GUIDELINES FOR CYCLONE RESISTANT CONSTRUCTION OF BUILDINGS IN GUJARAT. *Gujarat State Disaster Management Authority, Government of Gujarat.* Gujarat, India. December 2001.



Less good examples on the left: timber poles simply resting on ceramic disks not connected to any type of foundation. Bottom left: Ridge beam resting on wood trunk column without proper connection. Bottom right: hipped roof without a rigid truss.



Better examples on the right: concrete pole with T-footing for more anchorage, trunk stumps sunk into the soil carrying the timber frame structure, purlin held down with metal strap, gusset plate to form a proper roof truss.



(p16) LAYER ANALYSIS - STRUCTURE

JOINTS

The quality of connections plays a crucial role in both creating proper bracing and tie down. It is in the strength of the connections that forces impacting on the shelter are transferred well through the structure, down to the foundations. That doesn't mean that the structural elements (poles, timber etc) do not need to be strong, on the contrary. Strong connections between structurally weak elements will just cause failure to happen in these elements rather than in the connection points. Connections need to be thus fitting to the structural elements.

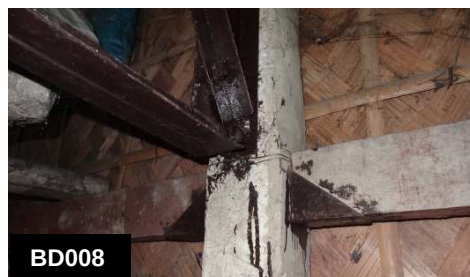
TIMBER JOINTING

Whether it is in the superstructure, in the roof or in the extensions and kitchens that the people build themselves, houses in the delta almost inevitably have timber connections. To resist impact from wind and water the rigidity and quality of these connections is crucial for the stability of the whole structure. A multitude of techniques is possible to create good joints; unfortunately not all shelters paid enough attention to them.

One agency distributed toolkits in the context of a recovery training for people with damaged houses and people building extensions to their shelter. Since connections are so crucial to increase the structural strength of the house, the agency included some galvanised L-profiles and metal straps in the toolkit.



Left: a double bolt. Double diagonal nailing reaching deep enough can be rather lasting, but bolts generally hold better than nails. Right: a timber connection that is reinforced with a metal gusset plate. It creates a strong ridge connection. Below from left to right: overlap joint (with loss of section though), timber hung up in a metal connector, rafter to purlin with metal angles.



MAKE THE RIGHT CONNECTIONS; A MANUAL ON SAFE CONSTRUCTION TECHNIQUES, prepared as part of the OAS/USAID Caribbean Disaster Mitigation Project (CDMP). *materials prepared by CRDC & SSI.* produced by the Safe Shelter Initiative and the National Development Foundation of Dominica.

HURRICANE-RESISTANT CONSTRUCTION MANUAL, ARE YOU WELL CONNECTED?. UNHCR & UNDP. Government of Montserrat.

METAL JOINTING

In the documented shelters, metal angles are primarily used in the roof structure. Most roofs are composed of trusses welded together. Welding on site can be delicate in this context because of insufficient skills, tools and safety measures. The environment requires strong welding joints that are coated afterwards. A lot of the trusses were pre-fabricated in a controlled environment and then bolted together on site. The connection to the supporting superstructure was done with bolting. From left to right: ridge connection, welded truss, welded truss bolted to RC column.



(P17) LAYER ANALYSIS - STRUCTURE

CORE SHELTER

The Ministry of Food and Disaster Management of the Government of Bangladesh in 2008 described core shelter as 'A small house of very strong cyclone-resistance materials that can be added onto by beneficiary households with storage spaces, verandas and extra rooms'. Many of the documented shelters are based on this concept. The main prerequisite to be labelled as a 'core shelter' is that cyclone resistance measures are taken in the structure (tie down, cross bracing, compact design, good foundations etc.). All other aspects of a house, such as division in rooms, proper walling etc, are considered less important. In the Brandt layer analysis of shelters, this means that the layer 'structure' is focused on more than the other layers. Many other shelters also only offer a minimal space, but, without resistance measures implemented, these need to be considered as transitional shelters rather than core shelters. Some core shelters are engineered (structural strength checked by qualified professionals), others are adaptations of best practice.

TIMBER CORE SHELTER



On the left, an example of a core shelter built in timber. The roof is hipped, has good jointing, a collar tie added to render the ridge connection sturdy. The timber structure is cross-braced and tied down to a concrete stump foundation with T-footing.



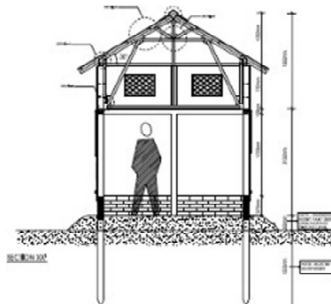
On the right, an example of an engineered core shelter out of reinforced concrete columns and a metal roof frame. The metal roof has strong connections and cross bracing has been added in all directions. This shelter has been calculated by engineers to resist very high wind force in cyclones.

RCC + STEEL CORE SHELTER



CORE SHELTER + EXTENSIONS

Core shelters are intended to be added to and completed by the inhabitants themselves. Some shelter designs have taken these extensions into account. The below example, also engineered, has been designed to become the core of an extended house. This core has a heightened hipped roof allowing for more storage and safe area in the roof. The roof reflects the local architecture where the surrounding verandas are built below the roof of the central part of the house.



Above: the original core structure of the shelter; a metal frame hipped roof on RC columns also serving as foundations, bound together by a 6 layers brick plinth. This structure was calculated by certified engineers to withstand cyclone level wind forces. Below: three different adaptations of this shelter design done by the inhabitants themselves.



(p18) LAYER ANALYSIS - SKIN

WALL CLADDING

BAMBOO MATS

In coherence with the fact that funding is most often not sufficient to answer to all the needs after disaster in Bangladesh on the one hand, and the preference for core shelter building of many agencies on the other, many shelters have been cladded with bamboo mats. These have a limited durability, even when treated. Painting with bitumen is the local damp-proofing, but treatment is often irregular. The quality of the bamboo, of the weaving and of the fixing can differ a lot.



From left to right: simple untreated bamboo cladding, untreated bamboo cladding in a locally built shelter, bamboo cladding protected with bitumen in the lower parts most exposed to rainwater, bamboo mat with proper fixing and combined with tin sheets.

TIN SHEETS



Quite some shelters are cladded with galvanised tin sheets. The auditory and thermal comfort in the shelter can be compromised by the use of tin sheets. On the other hand, it is a quickly applied solution that keeps the rain out better than bamboo mats. It is more durable than bamboo sheets, but also vulnerable in this humid and saline environment. On BD010 and BD015 the tin sheets are painted. Although coating may prolong the lifespan of the CGI sheeting it also absorbs more heat from the sun. Proper fixing of the tin sheets is important as well; tin sheets flying off during cyclones can cause injuries.

BRICK

On the right two shelters with masonry walls. In the first one, the brick masonry wall was not further finished on the inside. In the one on the extreme right the walls have been plastered and painted. In this saline environment with limited skills in cement works, the durability of the plastering could prove to be problematic.



PANELLING



On the left extensions built by the inhabitants themselves. Extreme left the wall of the veranda is out of timber paneling, with the lower part filled in with tin sheets since that part is most vulnerable to rainwater. This is a durable system but more expensive and time consuming than the majority of solutions practiced by agencies.

(p19) LAYER ANALYSIS - SKIN

OPENINGS



Most of the documented shelters have only one door. The Bangla way of living however, with the kitchen in a separate building in the back of the site, could benefit from one door in front and one door in the back. The door of the shelters documented opens towards the front of the house. A double panel door seems to be the most common local type of door. Some shelters have adopted this model, see left.

When the windows are concerned, a couple of different considerations are necessary. Windows are important for ventilation of the shelter, unless the walls allow for ventilation. With tin sheet or brick walls, the number and design of the windows become more important (see also below). Secondly privacy needs to be taken into account. Thirdly, in this context, quality windows and doors are not cheap; people can't necessarily pay for extra windows and doors. Lastly, not all construction techniques allow to add or remove windows easily.



The variety of doors and windows amongst the documented shelters is very high; some are quite qualitative whereas others will likely have to be replaced or repaired within years.

On the right, two examples of shelters that have taken extra measures to ensure enough ventilation through the shelter. The first one has some open joints in the masonry, the second one added a ventilation grill just under the roof.

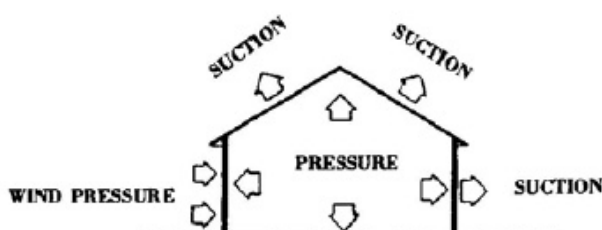


CYCLONE RESISTANCE

The choice of wall cladding affects the structural strength of the shelter. There are two options:

- a completely closed volume where the wind can move around easily
- a shelter where the wind can fly through without obstruction

In both options the building up of pressure inside of the shelter is avoided. That pressure causes the shelter to 'explode'; roof flying off and walls 'pushed' off.



For most of the shelters documented, this choice was not explicitly made. When the walls are out of bamboo mats, per definition the shelter can only opt for letting the wind pass through. For shelters that have tin sheets as skin, crossing of the wind through the house may be difficult. These shelters may benefit more from well designed windows and doors to render the shelter completely closed during storms.

(p20) LAYER ANALYSIS - SKIN

ROOF

Except for shelters BD003, BD004 (concrete roof) and BD017 (thatch) all the documented shelters have corrugated galvanized iron sheets as roof coverage.

Tin sheets flying off during storms are hazardous. Their proper fixing is thus crucial. The rhythm of fixings in relation to the thickness of the sheets is the first aspect to take into account. They need to be regular enough, and multiplied near the edges of the roof. On the other hand, if there are too many fixings, the sheet is perforated too much and can be ripped off along the holes of the fixings. Secondly the type of fixing is important. Capped roofing nails to protect the holes are a minimum, screws are better. Holding down the purlins with J-bolts or metal straps is an extra precaution to be taken. Lastly the roof ridge needs to be properly fixed. The quality of the tin sheets (thickness, galvanisation or coating, quality of the base material) can vary and needs to be looked at as well.



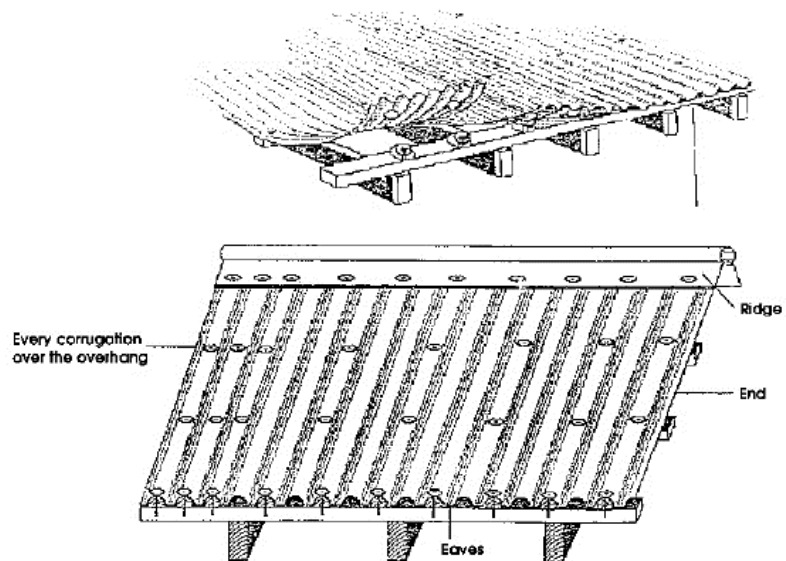
BD016



BD011



BD012



FIXINGS FOR SHEETINGS

SCREWS



- USE PROPER DRIVE CREWS FOR CORRUGATED GALVANIZED ROOF SHEETS.

- BE SURE THAT THE SCREWS GO INTO THE PURLINS AT LEAST TWO (2) INCHES.

- USE LARGE WASHERS UNDER THE SCREW HEADS TO PREVENT THE ROOF SHEETS FROM TEARING WHEN PULLED UPWARD BY HIGH WINDS.

NAILS



- REMEMBER TO USE SUFFICIENT SCREWS SO THAT THE HEADS WILL NOT TEAR THROUGH.

- NAILS DO NOT HOLD AS WELL AS SCREWS.

- USE NAILS WITH WIDE HEADS AND LONG ENOUGH TO BEND OVER BELOW THE LATH.

- GALVANIZED COATED NAILS ARE BETTER THAN ORDINARY WIRE NAILS.

LATHS SPACING AND FIXING

- SPACING FOR LATHS AND NUMBER OF FIXINGS WILL VARY WITH THE GAUGE OF SHEETING USED.

- SCREWS HOLD BETTER THAN NAILS SO FEWER SCREWS CAN BE USED. BUT THE SHEETING MUST BE THICK OR THEY WILL TEAR THROUGH.

- LATHS SHOULD BE PLACED CLOSER TOGETHER FOR THIN SHEETS TO PROVIDE SPACE FOR EXTRA FIXINGS.

- A GUIDE TO THE NUMBER OF FIXINGS AND SPACINGS OF LATHS IS SHOWN BELOW.

Gauge of Sheeting	Spacing of Laths
26	18 ins - 2 ft.
25	2 ft. - 2 ft. 6 ins.
24	2 ft. for nails 3 ft. for screws

Source : **Sushil K., Building construction, ed.11, Extract Roofs**

Tin sheets are mass produced and therefore interesting to use after a large scale disaster. They are also often preferred by the inhabitants. Tin sheet roofs however cause heat to build up in the shelter. In some of the documented shelters people have created a type of 'attic' to reduce the effect a bit. Rainfall causes auditory discomfort in the shelter. Lastly, the environment in the south of Bangladesh is not mild on the sheets, so the thinner and lower quality ones weather within a couple of years.

Thatch roofs, as the one in the picture right, in this climate are a good alternative for the problems mentioned. They regulate the climate in the house very well. It is however difficult to implement by agencies because of time shortage and procurement of this nor mass produced nor engineered material. Only a more intense participation by the beneficiaries can make this possible. This type of roof also needs more maintenance and repair.



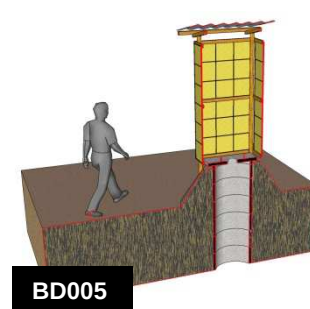
BD017

(p21) LAYER ANALYSIS - SERVICES

The housing in the south of Bangladesh is very poor; finished floors, climatisation, division of spaces, internal rendering of walls etc are far from the current living standard. Services are very minimal as well. In other contexts, in the Brandt layer analysis, services may be a substantial subject, in Bangladesh it is not. Only minimal amounts of money and effort were paid to services, because of the current living standard, and also because of limited funding. The documented shelters focus mostly on structural strenght and offering a minimal covered space. Only sanitation received attention in many of the documented shelters, still not in all.

SANITATION

Many of the documented shelters were built with an outside pit latrine toilet built in the back of the plot. The principle is mostly the same: a couple, 4 to 6, concrete rings are sunk into the soil and covered with a squatting slab. A minimal superstructure is built around the toilet. Some toilets were built with more attention for durability than others. Some toilets rise above the plot level and are organised on a heightened plinth, just as the houses are. This is certainly beneficial in times of flooding. The superstructure of some of the toilets has also been built with care for some basic durability measures. Other superstructures are rather flimsy, for the inhabitants themselves to improve over time.



From left to right: three pit latrines, with lesser and better superstructures; a pit latrine extraordinarily built inside a shelter; a typical pit latrine design.

Washing is done in the pond on the plot, in a corner of the plot sheltered by the house, or in a nearby river or pond. Since the current standard is so rudimentary, washing was not taken up in any of the shelters documented.

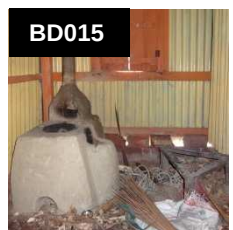
WATER

Clean water is an issue for most places in the south of Bangladesh. Communal wells are the most common source for water. Many wells however are contaminated with natural arsenic, or give saline water. On the right two examples of rain water collection included into the shelter project, and an example of a communal water pump as part of a relocation project.



OTHER SERVICES

Electricity is missing in many villages in the delta. Often there are slightly bigger settlements within kilometers of the villages, where people, from time to time, go to recharge their mobile phones for example. But, houses connected to an electricity network remain a scarcity. Light comes from kerosine lamps and /or with use of batteries. Cooking is done using fire wood and other natural materials. Each house has an area dedicated for cooking, mostly on a built in or portable stove, outside of the shelter in an especially built construction, or in the shelter itself.



Top from left to right: outside kitchen on porch, kitchen exceptionally built in inside of shelter, kitchen in separate built in the back of the plot, kitchen cupboard in the shelter.

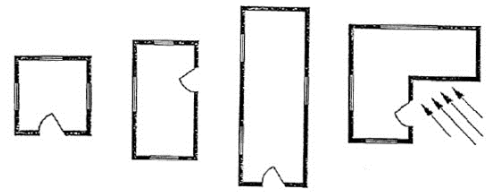


Bottom from left to right: two pictures of an extension built for storage and kitchen, inside of that extension, in the back, the kitchen is built in.

(p22) LAYER ANALYSIS - SPACEPLAN

SHAPE OF THE SHELTER

In terms of shape, the square resists wind forces best, then the rectangle. The long rectangle with the long side more than three times the short side, is less resistant. The most vulnerable shape in a cyclone is the L-shape. The wind cannot easily flow around the L-shape and therefore hits this shape shelter harder. All of the documented shelters are close to the square. The local practice of adding verandas along the whole length of the facades, with minimum depth, doesn't substantially change the shape of the shelter in this respect.



SHELTERS WITH AND WITHOUT VERANDAS

Many shelters designs included a veranda. Most often, these verandas were built in the same constructive principle as the rest of the shelter; mostly in RCC. All verandas were left open, as outside space in front of the shelter, but most of them were later on closed or partially closed by the inhabitants.



Many other shelters were built without veranda. But, as you can see in the pictures below, most don't remain without for a long time. People add verandas to their shelter, often not only in the front, but also on the sides of the shelter. They most often use techniques and materials that they are more accustomed to use, such as timber, timber and tin sheet paneling, or bamboo sticks, even in combination with thatch.



These self-built verandas have, in terms of structure, a different relation to the original shelter than the verandas that were built with the rest of the shelter, in one design. On the one hand, the question arises how attaching extensions to a structurally strange system can be facilitated. On the other hand, the impact of the verandas on the structural stability of the 'original', 'core' of the shelter is a question. Verandas catch wind forces differently than the core of the shelter. How that relates to the desired behaviour of shelters in storms has not been explicitly addressed by any of the agencies.

Verandas are important to regulate the relationship of the house with the surrounding, have a differentiation of spaces and provide some privacy in the inner of the shelter. Since life takes place outside for large parts of the day, the space plan of the shelter needs to be seen in relation to the site's 'space plan': where the kitchen is, the water, storage etc.

OTHER DIFFERENTIATION OF SPACES

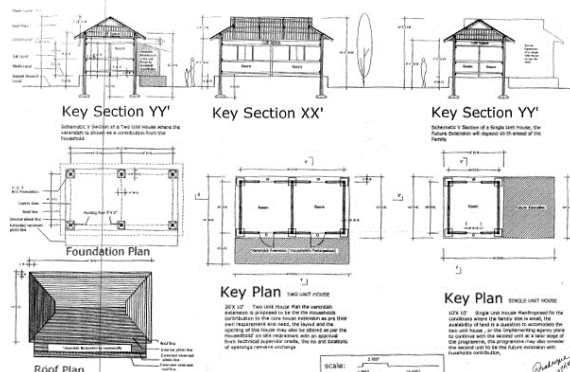


Left to right above: typical inside of shelter with large wooden bed; space in roof truss used as storage; typical setting in veranda; side extension for storage, built in natural materials. Extreme left: typical extra construction in the back of the site for cooking and/or storage. Left: less typical is a kitchen on the porch for example, such as a toilet inside of the shelter.

(p23) SIDR MINIMUM STANDARDS

In the aftermath of cyclone Sidr, the Government of Bangladesh, supported by the Shelter Working Group, developed Minimum Standards for shelter construction. A minimum of technical indications regarding construction techniques is offered, a standard minimum plan and 3 alternative construction techniques.

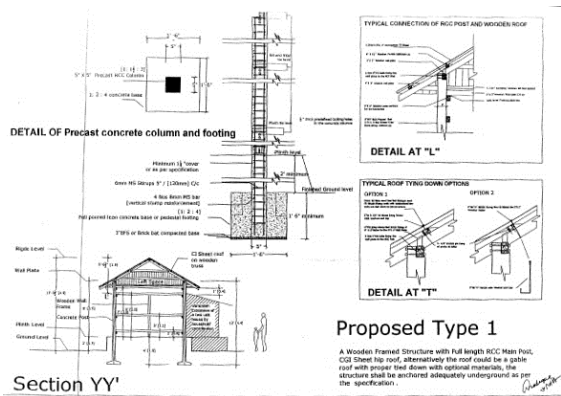
PLAN



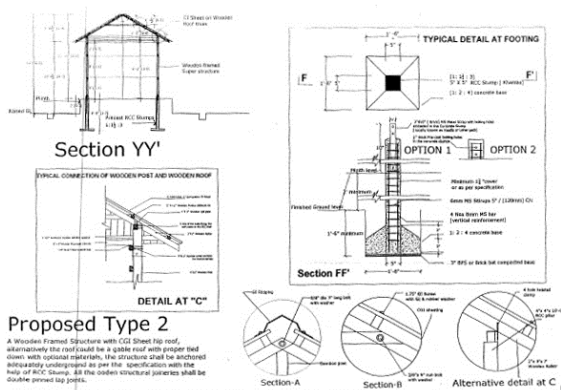
The proposed minimum unit measures 10'x10'; this is for smaller families or for families with a limited plot size. When possible, a double unit is recommended. The standard unit has one door in the front leading to one room, and 1 window in the back. A veranda is suggested to be built with participation of the beneficiary household and is not included in the design. It is also stipulated that the house layout can be altered in discussion with the household, and that the altered design needs to be approved by the technical supervisor.

The first alternative is a 'wooden framed structure with full length RCC main post, CGI sheet hip roof, alternatively the roof could be a gable roof with proper tied down with optional materials, the structure shall be anchored adequately underground as per the specification.' The second: 'a wooden framed structure with CGI sheet hip roof'. Also here a gable is suggested as alternative. Furthermore RCC stumps are recommended for foundations, and the need for double pinned lap joints is highlighted. Alternative 3: 'RCC main post, CGI sheet hip or gable roof on MS steel truss with proper tied down with optional materials, the structure shall be anchored adequately underground as per the specification'.

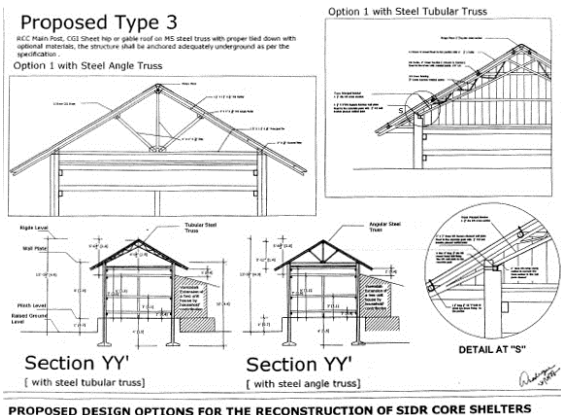
3 ALTERNATIVE TECHNIQUES



PROPOSED DESIGN OPTIONS FOR THE RECONSTRUCTION OF SIDR CORE SHELTERS



PROPOSED DESIGN OPTIONS FOR THE RECONSTRUCTION OF SIDR CORE SHELTERS



PROPOSED DESIGN OPTIONS FOR THE RECONSTRUCTION OF SIDR CORE SHELTERS

Elements	Specifications
House Size	Considering scarcity of available land, resource constraints or other limitations the minimum house size shall be 10 ft. X 10 ft. However, 10 ft. X 20 ft. size house is preferred.
Ceiling Height	The minimum ceiling height shall be 8 ft.
Roof	Sloping roof made of CGI sheet (0.35mm or 29 BS Gauge minimum thickness) with seasoned and treated hard wood rafters and purlins or steel frame (coated with metallic anti-corrosive paints). All C.I. sheets shall be tied firmly with superstructure by galvanized iron by J-bolts and/or by any other recommended device.
Wooden Framings	All wooden structural joineries shall have adequate double pinned lap joints. All frames shall have horizontal or diagonal bracings as appropriate. Lap joints shall be without reduction of timber sections.
Wall Cladding	Free Option
Column/Pillar	Pre-cast reinforced concrete pillars shall be cured for at least 14 days before transportation. The specifications for the RCC pillars should be as below: • Clear cover to MS bar for concrete: - 1 inch for pre-cast concrete members above ground - 1 ½ inch for cast-in-situ concrete above ground - 1 ¼ inch for pre-cast concrete members below ground - 2 inch for cast-in-situ concrete below ground • Coarse Aggregate: ½ inch downgraded gravels/P.J bricks • Fine Aggregate: Clean river sand free from salinity having • Fineness Modulus not less than 1.5. • Cement: Ordinary Portland Cement • Mild Steel: All Mild Steel shall be 40 grade (fy=40,000 psi) • Mix Ratio: Not leaner than 1: 1 ½ : 3 unless otherwise mentioned. • Slump for wet concrete: 1 ½ inches • Concrete Strength: Minimum concrete strength shall be 3,000 psi.
Plinth	• The most preferred plinth is earthen plinth with five (5) inches brick outer wall with cement mortars (1:4). • For Soil stabilized plinth minimum cement content shall be 5% • The minimum plinth height shall be 2 ft from the ground level.
Foundation	Foundation depth shall be 1 ft. 6 inch from Finished Ground Level.

This design, and its alternatives, and the technical specifications above, indicate a preference for structurally durable shelters and can be considered a core shelter. Many of the elements in the design can be found in many of the documented shelters, such as RC foundations with footing, a brick perimeter wall, cross-braced steel roof trusses etc.

(p24) TRAINING

Since the seventies much has changed in Bangladesh regarding disaster preparedness and response. Because of the frequent recurrence of disasters, and corresponding support of government and agencies, the awareness of principles of disaster management is quite high amongst the population in comparison to other contexts. Early warning systems for example have over the years seriously reduced the number of deaths caused by cyclones. It can thus be considered that there is a positive context for shelter training.

Workshop: One agency added a training aspect to their project. Technical volunteers were trained in simple construction techniques that can substantially improve the resistance of a house or a shelter. The training was partially theoretical and partially practical; as in the pictures below volunteers learned how cross-bracing can prevent shelters falling over, and how to make improved timber joints. These volunteers subsequently worked in the project offering technical assistance to people rebuilding, repairing or expanding their house.



Poster: The same agency put up and distributed posters that repeat some of the key lessons learned in the workshop and during the technical support offered to the affected households.



Often, the number of damaged houses in Bangladesh is so high that funding cannot match the need. Many families with partially damaged houses never receive any support at all. For built houses that are not damaged, or for extensions to the shelters, training can be very beneficial as well, as for poorer households that need to make the most of lesser materials, skills and plot sizes. Except for the examples presented here, also one agency, after Sidr, worked with a shelter model built in the affected village. Organising a 'housing information centre' is another option, and there are more.

'On-the-job training': Some agencies included skill training for construction workers in their shelter project, as a type of on-the-job training. While building shelters they improved their skills in techniques such as doing proper timber jointing and making reinforced concrete. Certainly this last skill deserves attention: more and more shelters are built with RC columns and foundations, while the skill level, locally, for construction, maintenance and repair is still quite low.



Leaflet: in a collaboration between different agencies, a leaflet was produced containing some of the most crucial elements of structurally sound construction techniques. It was translated into Bangla to be used in communication with the affected population. Also this leaflet has value outside of disaster times.

Though some initiatives have been taken regarding building safe shelter awareness and including training aspects into shelter projects, there is improvement possible, as for example:

- Define and share key issues (expand to site organisation, ensure structurally correct messages etc.)
- Test posters, leaflets and trainings to improve them and get messages across better
- Develop training curriculum, training of trainers
- Introduce training aspects in shelter projects more standardly
- Adjust to the different phases in sheltering; relief, recovery, preparedness
- Work on safe housing awareness outside of disaster times

See also: IFRC and BRC developed Participatory Approach to Safe Shelter Awareness (PASSA)

(p25) BUILDING FOR THE LANDLESS

Struck by poverty, many families in Bangladesh don't own land and revert to building houses on land that is not suitable for construction. Bangladesh's population is large; land is extremely wanted, every inch claimed. One mechanism, for example, causing land issues, is that rivers in the delta shift; taking often suitable and built on land along its outer curve bank while depositing loose sediment on the inner curve bank. Houses are lost to the river, and the newly deposited land is taken for growing crops and building weak shelters. 'Chars', low-lying islands created in rivers along the same principle are occupied by households that do not have land. These lands are extremely exposed to the elements. To occupy 'khas' (government owned) land is another option landless people revert to.

Of the for this publication documented shelters, only a few targeted landless families. For agencies, supporting landless people is particularly difficult. Since landless households cannot claim the land they occupy it is challenging to support them with more durable shelters.

EXAMPLES OF SHELTERS BUILT FOR LANDLESS



Above: In this case, with support of the government, land could be secured for a group of landless fishermen. They were relocated from on the beach to new residential land inside of the embankment.

Right: Though improvements in the structural quality of these houses, the services and the organisation of the site can be imagined, this housing scheme offers a reasonable alternative for otherwise homeless families.



Left: This project was still under construction at the time of survey. These shelters are built on low lying, vulnerable 'char' land. The design has been adapted to this context; it take into account that serious flooding is quite likely to happen, at regular times.

OTHER HOUSING SCHEME PROJECTS



Left an example of a social housing project. There are some examples of fairly successful social housing projects for the poor and landless. These often offer a higher density living environment than usual in the context. For now however, the need is far greater than the offer.

Below a largely unoccupied housing resettlement scheme.



Many resettlement and relocation projects in Bangladesh suffer from typical problems encountered with this type of projects. Houses are built on locations that are too far from income generating opportunities or with insufficient consideration for the creation of a pleasant living environment (problems of privacy, lack of or insufficient services, no privately useable outside space, no greenery etc.). This type of projects is extremely complex; a viable living environment with all its aspects needs to be created from scratch. To do it well, a lot of time and effort is needed, even outside of disaster times.

SIMPLIFIED CROSS ANALYSIS – TECHNIQUES

(p26)

CONSTRUCTIVE PRINCIPLE

	CONSTRUCTIVE PRINCIPLE				
	Post & Beam		Loadbearing Wall		
Post without footing (some reinforced with brick layers)	 		   		
Post with footing	 				
Strip	 		 		 
Pier					
	Gable		Hipped		Shed Flat

ROOF SHAPE

FOUNDATION

(p27) **SIMPLIFIED CROSS ANALYSIS – TYPES**

TEMPORARY	TRANSITIONAL	CORE	PERMANENT
No temporary shelters were documented.	Transitional shelters, here, are those that need serious structural improvement before they can be considered to survive serious tropical storms in the future.	Most of the shelters can be considered core shelters as their design included tied down and bracing measures, foundations and quality jointing. Not all of these shelters have however been executed up to the technical standard; some may nevertheless need improvements to resist future storms.	These shelters have been designed with the idea to offer a completed house to the inhabitants.
	 BD005	 BD001	 BD003
	 BD007	 BD006	 BD004
		 BD008	 BD011
		 BD010	
		 BD009	 BD016
		 BD012	 BD015
		 BD013	
		 BD014	

This type of division is never straightforward and can be discussed.

BD005: the roof truss is not executed as designed and has only a king post and no cross bracing measures.

BD003: though the construction technique is rather permanent, it is difficult to see that people will live in this house without building extensions to it. That makes it more of a core house than a permanent one

BD014: the brick infill makes it more of a permanent shelter, but it is too small to be permanent without extensions.

BD015: The structure is not of the highest quality but its setting (newly planned) and surrounding infrastructure do show the intention for it to be permanent.

(p28) REFERENCE MATERIAL

This list of reference materials focuses on what can deepen the understanding of technical issues in the context of sheltering in Bangladesh. Evidently more literature on process and planning aspects of sheltering in Bangladesh is available, as more specialised literature on construction techniques or sheltering in general. Also information regarding particular projects has been left out of this list.

BOOKS / REPORTS / PRESENTATIONS

BATTLING THE STORM, STUDY ON CYCLONE RESISTANT HOUSING, Bashirul Haq, BDRCS and GRC, Dhaka, Bangladesh, 1999.

CONSTRUCTION OF SIDR CORE SHELTERS, MINIMUM STANDARDS, Government of Bangladesh, Bangladesh, 2008.

CYCLONE RESISTANT BUILDING ARCHITECTURE, Ankush Agarwal, GoI – UNDP, Disaster Risk Management Programme, March 2007.

GUIDELINES FOR CYCLONE RESISTANT CONSTRUCTION OF BUILDINGS IN GUJARAT, Gujarat State Disaster Management Authority, Government of Gujarat, Gujarat, December 2001.

HANDBOOK ON DESIGN AND CONSTRUCTION OF HOUSING FOR FLOOD-PRONE AREAS OF BANGLADESH, Dr. K. Iftekhar Ahmed, ADPC, Bangkok, January 2005.

HURRICANE-RESISTANT CONSTRUCTION MANUAL, ARE YOU WELL CONNECTED?, UNHCR & UNDP, Government of Montserrat.

IMPLEMENTING HAZARD-RESISTANT HOUSING, Proceedings of the First International Housing and Hazards Workshop to Explore Practical Building for Safety Solutions, held in Dhaka, Bangladesh, December 1996, edited by Hodgson, Seraj and Choudhury.

MAKE THE RIGHT CONNECTIONS; A MANUAL ON SAFE CONSTRUCTION TECHNIQUES, prepared as part of the OAS/USAID Caribbean Disaster Mitigation Project (CDMP), materials prepared by CRDC & SSI, produced by the Safe Shelter Initiative and the National Development Foundation of Dominica

POST-CYCLONE SIDR FAMILY SHELTER CONSTRUCTION IN BANGLADESH, DOCUMENTATION OF PLANS AND PROCESSES, Shelter Working Group, Bangladesh, 2007-2009.

POST-SIDR FAMILY SHELTER RECONSTRUCTION BANGLADESH, Bill Flinn and Peter Bereford, Bangladesh, July 2009.

SHELTER PROGRAMMING RECOMMENDATIONS, Cyclone Sidr Shelter Cluster, Dhaka, Bangladesh, 2008.

WEBSITES

www.sheltercluster.org resources linked to a specific operation and country

www.housingandhazards.org proceedings of a number of workshops on rural housing in Bangladesh

www.sheltercentre.org central library on sheltering



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of Red Cross and Red Crescent Societies

Shelter Research Unit
an initiative of the Benelux Red Cross Societies

RC stump and timber frame shelter

BD001

IDENTIFICATION

Country: Bangladesh
Location: Kuakata, Pathuakhali
Climate: moist tropical
Landform: river delta
DISASTER & RELIEF
Immediate Cause: cyclone
Housing Strategy: by NGO
Shelter Phase: transitional
Building Back Option: relocation
Transitional Settlement: planned
Labour Method: contract labour

GENERAL PROPERTIES

Year of construction: 2008/9
Inhabitants: 2
Occupancy site: no legal status
Occupancy house: owner-occupier
Typology: detached
Storeys: 1
Rooms: 1
Floor area: 20m²
Construction cost: unknown
Construction time: unknown



DOCUMENTS AVAILABLE

Project documentation	no
BoQ	no
Design Drawings	yes
Site Plan	no
Pictures/ Video	yes
Google Earth	no



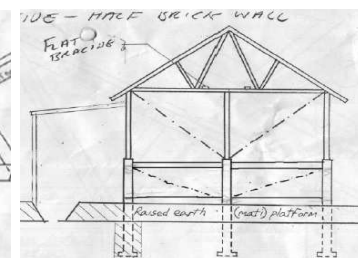
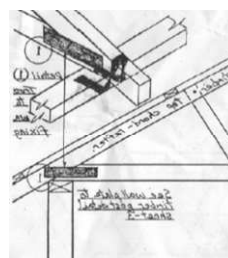
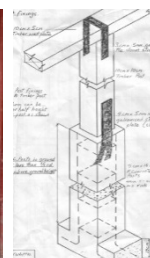
SITE

A group of landless fishermen living outside of the embankment, on the beach, was relocated to new residential land inside of the embankment. Each house was given some outside space to grow trees, keep animals, organise a kitchen etc. Since this land was not lived on before, the surrounding vegetation and relationship to the low-lying lands around it should be improved over time.



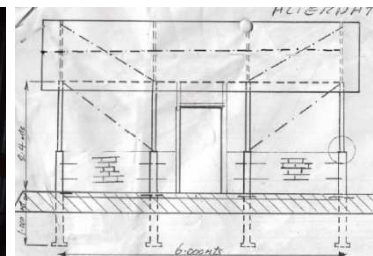
STRUCTURE

RCC pole foundations reach about 1m above the raised mud plinth level. A furthermore timber structure was bolted to the poles. Tie down and cross bracing have been provided, joints are reinforced with metal plates.



SKIN

Both walls and roof are covered with tin sheets. This has the benefit that the house can be completely closed down during storms, but can pose problems of lack of ventilation. Only the front side of the house has a door. Three windows were included. Windows and doors are out of tin sheet as well so the shelter can be closed down completely.



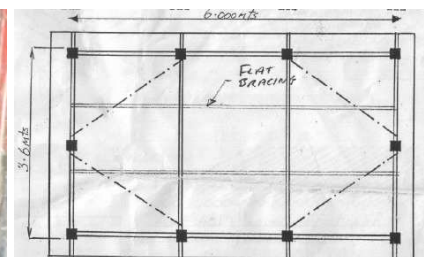
SERVICES

A pit latrine is built on site. Water supply is communal, from a well. An adjacent pond is also used for washing. The kitchen is located in a separate self-built hut on the plot, using a portable stove heated with wood/ biomass. There is no electricity on the site.



SPACEPLAN

There were no internal divisions foreseen in the shelter. Some covered space to the external façade was added by the inhabitants themselves.



RC column and timber frame shelter

BD002

IDENTIFICATION

Country: Bangladesh
Location: Mahipur, Pathuakhali
Climate: moist tropical
Landform: river delta
DISASTER & RELIEF
Immediate Cause: cyclone
Housing Strategy: by NGO
Shelter Phase: transitional
Building Back Option: rebuild
Transitional Settlement: self-settlement
Labour Method: contract labour

GENERAL PROPERTIES

Year of construction: 2010
Inhabitants: 4
Occupancy site: land-owner
Occupancy house: owner-occupier
Typology: detached
Storeys: 1
Rooms: 2
Floor area: 17m²
Construction cost: \$940
Construction time: 4days



DOCUMENTS AVAILABLE

Project documentation	no
BoQ	yes
Design Drawings	yes
Site Plan	no
Pictures/ Video	yes
Google Earth	yes



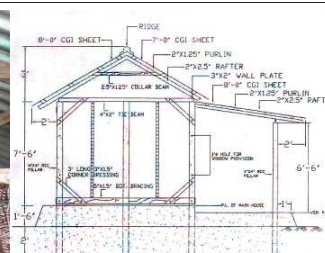
SITE

This shelter was built on the plot where the house was standing on previously. It is located in a type of residential 'ribbon' development along a river. It is higher up from the low-lying rice fields south of the house, and is surrounded by sturdy vegetation.



STRUCTURE

14 RC poles, many but rather slender, support a timber hipped roof. Hipped roofs resist strong winds better. Also the rectangular design is beneficial; the wind can easily go around the house. Cross bracing at wall level and in the roof and tie down from the roof down to the foundation are foreseen, but it is a bit minimal. The mud plinth suffers from rain and was somewhat protected by covering with bags.



SKIN

Bamboo poles have been used to attach bamboo matting as wall material to the structure. They have been tarred up to plinth level. The roof is covered with tin sheets. The shelter counts 1 door and 4 windows.



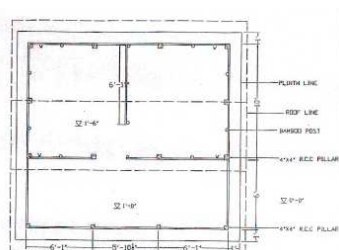
SERVICES

A pit latrine is built on site, 5 rings plus a slab. Water supply is communal, from a well. An adjacent pond is also used for washing. The cooking is done in a separate self-built hut on the plot, using a portable stove heated with wood/ biomass. There is no electricity.



SPACEPLAN

An internal division into two rooms is foreseen in the design. The front side is extended with an outside covered area. The space in the roof structure is used for storage.



Flat roof concrete & brick shelter

BD003

IDENTIFICATION

Country: Bangladesh
Location: Char Chapli, Patuakhali
Climate: moist tropical
Landform: river delta
DISASTER & RELIEF
Immediate Cause: cyclone
Housing Strategy: by NGO
Shelter Phase: permanent
Building Back Option: rebuild
Transitional Settlement: self-settlement
Labour Method: contract labour

GENERAL PROPERTIES

Year of construction: 2008
Inhabitants: 4
Occupancy site: landowner
Occupancy house: owner-occupier
Typology: detached
Storeys: 1
Rooms: 1
Floor area: approx. 10m²
Construction cost: unknown
Construction time: unknown

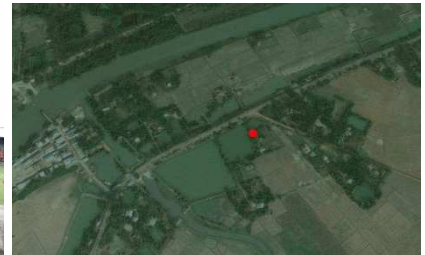
DOCUMENTS AVAILABLE

Project documentation	no
BoQ	no
Design Drawings	no
Site Plan	no
Pictures/ Video	yes
Google Earth	yes



SITE

This shelter is located on flat terrain, vulnerable to wind and flooding, such as most terrain in the south of Bangladesh. Little vegetation surrounds it, not a mass dense enough to break wind or water forces much. A small privatised garden is attached to the house on the left side.



STRUCTURE

A reinforced concrete column structure is filled in with brick wall. The shelter has a flat concrete roof structure. Heavier structures tend to resist heavy winds more easily. The raised concrete floor slab on a brick perimeter wall helps to resist flooding. In terms of design and materials used, this is an extraordinary shelter for the context. Issues will rather be with comfort of living rather than with strength (if built well). Secondly, adaptability and maintenance may be a problem, since local people are not accustomed to work with these materials and design.



SKIN

There are 3 large windows in the masonry wall providing ventilation, and one door in the front, on to the elevated 'porch' with kitchen. In the inside of the shelter the walls are plastered.



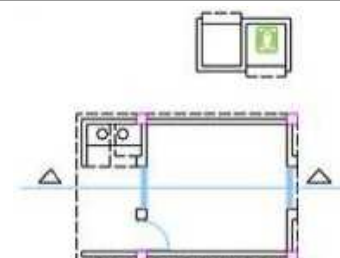
SERVICES

The shelter comes with a built in kitchen on the porch in the front of the house. Towards the back, a small reservoir is built to collect the water from the roof. On site a small separate toilet (pit latrine)/ washing area is built. Electricity is not available.



SPACEPLAN

Internally there are no divisions in the shelter. The 'porch' area has been given a particular separate use; that of cooking. The living area of this shelter is quite small, and there are no provisions to easily expand the shelter with verandas as is the local practice.



Concrete and brick shelter on stilts

BD004

IDENTIFICATION

Country: Bangladesh
Location: Char Chapli, Patuakhali
Climate: moist tropical
Landform: river delta
DISASTER & RELIEF
Immediate Cause: cyclone
Housing Strategy: by NGO
Shelter Phase: permanent
Building Back Option: relocate
Transitional Settlement: planned
Labour Method: contract labour

GENERAL PROPERTIES

Year of construction: 2011
Inhabitants: under construction
Occupancy site: no legal status
Occupancy house: owner-occupier
Typology: detached
Storeys: 1
Rooms: 1
Floor area: approx. 20m²
Construction cost: unknown
Construction time: unknown

DOCUMENTS AVAILABLE

Project documentation	no
BoQ	no
Design Drawings	no
Site Plan	no
Pictures/ Video	yes
Google Earth	yes



SITE

With support from the government, a new lot of land on this low-lying char was identified for new housing for otherwise homeless people. The surrounding vegetation is herbaceous. As in most relocation projects, the site still needs to be organised to create a living environment. Construction was on-going at the time of survey.



STRUCTURE

On a strip foundation six brick columns are erected that support a RC raised floor. The upper structure is out of brick supporting a concrete roof with a double slope. This is an exceptional design and use of materials for this region. This shelter is more durable but costly. The stilts provide a higher resistance to floods and flash floods. The heaviness of the structure, and the tie down from top to bottom, make the structure quite storm resistant. Points requiring attention during construction are the quality of the masonry, the reinforcements and the rigidity these give to the structure and specifically the stilts.



SKIN

2 window openings on the back side, a window each of the sides of the shelter and the two doors front provide ample ventilation in the shelter. The brick walls internally have not been plastered, but the construction was not finished yet.

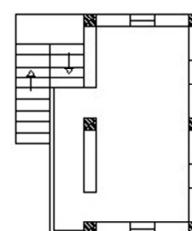


SERVICES

At this point in the construction it was unclear how water, sanitation and cooking would be organised in the house or on the surrounding site.

SPACEPLAN

There are no internal divisions in this shelter. The stairs lead to an open 'porch' in front of the front façade. As counts for many shelters made out of materials unusual in the context, extendibility, maintenance and adaptation may cause concern. This design particularly poses a challenge for inhabitants seeking more living space; the relationship of the house with the surrounding site is fundamentally different to what people are accustomed to. How this is received by the future inhabitants needs to be seen; Considering the high durability of this shelter this may not be considered a huge problem.



RC footing and timber frame shelter

BD005

IDENTIFICATION

Country: Bangladesh
Location: Sonatola, Barguna
Climate: moist tropical
Landform: river delta
DISASTER & RELIEF
Immediate Cause: cyclone
Housing Strategy: by NGO
Shelter Phase: transitional
Building Back Option: rebuild
Transitional Settlement: self-settlement
Labour Method: contract labour

GENERAL PROPERTIES

Year of construction: 2009
Inhabitants: 7
Occupancy site: landowner
Occupancy house: owner-occupier
Typology: detached
Storeys: 1
Rooms: 1
Floor area: XXX
Construction cost: unknown
Construction time: unknown



DOCUMENTS AVAILABLE

Project documentation	no
BoQ	yes
Design Drawings	yes
Site Plan	no
Pictures/ Video	yes
Google Earth	yes



SITE

In a typical ribbon type residential strip this shelter was rebuilt on the site of the house that was damaged or lost because of the cyclone. The shelter was therefore immediately integrated in its setting; surrounding garden, cooking spot and vegetation.



STRUCTURE

The foundation consists of 4 concrete poles reaching up to plinth level. To those poles a timber frame is attached. The short poles leave the lower sections of the timber frame vulnerable to humidity. A horizontal wooden band in lapped joints binds the structure just above plinth level and just under roof level. Though cross-bracing in the roof is part of the original design, this was not seen during survey. The roof structure is quite light.



SKIN

Following the concept of core shelter, this shelter was handed over without wall cladding. The inhabitants have used a mixture of thatch, recuperated tin sheets and bamboo mats to create walls and cover the extensions they built to the shelter.



SERVICES

A pit latrine was newly constructed on site by the agency. For all other services, the inhabitants resort to what they had before the cyclone; a wood/biomass portable stove for cooking outside of the core shelter, a communal water source and a pond for supplementary washing. There is no electricity on site.



SPACEPLAN

The original core of the shelter was not divided into separate spaces. The inhabitants expanded the shelter with verandas on three sides, in line with local building practices and way of living. These verandas become internal spaces of the house while at the same time regulating the relationship with the outside space; the veranda in the front is where visitors to the house will most likely spend their visit.



RC footing and timber frame shelter

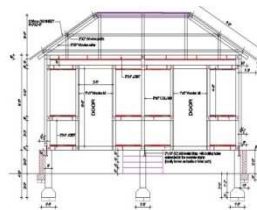
BD006

IDENTIFICATION

Country: Bangladesh
Location: Bhaijora, Bagerhat
Climate: moist tropical
Landform: river delta
DISASTER & RELIEF
Immediate Cause: cyclone
Housing Strategy: foreign government
Shelter Phase: transitional
Building Back Option: rebuild
Transitional Settlement: self-settlement
Labour Method: contract labour

GENERAL PROPERTIES

Year of construction: 2011
Inhabitants: 8
Occupancy site: landowner
Occupancy house: owner-occupier
Typology: detached
Storeys: 1
Rooms: 2
Floor area: 19m²
Construction cost: \$1700
Construction time: 12days



DOCUMENTS AVAILABLE

Project documentation	no
BoQ	no
Design Drawings	yes
Site Plan	no
Pictures/ Video	yes
Google Earth	yes



SITE

The shelter was built on the plot where the family's house was previously located on. The garden is thus fully planted and gives the house some supplementary resistance to flooding and wind. The plot is however not part of a larger ribbon or cluster development, but lays in a flat and open low-lying plane increasing the vulnerability of the house.



STRUCTURE

6 concrete columns with footing reaching plinth level support a timber frame. The roof is hipped making the structure more wind resistant. Cross bracing is provided in the vertical planes and in the roof in the form of collar ties. The mud plinth has a brick perimeter wall of about 6 layers high. This greatly increases its strength and compensates for the concrete columns only reaching up to plinth level.



SKIN

Both the roof and the walls are clad with tin sheets which may have a negative effect on the inside climate, though may last longer, without maintenance, than natural materials. 2 doors and 2 windows provide ventilation. The door has a double panel opening, in line with the local architecture. The inhabitants have created extensions to the house using primarily natural materials as thatch, timber planks and bamboo sheets.



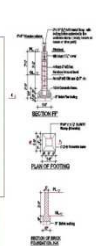
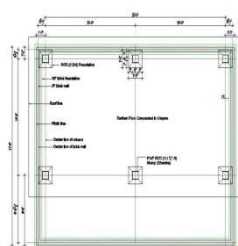
SERVICES

A pit latrine was newly constructed on site. Cooking is done outside of the shelter, in a space built for that specifically. The water source could not be identified but is probably communal. The pond is additionally used to wash. There is no electricity on site.



SPACEPLAN

Both doors give out to the front 'porch' of the house. A cross bracing inside of the shelter somewhat splits the inside area in two, but an actual partition was not foreseen nor a clear passage from one space to the other. At the time of survey, the porch was not fully covered yet. Extensions built by the inhabitants serve as storage space and kitchen.



RCC and timber frame shelter

BD007

IDENTIFICATION

Country: Bangladesh
Location: Gabtola, Bagerhat
Climate: moist tropical
Landform: river delta
DISASTER & RELIEF
Immediate Cause: cyclone
Housing Strategy: unknown
Shelter Phase: transitional
Building Back Option: rebuild
Transitional Settlement: self-settlement
Labour Method: contract labour

GENERAL PROPERTIES

Year of construction: 2011
Inhabitants: 3
Occupancy site: landowner
Occupancy house: owner-occupier
Typology: detached
Storeys: 1
Rooms: 1
Floor area: 20m²
Construction cost: \$670
Construction time: unknown



DOCUMENTS AVAILABLE

Project documentation	no
BoQ	no
Design Drawings	no
Site Plan	no
Pictures/ Video	yes
Google Earth	yes



SITE

The shelter was built on the plot where the family's house was previously located. The garden is fully planted and gives the house some supplementary resistance to flooding and wind. The plot is located in a residential ribbon along a river bank.



STRUCTURE

The raised plinth has been reinforced by some layers of masonry. An RC column supports the structure in each of the 4 corners of this shelter. The rest of the structure is out of timber with supplementary columns mid width, columns to support a veranda and externally fixed timber for cross-bracing in the wall plane. The gable shaped roof is also out of timber, but is rather weak in terms of wind resistant design.



SKIN

Bamboo wall sheeting has been attached to the RCC and timber structure of the shelter. The roof is covered with tin sheets. In the front, 1 door and 1 window were foreseen. A supplementary double pane door in the back facilitates the passage to the service hut built in the back of the garden. That hut is covered with thatch.



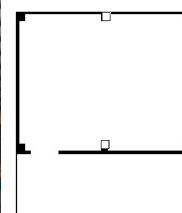
SERVICES

A pit latrine was not identified on site. The kitchen is organised in a separate construction in the back of the garden. Electricity was not available.



SPACEPLAN

The shelter has no internal divisions. In the roof structure storage was made possible. The front veranda is much in line with how people locally live. In the back, also typical, the inhabitants have built a second structure, in natural materials, to house cooking and storage activities.



RCC and heightened metal roof shelter

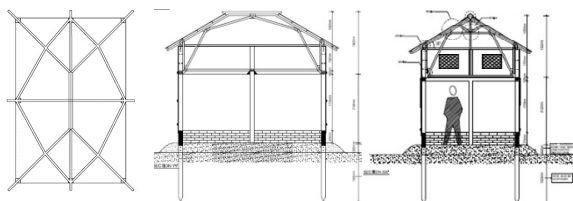
BD008

IDENTIFICATION

Country: Bangladesh
Location: Gabtola, Bagerhat
Climate: moist tropical
Landform: river delta
DISASTER & RELIEF
Immediate Cause: cyclone
Housing Strategy: by NGO
Shelter Phase: transitional
Building Back Option: rebuild
Transitional Settlement: self-settlement
Labour Method: contract labour

GENERAL PROPERTIES

Year of construction: 2009
Inhabitants: 6
Occupancy site: landowner
Occupancy house: owner-occupier
Typology: detached
Storeys: 1
Rooms: 4
Floor area: 75m²
Construction cost: \$2084
Construction time: 45 days



DOCUMENTS AVAILABLE

Project documentation	yes
BoQ	yes
Design Drawings	yes
Site Plan	no
Pictures/ Video	yes
Google Earth	yes



SITE

The shelter was built on the plot where the family's destroyed house was previously located on. The garden is fully planted and gives the house some supplementary resistance to flooding and wind. The plot is located in a residential ribbon along a river bank.



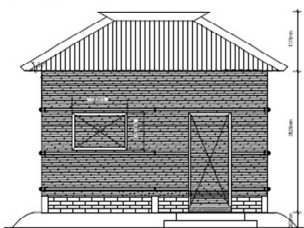
STRUCTURE

The central part of this shelter is an on an RC pile foundation built core shelter with a hipped roof in steel. The plinth is raised and reinforced with a couple of layers of masonry, binding the pillar foundation together. Cross-bracing and tie down have been foreseen throughout the shelter. This shelter design was engineered by a recognised office. The extensions were built by the inhabitants themselves, with financial and technical support from the agency.



SKIN

The central part of this shelter was given bamboo walls protected from weather by the extensions. The extensions are built with timber and covered with a panel structure with timber and tin sheet fill in. The central part was built with only one door and three windows. Now, the extensions regulate the relationship with the surroundings.



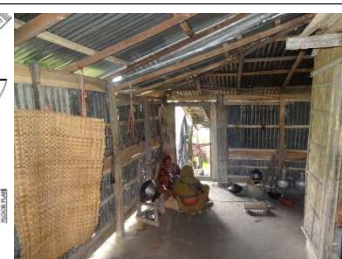
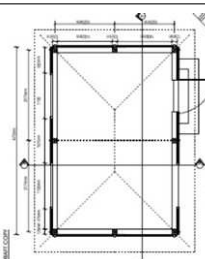
SERVICES

A pit latrine was built on the site, along the path aligning the pond. Furthermore the pond is used for washing. The water source for drinking and cooking is communal. Cooking is done in a separate hut built on site. There is no electricity.



SPACEPLAN

The spacious roof structure of this shelter allows for internal storage space and a safe place during times of flooding. The shelter is in fact the higher central part of a future house, surrounded by verandas in line with local architecture. The central part of this shelter was not divided into different spaces. The large extensions built by the inhabitants turn this into a 4 room house.



RCC and timber frame shelter

BD009

IDENTIFICATION

Country: Bangladesh
Location: Baniakhali, Bagerhat
Climate: moist tropical
Landform: river delta
DISASTER & RELIEF
Immediate Cause: cyclone
Housing Strategy: by NGO
Shelter Phase: transitional
Building Back Option: rebuild
Transitional Settlement: self-settlement
Labour Method: contract labour

GENERAL PROPERTIES

Year of construction: 2008
Inhabitants: 4
Occupancy site: landowner
Occupancy house: owner-occupier
Typology: detached
Storeys: 1
Rooms: 1
Floor area: 14m²
Construction cost: \$1000
Construction time: 50 days

DOCUMENTS AVAILABLE

Project documentation	no
BoQ	yes
Design Drawings	yes
Site Plan	no
Pictures/ Video	yes
Google Earth	yes



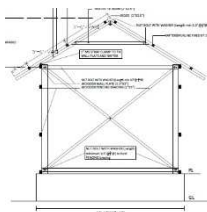
SITE

The shelter was built on the plot where the family's house was previously located on. The garden is planted and gives the house supplementary resistance to flooding and wind. The plot is located in a residential ribbon protecting it furthermore.



STRUCTURE

Based on UNDP standard design, this shelter is built on 6 RC columns in a raised plinth reinforced with a couple of layers of brick tying the columns together. The gable roof is out of timber, with double nailing and bolting. Collar ties render the roof more wind resistant. Tie down and cross-bracing have been included into the design.



SKIN

The walls of the shelter are out of bamboo mats. The roof is covered with tin sheets. The veranda is covered with recuperated tin sheets supplementary kept down with bamboo poles. There is only one door, in the front. There are two windows.



SERVICES

Little information regarding services was collected for this shelter. Cooking is done in a separate hut built on site. There is no electricity on the site.



SPACEPLAN

The shelter has no internal divisions. It has a veranda in the front, out of bamboo and recuperated tin sheets. One extension is built by the inhabitants to the side of the shelter. This is mostly used to store materials. A separate kitchen hut is built with wooden sticks and thatch roof.



RC and timber frame shelter

BD010

IDENTIFICATION

Country: Bangladesh
Location: Sarankhola, Bagerhat
Climate: moist tropical
Landform: river delta
DISASTER & RELIEF
Immediate Cause: cyclone
Housing Strategy: by NGO
Shelter Phase: transitional
Building Back Option: rebuild
Transitional Settlement: self-settlement
Labour Method: contract labour

GENERAL PROPERTIES

Year of construction: 2008
Inhabitants: 5
Occupancy site: landowner
Occupancy house: owner-occupier
Typology: detached
Storeys: 1
Rooms: 3
Floor area: 43m²
Construction cost: \$1100
Construction time: 10 days



DOCUMENTS AVAILABLE

Project documentation	no
BoQ	yes
Design Drawings	yes
Site Plan	no
Pictures/ Video	yes
Google Earth	yes



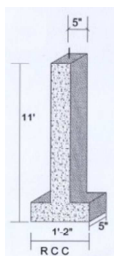
SITE

The shelter was built on the plot where the family's destroyed house was previously located on. The garden is planted and the plot is located in a quite dense residential cluster. This gives the house supplementary resistance to flooding and wind.



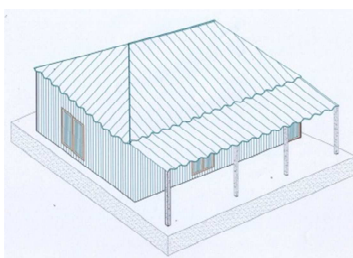
STRUCTURE

14 RCC columns with footing support this structure, both the central living area as the front veranda. The roof is a hipped roof out of timber, tied down to the supporting columns. Timber elements of the wall structure rest on ceramic disks on the mud plinth.



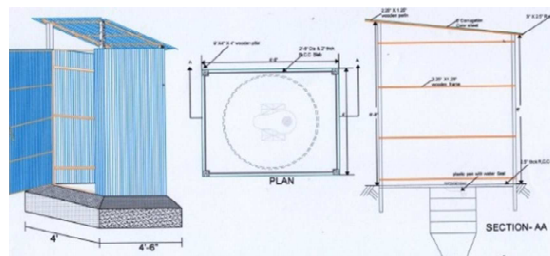
SKIN

The central shelter was clad with tin sheets for roof and walling. Those used for the wall were painted to resist the saline environment better. The all-round use of tin sheets may cause issues with climate (heat and lesser ventilation) and noise inside the shelter. In building the extensions, the inhabitants provided for ventilation by keeping the upper parts of the walls open or half-open. The central shelter counted 1 door and 3 or 4 windows.



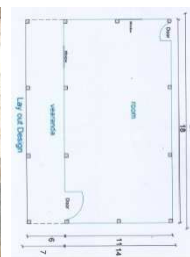
SERVICES

A new pit latrine was built on the site. The water source is communal. A kitchen with portable stove is organised by the inhabitants on site. There is no electricity on the site.



SPACEPLAN

The original shelter was not divided into separate spaces. The roof structure is used as storage space. The front veranda included in the design of the shelter was closed by the inhabitants with recovered tin sheets and wood. An extra extension was built to the back site of the shelter, totalling the number of rooms to 3. Another separate covered space is being constructed in the back of the site.



Cemented brick and wooden roof shelter

BD011

IDENTIFICATION

Country: Bangladesh
Location: Sarankhola, Bagerhat
Climate: moist tropical
Landform: river delta
DISASTER & RELIEF
Immediate Cause: cyclone
Housing Strategy: by NGO
Shelter Phase: permanent
Building Back Option: rebuild
Transitional Settlement: self-settlement
Labour Method: community labour

GENERAL PROPERTIES

Year of construction: 2008
Inhabitants: 6
Occupancy site: landowner
Occupancy house: owner-occupier
Typology: detached
Storeys: 1
Rooms: 2
Floor area: 33m²
Construction cost: \$3085
Construction time: 90 days



DOCUMENTS AVAILABLE

Project documentation	no
BoQ	yes
Design Drawings	yes
Site Plan	no
Pictures/ Video	yes
Google Earth	yes



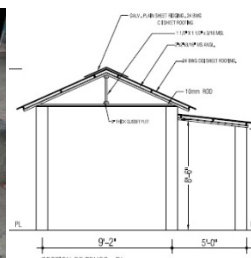
SITE

The shelter was built on the plot where the family's destroyed house was previously located on. The garden is planted and the plot is located in a quite dense residential ribbon. This gives the house supplementary resistance to flooding and wind.



STRUCTURE

This shelter has a stepped brick foundation with RC columns and masonry wall infill. Two ring beams, at the bottom and the top, tie the structure together. The roof is hip shaped, constructed in timber with provisions for tie down. Heavier structures tend to resist wind impact better. This type of construction is also by the people considered to be stronger and therefore preferred by many.



SKIN

The brick walls are plastered on the outside and the inside with a sand cement mix. The walls have been painted. In this humid climate plastering is not often used, and it is unsure whether the inhabitants can keep up the required maintenance. The roof is covered with tin sheets. A total of 6 windows allow for ample ventilation. 2 doors make the two rooms in the shelter accessible from the front porch.



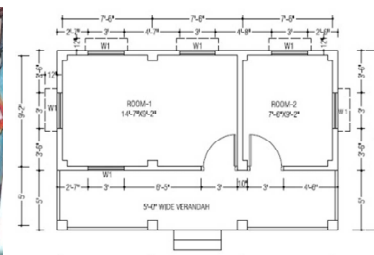
SERVICES

A new pit latrine was built on the site. The water source is communal. A kitchen with portable stove is organised on site.



SPACEPLAN

The shelter is divided into two separate rooms. A veranda in the front is part of the original construction and is supported as well by RC columns. On the plot a supplementary covered space was built for storage and cooking. The space in the roof structure is used for storage.



RCC and metal roof shelter

BD012

IDENTIFICATION

Country: Bangladesh
Location: Sarankhola, Bagerhat
Climate: moist tropical
Landform: river delta
DISASTER & RELIEF
Immediate Cause: cyclone
Housing Strategy: by NGO
Shelter Phase: transitional
Building Back Option: rebuild
Transitional Settlement: self-settlement
Labour Method: contract labour

GENERAL PROPERTIES

Year of construction: 2008
Inhabitants: 4
Occupancy site: landowner
Occupancy house: owner-occupier
Typology: detached
Storeys: 1
Rooms: 1
Floor area: 26m²
Construction cost: \$1500
Construction time: unknown



DOCUMENTS AVAILABLE

Project documentation	no
BoQ	no
Design Drawings	yes
Site Plan	no
Pictures/ Video	yes
Google Earth	yes



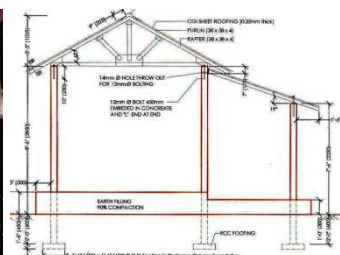
SITE

The shelter was built on the plot where the family's house was previously located on. The shelter is located in a quite dense residential cluster along a road. In the extremely vulnerable landscape of the South of Bangladesh this is a quite suitable plot.



STRUCTURE

12 RC columns with footing support a steel angle roof structure. The connections in the roof are rendered rigid with gusset plates. The roof truss design takes high wind forces into account. Also tie down has been considered from top to bottom. The plinth is of compacted earth without any reinforcement.



SKIN

The roof of this shelter and the open ends of the gable roof are covered with tin sheets, the walls with bamboo mats. The shelter counts one double panel door in the front and 4 windows. The veranda was originally left open, later closed partially by the inhabitants themselves, mostly with recuperated materials.



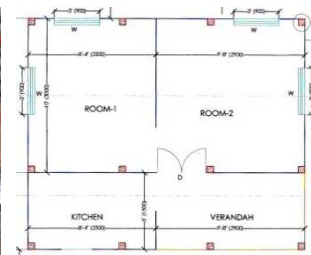
SERVICES

A new pit latrine was included in the original design of the shelter project. Also a water tank was built together with the shelter. A cooking area has been defined in the veranda attached to the front of the shelter.



SPACEPLAN

In the design, the plan defines 2 rooms internal to the shelter, and a veranda with a designated cooking area. The plot is rather small, so far the inhabitants haven't added any supplementary constructions on the plot.



RCC and metal roof shelter

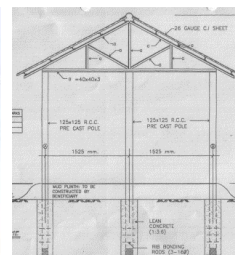
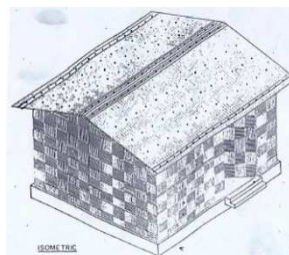
BD013

IDENTIFICATION

Country: Bangladesh
Location: Baraikhali, Bagerhat
Climate: moist tropical
Landform: river delta
DISASTER & RELIEF
Immediate Cause: cyclone
Housing Strategy: by NGO
Shelter Phase: transitional
Building Back Option: rebuild
Transitional Settlement: self-settlement
Labour Method: contract labour

GENERAL PROPERTIES

Year of construction: 2008
Inhabitants: 4
Occupancy site: landowner
Occupancy house: owner-occupier
Typology: detached
Storeys: 1
Rooms: 3
Floor area: 27m²
Construction cost: \$870
Construction time: 10 days



DOCUMENTS AVAILABLE

Project documentation	no
BoQ	no
Design Drawings	yes
Site Plan	no
Pictures/ Video	yes
Google Earth	yes



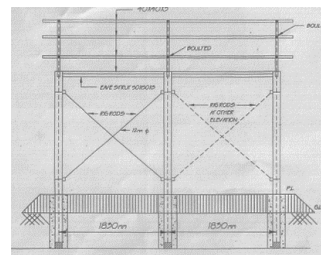
SITE

Right on the riverbank, this plot is very vulnerable to impact from storms and cyclones; impact from wind, floods and surges. Though the shelter is built on a fully planted plot, where the previous house was on, in a rather dense residential cluster, the closeness of the river is crucial; where and how a river embankment is built in relation to the site.



STRUCTURE

This design evolved out of a series of shelter projects after subsequent cyclones in the '90ies. In the response to the '97 cyclone, it was decided to properly calculate the structural strength of this shelter, with the aim to make it as cyclone resistant as possible. An 8 pile foundation supports a steel angle gable roof with by gusset plates strengthened joints. Cross-bracing in the roof and wall planes is provided for by steel elements. The tie down has been completed from top to bottom.



SKIN

The roof of this shelter is covered with tin sheets and the entire wall with bamboo mats. The veranda built by the inhabitants is out of a typical wooden panel structure and wooden and tin sheets infill. The original shelter was built with only one door in the front, and no windows.



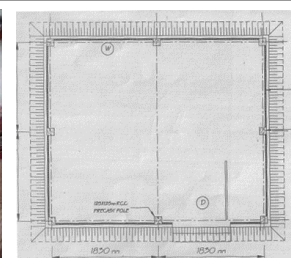
SERVICES

There is not much known about the services of this shelter, people continue to use what they did before the cyclone hit. The cooking is organised in the veranda added to the front of the shelter.



SPACEPLAN

This design does not define separate spaces. Also a veranda was not included in the original design but afterwards added by the inhabitants themselves, with some technical support from the agency. The space in the roof structure is equipped to use for storage.



RCC and metal roof shelter

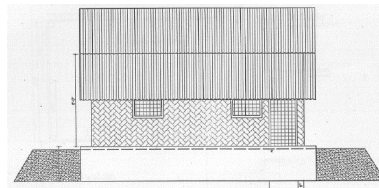
BD014

IDENTIFICATION

Country: Bangladesh
Location: Banstala, Bagerhat
Climate: moist tropical
Landform: river delta
DISASTER & RELIEF
Immediate Cause: cyclone
Housing Strategy: by NGO
Shelter Phase: transitional
Building Back Option: rebuild
Transitional Settlement: self-settlement
Labour Method: contract labour

GENERAL PROPERTIES

Year of construction: 2009
Inhabitants: 4
Occupancy site: landowner
Occupancy house: owner-occupier
Typology: detached
Storeys: 1
Rooms: 1
Floor area: 28m²
Construction cost: unknown
Construction time: unknown



DOCUMENTS AVAILABLE

Project documentation	no
BoQ	no
Design Drawings	yes
Site Plan	no
Pictures/ Video	yes
Google Earth	yes



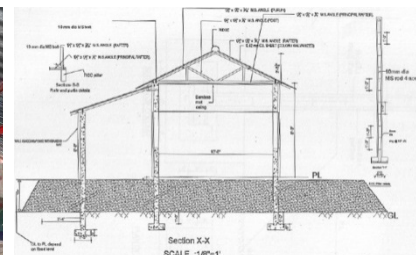
SITE

This shelter is built on the plot where the destroyed house of this family was previously located on. The site is part of a thin residential ribbon. A half-closed canopy provides some breakage of wind forces, but this could be improved.



STRUCTURE

9 RC columns with footing support a metal truss roof structure. The plinth has been raised. The columns and roof structure are quite slender and light, but do include cross bracing and tie down.



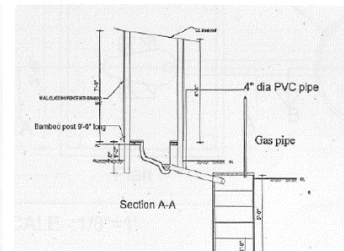
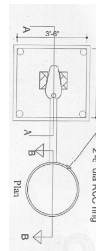
SKIN

The roof of this shelter is covered with tin sheets and the entire wall with bamboo mats. The shelter was designed with one door in the front, leading to the veranda, and three windows. The veranda has been partially closed by the inhabitants themselves.



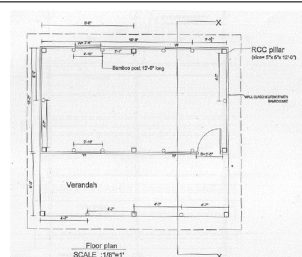
SERVICES

The construction of this shelter included the construction of a new pit latrine on the plot. There is a communal water source, and a pond is used for supplementary cleaning. Cooking is done in a separate construction outside of the shelter on the plot. There is no electricity on this site.



SPACEPLAN

The inside of the shelter was not split up into different rooms. The design includes a veranda in front.



RCC and timber frame shelter

BD015

IDENTIFICATION

Country: Bangladesh
Location: Amtoli, Bagerhat
Climate: moist tropical
Landform: river delta
DISASTER & RELIEF
Immediate Cause: cyclone
Housing Strategy: foreign government
Shelter Phase: transitional
Building Back Option: relocate
Transitional Settlement: self-settlement
Labour Method: contract labour

GENERAL PROPERTIES

Year of construction: 2008
Inhabitants: 4
Occupancy site: no legal status
Occupancy house: owner-occupier
Typology: detached
Storeys: 1
Rooms: 3
Floor area: 31m²
Construction cost: unknown
Construction time: unknown



DOCUMENTS AVAILABLE

Project documentation	no
BoQ	no
Design Drawings	no
Site Plan	no
Pictures/ Video	yes
Google Earth	yes



SITE

This shelter is part of a housing project for families previously not owning land. On a limited portion of newly for residences claimed land, streets and plots were laid out to accommodate for a denser living fabric than usual in this rural area. The denser living pattern required a more structured surroundings with for example front and side alleys, provision for some planting along the sides of the house, provision of services within the volume of the shelter etc.



STRUCTURE

The shelter is built on a slightly elevated, but with concrete reinforced plinth supporting the structure. A concrete strip around the plinth protects the base further from impact from rainwater. Concrete columns support a timber roof structure that lacks cross bracing and tie down. The hipped roof shape increases its wind resistance.



SKIN

The entire shelter is covered with painted tin sheets. The shelter has one front door, 4 windows and an additional opening in the wall for ventilation. The overall coverage with tin sheets, the closeness of the different shelters, and the fact that both toilet and kitchen are inside of the shelter make ventilation a crucial issue for this shelter.



SERVICES

Due to the limited size of the site, a pit latrine and a cooking area have been organised within the volume of the shelter. Also a new communal water point has been provided, in the side alleys. Certainly the inside toilet is not a well-known concept in this rural area; proper maintenance may be an issue.



SPACEPLAN

The shelter has an extended front, a sort of closed veranda incorporated completely into the volume of the shelter. The shelter is built right onto the paved front alley. Inside, separate spaces have been closed off for the toilet and the pit latrine. Along the sides of the house, there is a narrow strip that allows for some planting.



Brick and metal roof shelter

BD016

IDENTIFICATION

Country: Bangladesh
Location: Baga, Bagerhat
Climate: moist tropical
Landform: river delta
DISASTER & RELIEF
Immediate Cause: cyclone
Housing Strategy: NGO
Shelter Phase: transitional
Building Back Option: rebuild
Transitional Settlement: self-settlement
Labour Method: contract labour

GENERAL PROPERTIES

Year of construction: 2009
Inhabitants: 3
Occupancy site: landowner
Occupancy house: owner-occupier
Typology: detached
Storeys: 1
Rooms: 2
Floor area: 41m²
Construction cost: unknown
Construction time: unknown



DOCUMENTS AVAILABLE

Project documentation	no
BoQ	no
Design Drawings	yes
Site Plan	no
Pictures/ Video	yes
Google Earth	yes



SITE

This shelter is rebuilt on the plot where this family's house was built on before. The plot is part of a residential ribbon development. A heightened communal plinth with rather dense high and low vegetation helps to break the force of wind and water during storms.



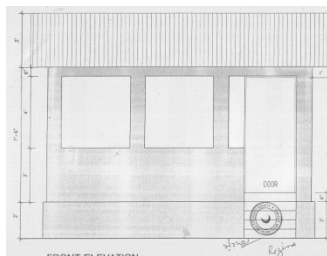
STRUCTURE

The shelter is built on a brick strip foundation, with a cemented plinth, reinforced brick columns and infill. A ring beam supports a metal angle gable roof structure. The joints in the roof structure are reinforced with metal plates. Tie down of the roof is to metal plates out of the columns. The truss design takes cross bracing into account.



SKIN

The brick columns have been plastered, the inside of the brick walls are plastered, as is the floor. Many openings have been kept in the walls; they have been partially filled up with brick, and partially with windows. Extra ventilation is provided by openings in the masonry at window and roof level. The triangle sides of the gable roof have also been filled in loosely with masonry. The shelter counts 1 door.



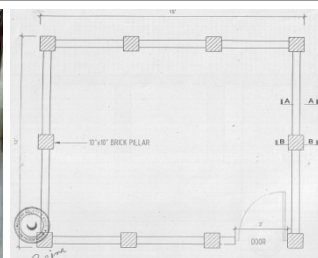
SERVICES

There is no information available about the water supply and sanitation. Cooking is done in a separate construction in the back of the house.



SPACEPLAN

The shelter is designed without division of internal spaces. The inhabitants have added a veranda to the front and side of the shelter, built as a wooden frame with tin sheet roof attached to the brick core. The space in the roof truss is used as storage space.



Timber frame and thatch shelter

BD017

IDENTIFICATION

Country: Bangladesh
Location: Vasha, Bagerhat
Climate: moist tropical
Landform: river delta
DISASTER & RELIEF
Immediate Cause: cyclone
Housing Strategy: self-built
Shelter Phase: transitional
Building Back Option: relocate
Transitional Settlement: self-settlement
Labour Method: direct labour

GENERAL PROPERTIES

Year of construction: 2009
Inhabitants: 4
Occupancy site: landowner
Occupancy house: owner-occupier
Typology: detached
Storeys: 1
Rooms: 2
Floor area: 40m²
Construction cost: 1075\$
Construction time: 10days



DOCUMENTS AVAILABLE

Project documentation	no
BoQ	no
Design Drawings	no
Site Plan	no
Pictures/ Video	yes
Google Earth	yes



SITE

This shelter is built without assistance, by the family whose house was destroyed, on the plot where their house was previously located on. The plot is not surrounded by other residential plots. Though the plot itself is heightened above the surrounding field level, and is planted, it is quite exposed to wind and water.



STRUCTURE

Wooden columns in a raised and with cement mixture reinforced plinth are the supporting structure of this house. The roof structure, hipped, is out of timber planks and sticks in a dense rhythm, tied down to the vertical structure. Supplementary cross-bracing is absent. The columns of the verandas rest on ceramic plates to avoid contact with ground water.



SKIN

The roof of this house is in thatch. Also the walls are entirely out of natural materials. There are two doors but no windows. The verandas are largely kept open. Because of the natural walls and roof, there is plenty ventilation in this house.



SERVICES

No specific information about water and sanitation on this plot was collected.

SPACEPLAN

The centre part of this shelter has been surrounded by extensions on three sides. The front veranda organises the access to the house. The veranda on the side is mostly used for storage. Inside, the house has been divided into two rooms.

