Improvement of vernacular housing for disaster prone areas in Bangladesh: a six year experience

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ABSTRACT: All around the world, societies show capacities to evolve their living conditions taking into account their environment, cultural, social and economical specificities. In hazard prone areas, this process goes through phases of normality, crisis, and rehabilitation. Working in such context it is important to identify local best practices, integrate the whole concept of sustainable development and develop strategies linking emergency, rehabilitation and development. Bangladesh is a multi-hazardous and disaster prone country. In 2007, super cyclone Sidr devastated one-third of the country and along with various supports Caritas assisted affected people through housing project. However, evaluation of the housing project showed even though that if technical solution was adequate, it was more focused on house than housing. To improve this, Caritas involved CRAterre and BUET to provide support for development of disaster resilient houses. Caritas is involved in house/shelter building since 1970. CRAterre is involved in disaster response for more than 13 years. Although more than 80% population lives in non-engineered low cost houses, BUET conducts only few researches in this field and wants to improve this situation. A pilot project was initiated in 2009 in two different regions. A thorough local survey was carried out for understanding the local building culture, its strength and weaknesses. Based on testing of materials available and a 3D stress analysis of the structure, and including cultural, social, environmental and economical aspects, initial design was developed. After two levels of validation by beneficiaries, 25 houses were built in each location under cyclone and flood prone areas. Based upon the lessons learnt, a 3 year extended project, covering the whole country, started in 2011, solutions are developed through a strong participatory approach and a deep understanding of local existing context. This paper presents the learning of the past and some of ongoing and expected further phases of the project.

1 INTRODUCTION

Bangladesh is known as one of the most disaster prone countries in the world due to its geographic location and socio-economic condition of people. About 50% of the land is within 6-7 m from Mean Sea Level (DMB, 2008). Common disasters of Bangladesh are flood, cyclone, tidal surge, land slide, river bank erosion, draught and earthquakes. Lots of houses are damaged due to disasters on a regular basis and cause the most economic losses during disasters (DMB, 2008). In recent years, these have caused extra burden for the marginal people of the country and jeopardizing its economic growth as a whole. Although it is a small country, its culture, disaster, availability of building materials are diverse and the housing practices are also widely varied.

Government and NGOs provide housing to the disaster affected people. Some are very costly and strong enough and some are very nominal and temporary. However, constructions of these houses generally do not respect local culture and sometimes constructed in highly vulnerable locations. After the construction of external agency led houses, it is rare that the community replicates the same design. In 2007, a super cyclone Sidr (wind velocity: 242 km/hr and tidal surge height: 5m) passed through Bangladesh and damaged lots of houses. In response to that cyclone many houses also were constructed by government and NGOs. However, as can be seen from the photograph of the Figure 1 that many houses were constructed in the bank of river which is very vulnerable location.

Different international guidelines are available for a number of years. At the same time there is a lot to learn from existing vernacular houses even they lack technical adequacy. A question may naturally be asked: why are these not being followed in practice? The answer is that R&D does not focus enough on local practice; do not take into account local technical and financial capacities and that the fruits of existing R&D are not being transferred into the field as these houses are mostly designed and built by owners or artisans who do not have access to these booklets. Current codes also do not have provisions for disaster resistant rural house design and so, there is no policy related to rural housing improvement that may end to risk reduction and disaster preparedness strategy in this particular sector.

There is a gap among the responding agencies for not having an effective design and technology for the construction of Low Cost Houses (LCH). When implementing post disaster program, most of the time, they are focusing in providing approaches (give back a roof to the people) than in enabling strategies (help people to access to a roof and a knowledge that will help them to build on their own more resilient houses).This is important to take into account that each of the community has their own construction techniques and materials for LCH. Some of them are very effective and scientific. These are sometimes overlooked and so, there is a gap in understanding the local knowledge for having effective design and technology for the construction of LCH. Obviously, there is a necessity for bridging this gap by learning from the people and then, transferring back the improvement to them through disseminating this know how to responding agencies. There is no doubt that input of local people, local artisans, and strong understanding of local culture and general context should be considered for sustainability. To this context, at the first phase a one year project (2009) has been completed in Bangladesh. Upon its successful completion, an extended three years (2010 - 2014) project is being undertaken.

2 BACKGROUND AND OBJECTIVE OF THE PROJECT

Caritas Bangladesh (CB) as a human development organization have been constructing shelters i.e. Low

Figure 1. Construction of houses after the cyclone Sidr 2007. (Photo: M. Shariful Islam, BUET).

Cost Houses (LCH) for disaster-affected families since 1970. As of June 2012, CB provided shelter support for 377,687 families all over the country. Amongst all this years, CB came to assess that type of context (including hazards) is different and the people have cultural distinctions. Moreover, the natural resources are different from one site to other; therefore, the coping strategies for shelter are also not same. But, previously one particular model house design was prepared by CB for all areas of Bangladesh. Some modifications were done from time to time, this considering disaster, geographical area, cultural aspects were also considered in some cases. Community people's opinions were sometimes taken into considerations for design of houses. But these were not adequate as proper and systematic methodology were not implemented. Similarly Caritas Bangladesh constructed LCHs in Sidr 2007 affected areas having financial support from Secours Catholique/Caritas France. An evaluation was carried out in 2008 by International Centre for Earth Construction (CRAterre-ENSAG) for Caritas France supported houses. In the evaluation report, it was recommended that local context should be more taken into account to help such program to achieve better impact in local houses resilience. To this context, CRAterre suggested CB to approach BUET to provide technical assistance towards their Low-Cost Housing Project in Disaster-prone areas. CRAterre as a consultant to Caritas France also joined to provide technical and methodological support.

With financial support from Caritas France, one pilot project was implemented in 2009 - 2010 to apply the suggested new approach. Two context were studied. One in Kuakata of Patuakhali district (Cyclone prone area) and Sirajdikhan of Munshiganj district (flood prone area). This project showed that it is feasible to develop contextual solution that fit better to people needs and that have better impact, both in the local economy and the local building practices.

Upon successful completion of first phase CB took up its second phase (October 2011- September 2014) for other six regions of Bangladesh with funding support of Caritas France and Caritas Luxembourg wherein CRAterre-ENSAG and BUET are the technical partners for the project. Findings from first phase have been considered for the project extension. Main objective is to develop adequate methodological approach in order to minimize the impact of recurrent disasters on LCH to ensure that people of disaster affected households live in disaster risk resilient houses. In the project, 30 types of LCH are being designed for 30 disaster prone areas, at the same time 60 pilot LCHs are being constructed and 48 demonstrations on how to improve existing houses will be done.

Idea is to simultaneously work on housing improvement, aiming at reduce future risk, and to work on disaster preparedness by developing LCH (to be implemented after any disaster) that will be core houses that could be further evolved in same more resilent houses developed in the housing improvement component of the project. Figure 2 shows the conceptual approach of LCH project.

Finally, the learning will be disseminated to the rural people, engineers, other NGOs and educators. This paper presents the findings of the completed first phase of the project and also briefly present the salient features of some regions (cyclone, flood, river bank erosion and hilly) of the ongoing phase.

3 PROJECT LOCATIONS

At the first phase of the project one area was selected in the cyclone prone region (Kuakata of Patuakhali district) and another area was selected in the flood prone region (Sirajdikhan of Munshiganj district). At the second phase, the project areas were selected in Bandarban (flash flood, cold wave, landslide and fire), Asasuni (cyclone), Kanighat (flood zone), Dhubaura (flash flood), Gaibandha (river bank erosion) and Porsha (drought and cold wave). The project locations are presented in the map of Bangladesh in Figure 3a. Figures 3b and 3c present the close view of the Kuakata and Sirajdikhan region, respectively.

4 DESIGN STRATEGIES AND PROJECT SEQUENCES

Project sequences have been presented in Figure 4. Three-stage community level meetings were held to collect local information and views of the people along with the artisans. Properties of the local construction materials were ascertained from laboratory tests. Considering the service and environmental loads, designs were finalized based on Finite Element Modeling (FEM). Model houses were constructed at the selected locations to demonstrate them to the local community with an aim that new design or at least some features would be replicated. Performances of these model houses are being monitored. The main aspects of development of disaster resistant housing consists of (i) survey, (ii) design, (3) construction and technical improvement, (iii) dissemination of learning, (iv) follow up and monitoring.

As shown in Figure 4, at first, information was collected from the site using a questionnaire survey. A detailed questionnaire has been developed to collect social, economic, and technical demand related information.

Based on the collected data, preliminary design for better resilient houses was conducted by BUET, CRAterre and Caritas Bangladesh. This design was validated by the community people including local allies and artisans and the design is revised considering these feedbacks. Again the revised design was validated by the community. Thus final model design for any particular context was developed. Based on this models houses was constructed in concern areas. Feedbacks of the community were taken again on the model house. Adjusting the applicable comments improved the design and another house was constructed.

Based on the experience of survey, two developments take place. Design and construction of, LCH prototype, to be implemented at rapid response just after the disaster, and proposal for existing houses improvement in order to achieve better resilient houses. These two design approach are also validated by the community. LCH prototypes as well as solutions for housing improvements are also demonstrated for training local artisans, sensitize populations and getting feedback from the local people.

4.1 *Survey*

Following are the key features of the survey which has been carried out using the questionnaire:

- Inform the local people about the LCH programme.
- Rapport building based on meeting with local authorities, community leaders, etc.
- Development of survey formats for obtaining the social and technical information.
- Survey the types of existing houses, size, material costs and social map.
- Community meeting to understand the overall situation in the village (social and economic conditions, including housing).
- Transect walk /observation and selection of houses to be assessed.
- Individual house assessment (technical detail).
- Meeting with artisans and people involved in the construction to understand types of houses and availability of artisans, materials, rates etc.
- Analysis of the survey to determine the design strategy for different types of LCH.

4.2 *Design Steps*

Main steps in the design followed:

- Preparation of preliminary design based on primary survey (BUET)
- Sharing among CB, BUET and CRAterre for feedbacks
- Preparation of the draft design (BUET)
- Selection of treatment method for different elements of the structure (CB, BUET, CRAterre)
- Cost estimation (CB)
- Sharing the design with the community for their inputs (CB and BUET)
- Incorporate feedbacks and validation with community

- Preparation of the final design (BUET)

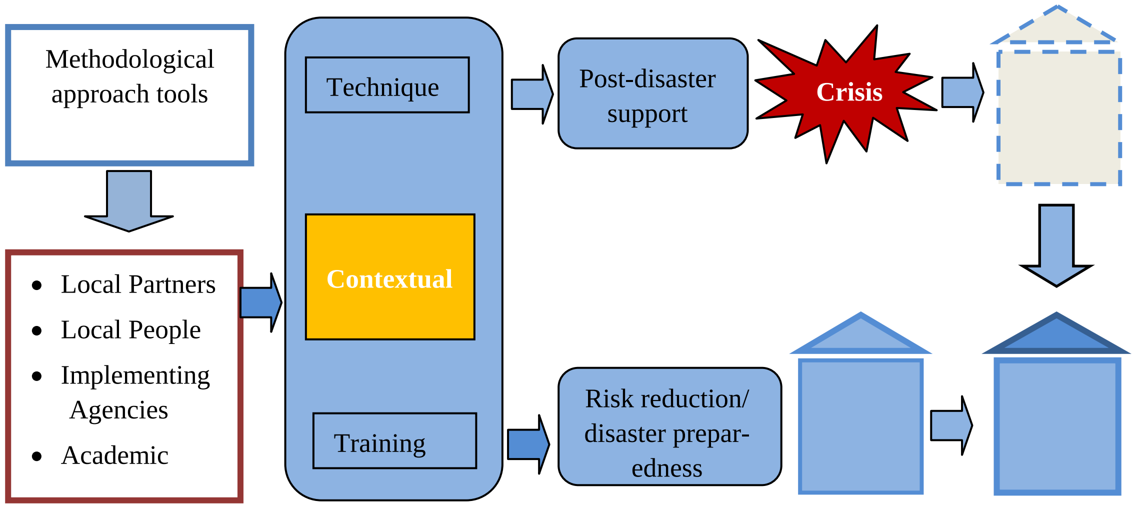


Figure 2. The conceptual approach of LCH project (after Caimi and Moles, 2012).

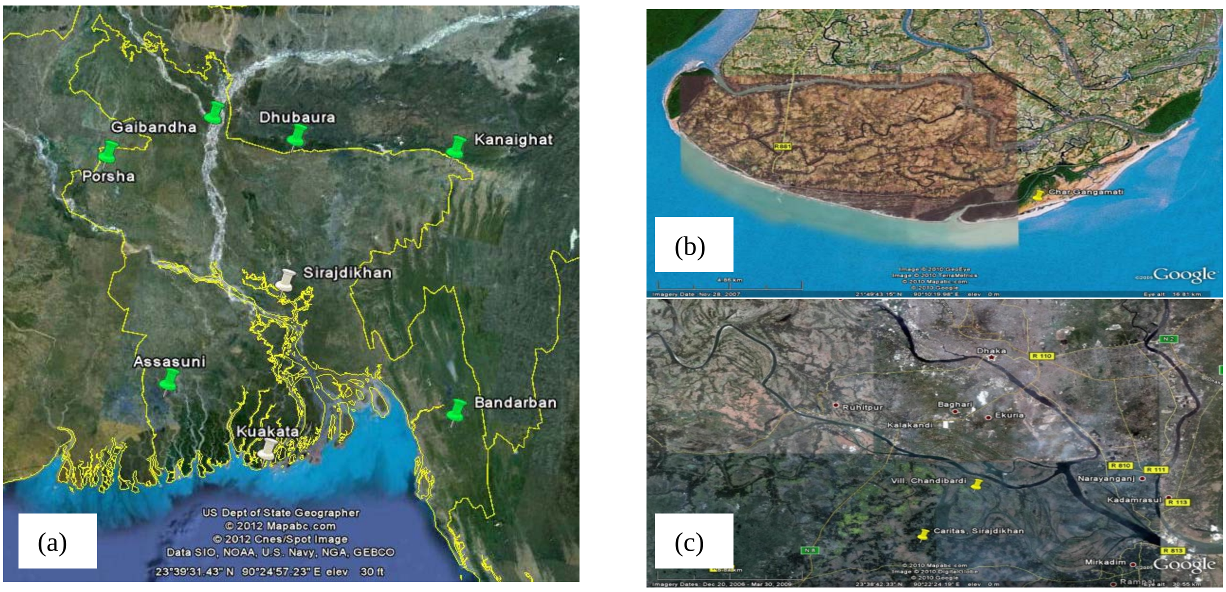


Figure 3. (a) Project locations on the map of Bangladesh; (b) close view of Kuakata(cyclone prone zone) and (c) close view of Si-rajdikhan (flood prone zone).

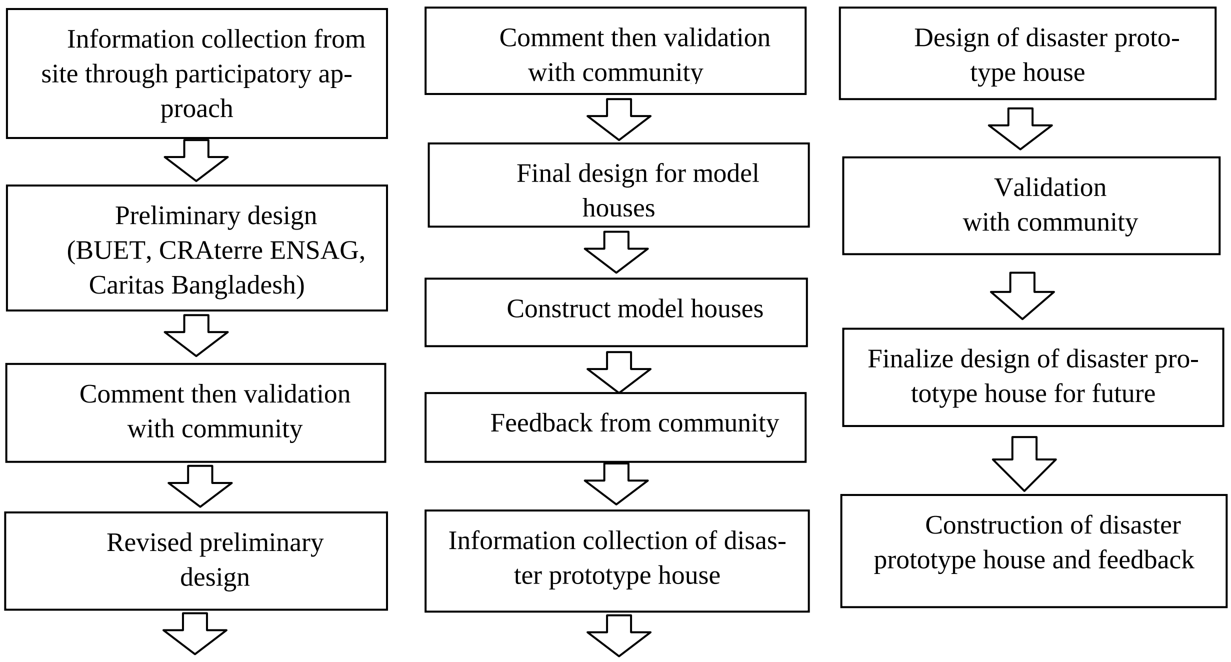


Figure 4. Sequence followed for developing the design of LCH in the project.

4.3 *Construction of Houses/Shelter*

Main steps in the design followed:

- Formation of Project Committee (PC)
- Community-led beneficiaries selection (CB)
- Training of artisans (CB and PC)
- Selection of artisans (CB and PC)
- Procurement of materials (CB and PC)
- Treatment of materials (CB, artisans and PC)
- Organization of the house, position and space arrangement (CB, beneficiary, artisans and PC)
- Construction of 2 houses, one for each model (CB, PC, artisans and community)
- Validation of 2 houses for improvements (CB, BUET, PC, artisans, community and beneficiaries)
- Providing feedbacks for improvements (CB and BUET)
- Construction of the rest 2 houses (CB, PC, artisans and community)
- Improvement/ repair of houses
- Construction of 6 disaster prototype houses in 3 disaster risk areas

4.4 *Monitoring/Follow up phase*

Performance of constructed houses is being monitored in the following way:

- During construction (CB and BUET)
- After construction: every 6 months (CB)

5 DESIGN OF LCHS

Proposed LCH design should respect local practice and culture. Information is collected to identify the client/beneficiary needs. And also the local mason, carpenter availability is given consideration. Meanwhile, it is also particularly important to be accountable from what is delivered to local population. For this reason, it was crucial to be able to scientifically assess the behavior of the various concept developed within the whole project.

5.1 *Design in Cyclone-prone Area*

5.1.1 *Design Considerations*

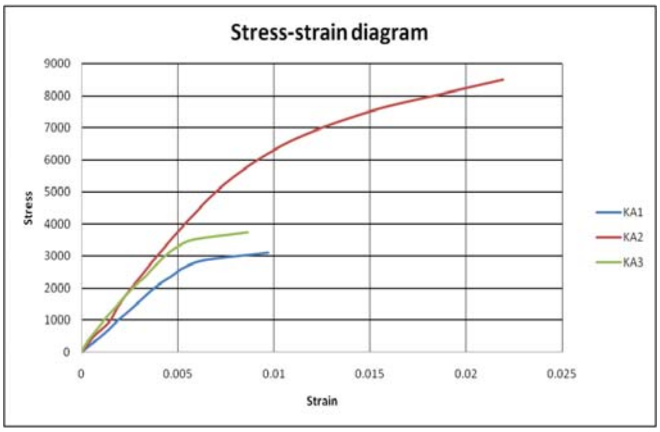
A four pitched roof is selected for better wind resistance in the cyclone-prone area. As per BNBC, 1993 the house should be designed for 260 km/h fastest mile. However, as these houses are not alternative to cyclone shelter, a realistic compromise on wind speed had been reached. Since these houses are vernacular in nature and cannot be treated as an engineered, these buildings can not satisfy the building code requirements. A RC and timber framing system, which is common in the area, is chosen. For the post, 1:2:4 concrete post reinforced with mild steel bars is selected whereas timber from locally available rain tree is used for beams and roof rafters. Timber properties have been ascertained from laboratory testing. A stepped earth plinth is chosen for better protection as the local soils are silty sand. Two parts of bamboo fences were used for better maintenance/repair of the lower part fence.

5.1.2 *Material Testing*

Collected soil samples, local building materials (wood, water) were tested at the BUET laboratory. Typical test results on wood sample (Rain Tree) are presented in Figure 5a. It can be seen that water content has significant effect on the strength of the wood. Figure 5b shows the failure pattern of a wooden beam during bending testing.

5.1.3 *Finite Element Analysis*

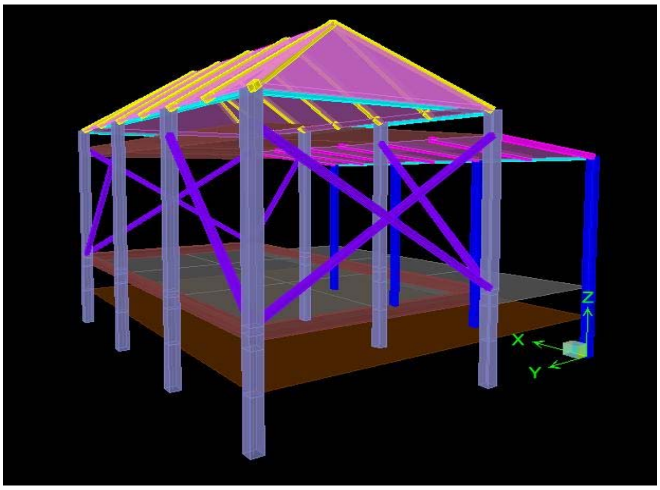
Based on the considerations, a 3-D finite element analysis was conducted (Figure 6a). The photograph of the Figure 6b shows the constructed house. FE analyses show that diagonal bracing would be better



(a)

(b)

Figure 5. (a) Stress-strain relationships of wood in compression (KA1: air-dry for 3 weeks, moisture content: 47%; KA2: immerged in water for 2 weeks, oven dry; KA3: immerged in water for 3 weeks, 1 week air-dry, moisture content= 73%) and (b) photograph of a failed sample in bending.



(a)

(b)

Figure 6. (a) 3-D finite element model of the proposed house in Kuakata; (b) photograph of completed house.

resistant to wind. However, finally due to construction difficulty, the diagonal bracings were changed to corner bracing as can be seen from Figure 6b.

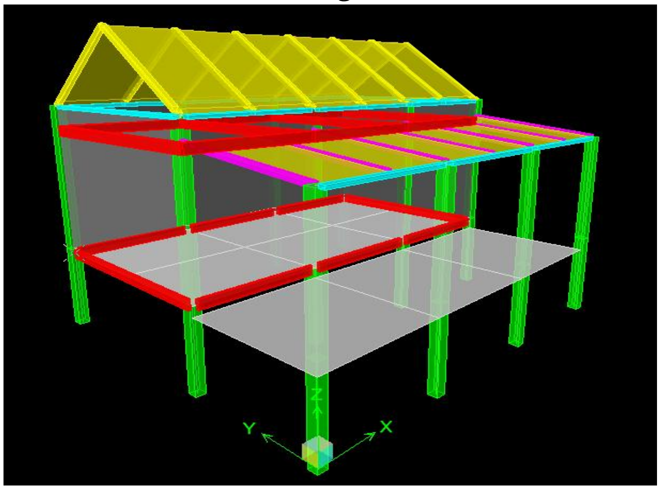
5.2 *Design in Flood Prone Area and River Bank*

5.2.1 *Design Considerations*

A two pitched roof is selected for better wind resistance in the flood-prone area. As per BNBC, 1993 the house should be designed for 210 km/h faster mile. However, a realistic compromise on wind speed had been reached. A RC and timber framing system, which is common in the area, is chosen. For the post, 1:2:4 concrete post reinforced with mild steel bars is selected whereas timber from locally available rain tree or Mehagani is used for beams and roof rafters. Timber properties have been ascertained from laboratory testing. A stepped high earth plinth is chosen for better protection as the area is flood prone. Two parts of the bamboo fences are considered for better maintenance/repair of the lower part fence. A loft is provided to save valuables during flood.

5.2.2 *Finite Element Analysis*

Based on the design considerations, a 3-D finite element analysis was conducted (Figure 7a). The photograph of the Figure 7b shows the constructed house. Although in the regions near or on the bank of the river, flooding is a common problem, river bank erosion causes shifting of houses.



(a)

(b)

Figure 7. (a) 3-D finite element model for the house in Sirajdikhan and (b) photograph of completed house.

Figure 8. Photograph of completed house at Gaibandha.

Main design considerations were to construct a house which can be dismantled within a short notice (based on local practice identified during the assessment of local practice). Also different types of '*katla*'(which provides joint between the post and foundation) have been used to see their performances. Stepped footing and three part fencing have been used in the design for better protection against rain-cut erosion. Photograph in the Figure 8 shows a completed house in the Gaibandha region.

5.3 *Design in Hilly Region*

For the hilly region of Bandarban, in order to address cultural specificities of communities living together in existing villages, two types of houses were designed i.e., 'Machan House' and 'House on Ground'. Machan House traditional practice of the region whereas Houses on Ground are another alternative due to cultural diversity. The Machan designed followed the traditional shape of original inhabitant while the house on ground is the fact of newly implemented communities. However, some improvements have been tried:

- Lesser number of bottom post have been found to be adequate.
- Corner bracings have been added to improve wind resistance.
- Treatment plan for bamboo and wood have been considered compare different methods.
- Different 'katla' arrangements have been tried.

Main Two different types of houses are presented in Figures 9a and 9b.

6 FUTURE PLAN

In this project LCH prototype has been developed for all the selected areas. It is also determined what improvement to be done on existing housing and local practice in order to make these houses more resilient to existing local hazards. New areas were also adopted. CB identified that, due to change on local practice, some medium income people are becoming the main targeted group for risk reduction. In Shylet, due to recurrent flood, local people are shifting from earthen architecture to fired brick houses. Due to lack in the financial capacities, local peoples are motivated to construct 50 mm thick fired brick walled houses. This type of houses might be resistant to flood but vulnerable to earthquake.

Another challenge for the next project step is to try to access the closest resources for implementing post disaster response or housing improvement project. This means materials, labors, management, etc. Strategy is to assess the needs of each of these resources for the needs to build 1, 10, 100, 1000, 10 000 houses, and to identify for each case at which level the resources will be available (village, district, region, country, international). Then, for each context, strategies to make the resources available closer to the implementation area will be defined (architectural concept, trainings, etc…). This will end to more contextual design, as well as to help local people not only to benefit from a roof after a disaster, but also to benefit from the money of this roof. Table 1 shows the proposed strategies in order to improve local impact and resilience at the local level.

(a)

(b)

Figure 9. Design of Houses in Bandarban: (a*) Machan* house and (b) house on ground.

7 SUMMARY AND RECOMMENDATIONS

About 60% families in Bangladesh live in vernacular houses. This sort of infrastructure is easily damaged by natural disasters such as flood and cyclone. So, preparation for appropriate design and structure of LCH is a crying need of the day. It is a social responsibility of architects, engineers, educational institutions and civil society members to take positive initiatives for this issue.

Table 1. Proposed strategies in order to improve local impact and resilience at the local level

Items	For 1 House	For 10 Houses	For 100 Houses	For 1000 Houses	For 10000 Houses
Quantities required? • Materials • Labour • Management					
Where resources are available? • Local • District • Region • Country • Outside the country					
Strategies					

The main aspects of the research project are as follows:

1) In designing houses the level of hazard needs to be estimated. It is important to use locally available materials and technology and show respect for local culture and practice. Importance must be attached to affordability, safety and re-applicability of the community. Even in the same area house design varies significantly.
2) Model houses are designed and constructed in four disaster prone areas of Bangladesh based on community participation. For designing the houses, local materials were chosen and the skill of local mason and carpenters were kept in mind.
3) The completed houses performed well and these are well accepted by the local community. However, performances of the constructed houses are being monitored.
4) Caritas staff members should incorporate their knowledge and skills in disaster preparedness and emergency response activities. CB may propagate the acquired knowledge learning to national and international NGOs, government sectors and Caritas International partners.
5) Educational institutes like BUET and practicing engineers can incorporate the learning from the project into the building code, text book etc. Expansion of research regarding LCH and related topics will have to be included in the curriculum of the technical institutes and universities without delay.

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