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MICRO CLIMATIC HOUSE DESIGN: A WAY TO ADAPT TO CLIMATE CHANGE? THE CASE OF GHAR KUMARPUR VILLAGE IN BANGLADESH

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Abstract
Doubt on global warming is over in the presence of firm scientific evidence supporting this phenomenon. There is not enough room to indefinitely explore the discourses on climate change; rather it is the time to act together in local and global scale for the common future of this planet. This, then, raises the question of what actions should be taken by the communities within their respective nation states and larger multi-national and global associations. Especially, in the case of developing countries, which are worst affected being in the forefront of global climate change, actions at the community level becomes paramount. One of the poorest nations-Bangladesh is worst hit by the recurrent floods and cyclones that are caused by increased global warming. The recent cyclone *Sidr*, which caused around 3,000 deaths and several million dollars of property loss, is an example of the devastating consequences of climatic change. Coastal areas of this country are in danger and highly vulnerable to cyclones and floods. This paper is based on the study carried out on the south-western coastal areas adjacent to the *Sundarbans* and such adjacency makes them unique in relation to dependency on resources. Prime focus of this paper is on the micro-climatic design of houses in response to frequent cyclone and the ways they should be designed in a more sustainable way, with available resources affordable to the community habitants. In the end, this paper raises some general questions about urban design and climate change.
Keywords: global warming, climate change, micro-climatic design, urban design

1. Introduction

There is no doubt over climate change and that it's a global phenomenon caused by the human activities in different nation states. Though it's a global problem, the solution has to come both from international and community scale. This paper focuses on the actions that should be undertaken at the community level beside the initiatives being taken at national and international level. Among the developing countries Bangladesh is considered as one of the worst victims of climate change and it has been reflected through frequent and devastating natural calamities. Among them, flood is a frequently occurred natural disaster, resulting 30-70% of the country normally flooded each year (GoB, 1993). The huge sediment loads brought by three Himalayan rivers, coupled with a negligible flow gradient, add drainage congestion problems and exacerbate the extent of flooding. The societal exposure to such risks is further enhanced by Bangladesh's very high population and population density i.e., 932.7 per sq. km[1]. The rapid explosion of population manifested in a continuous over-growth population coupled with the new climatic changes and reduction of natural resources in the coastal areas will be an enormous problem with far-reaching and devastating consequences. It would appear that population growth is a major factor in this looming crisis, directly affecting the built environment, therefore making urban design a crucial theme and tool in dealing with this. However, many projected climate change impacts including sea level rise, higher temperatures (mean temperature increases of 1.4°C and 2.4°C are projected by 2050 and 2100 respectively), evapotranspiration losses, enhanced monsoon precipitation and run-off, potentially reduced dry season precipitation, and increase in cyclone intensity would in fact reinforce many of these baseline stresses that already pose a serious impediment to the economic development of Bangladesh (Seraj et al., 1996). A subjective ranking of key climate change impacts and vulnerabilities for Bangladesh identifies water and coastal resources as being of the highest priority in terms of certainty, urgency, and severity of impact, as well as the importance of the resources being affected (Agrawala, 2003). The context of this study, therefore, is south-western coastal belt where housing was chosen as unit of analysis. A comprehensive study was undertaken in a village of this coastal belt to see resources dependencies on the mangrove forest Sundarbans in order to frame out a system for sustainable resources management and to identify the available and affordable resources that could be spent to build sustainable climate resistant houses by using indigenous knowledge shaped by modern technology and in line with urban design principles.

2. Damages on housing due to cyclone (*Sidr*) and flood as examples

The location settings offer to Bangladesh, the largest deltaic island on the earth, a lot of cyclones and floods, which used to occur in a regular pattern and in low intensity. But since the 90s due to global climate change the occurrence of natural disasters have become irregular and their intensity and

[1] http://original.britannica.com/eb/question-51736/6/density-sq-km-Bangladesh accessed on July 29, 2008

frequency have become very high. One of the strongest named cyclones in the Bay of Bengal was cyclone Sidr. The number of deaths caused by Sidr was estimated at 3,406, with 1,001 still missing, and over 55,000 people sustaining physical injuries. The Joint Damage, Loss, and Needs Assessment (JDNLA) estimated the total damage and losses caused by the cyclone to be 1.7 billion USD. Loss on housing due to cyclone Sidr was 893 millions USD (GoB, 2008). The impact is primarily felt by the poor people who hardly have any affordability to build cyclone resistant house and thereby to save their lives. In the flood history, flood in 2004 were likely to be as devastating as the 1998 floods in many ways. The joint mission's preliminary estimates show that total damage to assets and output losses are approximately about 2.2 billion USD or 3.9% of GDP, most of which correspond to lost assets (houses)[2].

3. Study area and method

Ghar Kumarpur village is situated in the eastern part of *Shyamnagar* thana[3]. This village is located in south-western coastal belt and near to the Sundarbans which is known as the largest chunk of mangrove forest in the world. This contextual setting has made the study area unique compare to other coastal areas in Bangladesh (Forest Department, 2000). The housing characteristics (*see latter part of this paper*) couple with frequent natural calamities has made it distinct to draw attention for research and education (Forest Department, 2000).

Morphology and land use categories and their information were collected by means of observation and land use survey respectively. A questionnaire survey was conducted following a sampling technique. Stratified sampling, also known as *restricted random sampling* (Sufian, 1998), was selected to draw plausible information about the study. The entire households were divided into 8 categories (*see table 1; had been identified from survey and categorized accordingly*) according to construction materials of roof, wall and floor. The purpose of dividing the households was to achieve greater degree homogeneity within each type and grater degree of heterogeneity between the types.

From each type of house (or strata) a sample was drawn based on *optimum allocation method.* According to this method a sample was drawn randomly depending on the size and variability of each

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[2] http://www.adb.org/Documents/Economic_Updates/BAN/2004/eco-update-ban.pdf accessed on July 29, 2008
[3] third administrative hierarchical body from the top

stratum. On an average 35% households were surveyed depending on the number of houses in each typology, and it makes a total of 100 households out of 282.

TABLE 1. HOUSE TYPOLOGIES IN THE STUDY AREA

Category	Construction Materials		
	Roof	Wall	Floor
Type-A	Tiles	Mud and Date leaf	Mud
Type-B	Golpata	Mud and bamboo stick	Mud
Type-C	Golpata	Bamboo mat	Mud
Type-D	Coconut leaves	Bamboo mat	Mud
Type-E	Golpata	Bamboo mat	Bricks
Type-F	CI sheet	Bamboo	Mud
Type-G	Tiles	Mud and bamboo mat	Mud
Type-H	CI sheet/ Concrete	Bricks	Bricks

Source: Field survey, 2007

4. Settlement pattern in this coastal belt

Settlement pattern was identified using the mathematical equation[4] of Clark and Evans (1954). In the word of urban design, settlement pattern is defined as objects and spacing among objects to perform desired functions. However, the amount of 'nearly regular' pattern of settlement in the study area (figure 1) is high and this is figured to 52.4%. This pattern is addressed as the middle ground between the random and complete pattern of settlement (Sultana, 1993). From the questionnaire survey average damage of each cluster of this pattern was found 194 USD[5] (13,200 BDT).

In this village the clustered pattern of settlement (figure 2) was found 25.8%. Empirical data show that average physical damage in such type of settlement is low. In fact, people have learnt such clustering technique to get more protection from cyclone and through a learning paradigm- *experiential learning*.

The clustering technique could be regarded as a prominent feature of vernacular architecture and mass in urban design that has been evolved from the beginning of human settlement to cope and survive in the harsh climate. This area is prone to nor-western storm and cyclone and therefore settlement pattern is highly influenced by such hostile weather. Due to flood, most of the housing units are elevated by 2-3

[4] *Nearest-neighbour Analysis:*

$$R_n = \frac{D}{0.5\{1/\sqrt{A/N}\}}$$

Rn is the description of the distributional pattern of settlement, **D** is the mean distance between the nearest neighbour, **A** is the area under study, **N** is the number of points in the study area.

[5] I US Dollar is equivalent to 68 Bangladeshi Taka (BDT)

feet from the ground. Existing building morphology of the study area explicitly embodies that settlements are mostly nearly random and clustered in nature. The technology is based on indigenous knowledge and is rudimentary in nature, being primarily generated from the need of survival. There are numerous examples of juxtaposition of modern technologies without necessarily understanding the indigenous knowledge and its practice and resources available at hand. In the name of sustainable housing development a number of projects have been carried out in the coastal areas leaving the question that in what ways those house models are sustainable when they are unaffordable to a larger section of the society and resources (construction materials) are not, at all, easily available (Seraj et al., 2000).

FIGURE 1. NEARLY REGULAR PATTERN OF SETTLEMENT
Source: Authors, 2007

FIGURE 2. CLUSTERED PATTERN OF SETTLEMENT
Source: Authors, 2007

5. House types in this coastal belt

From observation survey 8 different types of house were identified according to the structural materials of main housing unit, kitchen, cow shed and granary (see Table 2). *Golpata*[6] is the widely used material, from the Sundarbans, for different units of house.

TABLE 2. HOUSING TYPOLOGY ACCORDING TO STRUCTURE

Housing Typology		Main Unit (%)	Kitchen (%)	Cow Shed (%)	Granary (%)
Type-A	**Roof**-Tiles, **Wall**- Mud & Date leaf	2	-	-	-
Type-B	**Roof**- Golpata, **Wall**- Mud & Bamboo stick	73	59	93	70
Type-C	**Roof**- Golpata, **Wall**- Bamboo mat	9	13	1	-
Type-D	**Roof**- Coconut leaf, **Wall**- Bamboo mat	5	26	6	-
Type-E	**Roof**- Golpata, **Floor**- Bricks, **Wall**- Bamboo mat	2	-	-	20
Type-F	**Roof**- CI sheet, **Wall**- Bamboo, **Floor**- mud	6	-	-	-
Type-G	**Roof**- Tiles, **Wall**- Mud & Bamboo mat, **Floor**-mud	1	2	-	10
Type-H	**Roof**- CI sheet/ Concrete, **Wall**- Bricks, **Floor**- concrete	2	-	-	-
Total		100	100	100	100

Source: Field survey, 2007

73% residential unit, 59% kitchen, 93% cow shed and 70% granary are built by *Golpata*, mud and bamboo sticks. This means on an average 73.75% (average of the four) household use *Golpata*, mud and bamboo as construction materials which belong to Typology B. Formally this type of house is also recognized as *wattle-and-daub* (Ahmed, 1994). The British word *hurdle* is intended to mean a portable wall panel (or fencing) made of intertwined branches or wattle. This wattle is held in place by a bamboo frame and bamboo laths. In some cases, instead of wattle, mats made of interwoven split bamboo are used. This is quite common mats can be found in a wide variety of weaving techniques. The important piece of information is sometimes the hurdles or mats are plastered with cow dung and clay. This, of course, is a version of the wattle-and-daub system in the village area.

Construction of A-type house involves higher amount of labour cost together with tiles. Tiles are imported in water transport by boat, which contributes to an extra cost to the total price. But mud and date leaf are mostly available for free of cost in and around the village area and therefore it costs nothing. Only 2% main unit (residence) of households falls to this typology.

[6] It is, also popularly known as 'shelter leaf,' grows abundantly near the rivers, on the seashore. A leaf gains a height up to a maximum of 15 to 20 feet. Saline water and silted ground are suitable for its cultivation

B-type house is the most dominant and widely used by the inhabitants of this village. Cheap cost, comparatively long lasting durability and easy availability has made *Golpata* widely used materials for house construction. Construction of this house type involves less labour cost and this is because of the fact that both men and women assist actively during construction though division of labour depends on the physical strength of the individuals. Women usually take part in the construction as *jogaldar*- helper.

Cost of roof for house type C is least because of easily available construction material- *Golpata*. But the cost of bamboo and labour cost is higher in comparison with other components because of the reason that additional labours are needed for weaving mats.

For the house type D some of the construction materials like mud and coconut leaves are found free of cost. Despite such free materials, overall cost of this type is bit high because of additional labour cost for weaving of bamboo mats.

Construction of house type E is comparatively expensive because the floor is made of bricks. In comparison with others as more skilled labors are required for construction of floors, it increases the overall price accordingly.

Cost components of house type F reveal that CI sheet is comparatively expensive or construction. It was found that cost of one bundle CI sheet is about 32.5 USD (2,200 BDT). In terms of strength this house type is recognized as natural calamity resistant house but only middle and high income class people can afford house of this sort.

Total cost of house type G provides a view that tile's cost is not so high among other materials but labour involvement hikes the over all cost a bit. This is, indeed, not a popular type of house in the study area which has been reflected by its presence i.e., only 1% is used as main unit and 20% as granary.

Type-H house is completely built structure and its number is only quite a few in this village. Only the higher income class people can afford to enjoy this type. The cost of such house was estimated from the cost-estimation chart by Eastern housing private limited, a Dhaka based real estate company. According to its price index, cost of each square foot well furnished structure is 11 USD (750 BDT) which is far from being affordable by the low income people who are the majority in the society.

A cost matrix table (table 3) for different types of house, situated in this coast, has been prepared in order to provide an idea on economic viability for different income people. This, in the end, has helped to devise a *house* type which is climate resistant and economically affordable to all income class. These are the prime parameters for sustainability and sustainable house design.

TABLE 3. COST MATRIX FOR DIFFERENT OF TYPOLOGIES OF HOUSE.

Housing typology	Cost (USD)					Total Cost (in USD)
	1 Main unit (180 Sq. ft.)	1 kitchen (120 Sq. ft.)	1 Cow shed (150 Sq. ft.)	1 Granary (100 Sq. ft.)	Toilet (49 Sq. ft.)	
Type-A	28	13	24	8	4	77
Type-B	23	20	12.5	12	6	73.5
Type-C	25	20	13	12	6	76
Type-D	22	18	10.5	11	5.5	67
Type-E	82.5	55	51	44	22	254.5
Type-F	34	26	20.6	17	8.5	106.1
Type-G	39	23.5	31	14	7	114.5
Type-H	1985	1323.5	1654	1103	441	6506.5

Source: Field survey, 2007

6. Spatial setting of the houses

Here spatial setting refers to spatial distribution of housing units within household and surrounding natural elements. Orchard, water body and agricultural land are parts of housing and it is interesting to observe how they are being spatially distributed to protect households from natural calamities. A typical pattern has been shown in figure 3 to give an idea of indigenous knowledge on house units in relation to their surroundings.

Most of the residential units are oriented towards south and east direction (*see table 4*) and 83% orchards are located behind the housing unit. This spatial setting is due the fact that the villagers are frequently affected by the Nor-western storms (as come from north-western side), which occurs 2-5 times in a year, especially in the Bengali months of *Baishakh-Jaistha* (April-May).

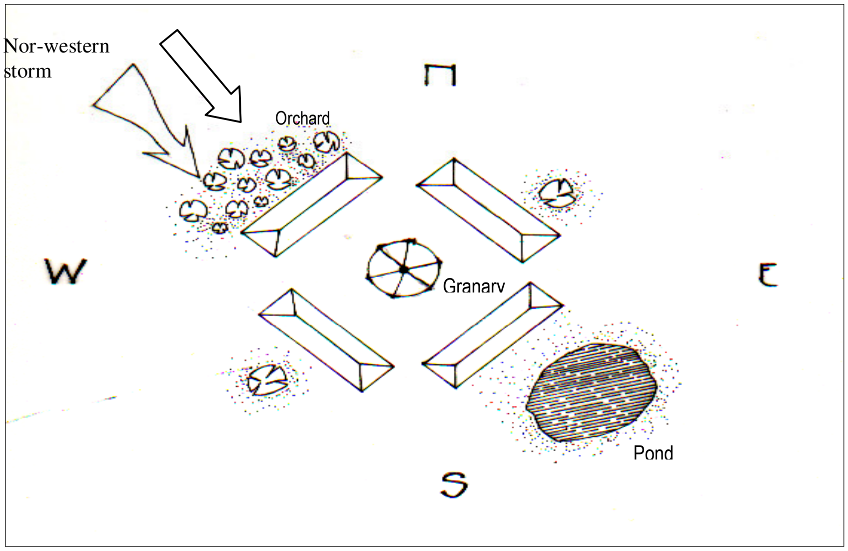

FIGURE 3. A TYPICAL SETTING OF HOUSE UNITS IN *GHAR KUMARPUR* VILLAGE

TABLE 4. SPATIAL SETTING OF HOUSES

Type	Avg. amount of land (in *Katha*[7]) owned by each household	Orientation[8]				Location	
		North (%)	South (%)	West (%)	East (%)	Front (%)	Rear (%)
Residential unit[9]	12.31	-	48	13	39	-	-
Orchard	3.29	-	-	-	-	17	83
Water body	1.93	-	-	-	-	76	24
Agriculture land	76.6	*Far from household but within walkable distance*					

Source: Field survey, 2007

Though some households are facing towards the west, their orientation is being compensated by the fact that they are located in a clustered way to protect themselves from strong storms, cyclones etc.

7. Designing a micro-climatic house

After the most devastating cyclone of 1994, it was found that there is less likelihood of house damage in cyclone affected areas if the roof structure of the house is strong and secured to the vertical support system which is firmly anchored to the foundation (Huq, 1995). Considering this phenomenon, following guidelines can be followed for proposed cyclone resistant house.

[7] *Katha* is locally used unit of land measurement which is equivalent to 720 sq. ft
[8] Orientation only for residential unit
[9] It includes- residence, kitchen, cowshed, granary and courtyard

Lay-out and Orientation**:** Lay-out of the houses should be oriented in a manner that the shorter face of the house is facing towards the windward direction of the cyclone or nor-western storm.

House Plan**:** The best plan shape is a square or rectangular for wind resistance. The traditional houses in this area are mostly rectangular with length and width ratio within 2:1 (Field survey, 2007). The length to width ratio of house plan should be 3:1 as houses being built in such a ration are considered to be cyclone resistant (Huq, 1995).

Tree plantation and orchard in the backyard**:** A well thought out plan of plantation helps to reduce the impact of both cyclone and tidal surge (Huq, 1995). Tree plantation should be undertaken by involving participation of local people in order to select species of trees such as *Shishu* and location of plants. In this area 48% houses are facing towards the south and the 39% towards the east giving a total sum of 87% housing units that are oriented to south and east directions because of nor-western storm and cyclone. Most of the orchards/gardens are located in the rear side of housing units which offer a primary protection from any intensity of storms (Field survey, 2007). Such indigenous technique of house construction have been evolved because of the fact that it take advantages from the nature by, on one hand, setting up facade of houses into opposite direction of cyclone and, on the other, planting tress on the rear side of house.

House roof shape**:** Traditional south-eastern coastal houses have different construction mechanism which has been characterized by *hip* roof over the *Ghar* and very low roof over the *Pashchati* which is separated from the hip roof (*see figure 4*). House roof's characteristics in the study area are different than what are located in south-eastern coast. But empirical evidence proves south-eastern coastal houses are more resistant against cyclone (Huq, 1995). This model of cyclone resistant roof is suggested to be constructed in the study area to offer more resistance.

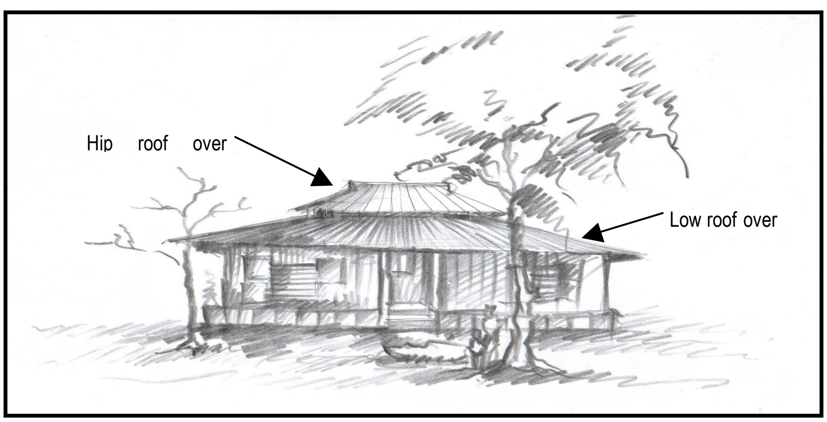

FIGURE 4. HOUSE ROOF'S SHAPE IN THE SOUTH-EASTERN

***Use of Sundari[10] and Goran (beside bamboo) as prime materials*:** *Sundari* and *Goran* should be treated with preservatives to enhance their durability and strength. In most of the cases bamboo and in some cases *Goran* and *Sundari* are used without treatment by appropriate preservatives for protection against decay, insects, fungi, termite attack, and when in contact in moist ground. The preservatives treatment of *Sundari*, *Goran* and bamboo include the following guidelines which should be followed before its use (figure 5):

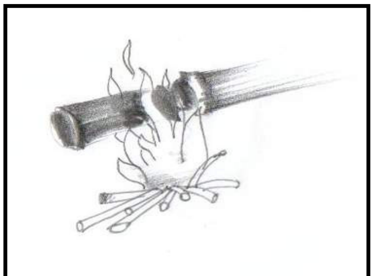

FIGURE 5A: BURNING TILL IT IS BLACK

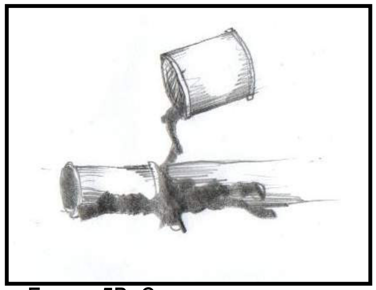

FIGURE 5B: COVER IT WITH OLD SUMP / MOTOR OIL

FIGURE 5C: SOAKING IT IN BITUMEN FOR 24 HOURS

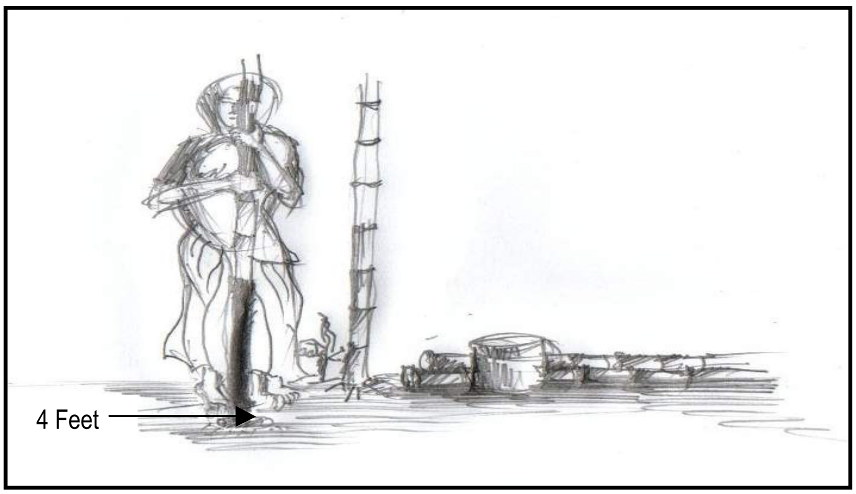

FIGURE 5. PROPOSED TREATMENT OF BAMBOO POSTS TO BE EMBEDDED INTO THE GROUND
Adapted from Ahmed, 1994

1. Burning of the lower 4 ft till it is black (*see figure 5A*).
2. Cover the lower 4 ft with old sump or motor oil (*see figure 5B*).
3. Or after burning, soak Sundari, Goran or bamboo timber in bitumen for 24 hours (*see figure 5C*).
4. Then this is amenable for use for house construction.

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[10] Scientific name is Heritiera fomes

Land elevation: A river called *Kholpetua* is situated neighbouring *Ghar Kumarpur* village. As the village is prone to flood during the rainy season, an embankment has been constructed around the village to protect from river erosion. Sometimes the embankment itself becomes a cause of water logging as there is lack of proper drainage provision. However, proper drainage provision should be created to drain out water to the river. For safety reason each house should be elevated by 4 ft from the ground level.

Foundations: *Sundari*, *Goran* and bamboo should be selected on the basis of appearance and strength for foundation of houses. Foundation of each house unit should be designed according to the instructions given below (*see figure 6*) to improve anchoring of the vertical support firmly to the ground giving sufficient weight to the house.

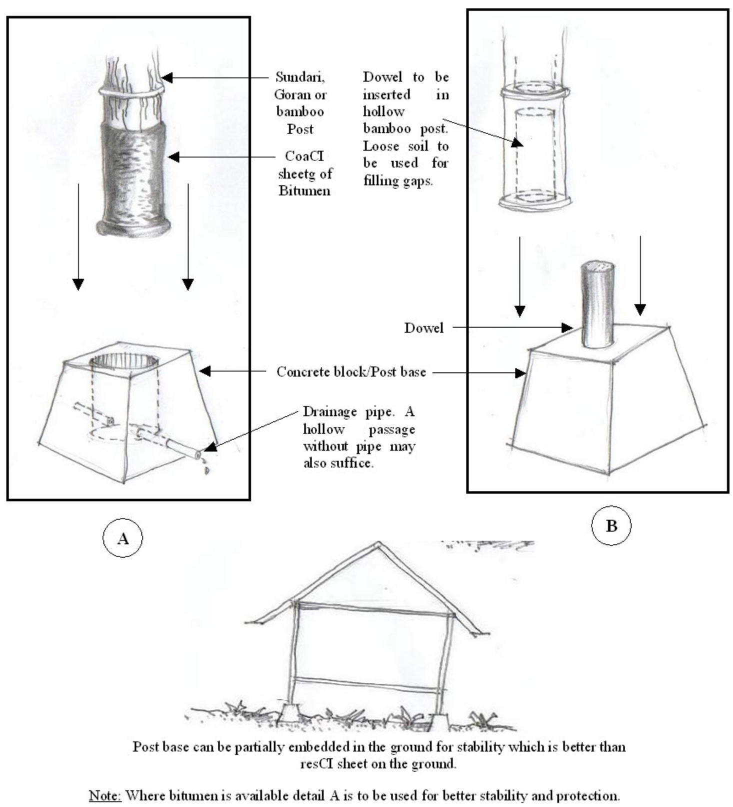

FIGURE 6. PROPOSED CONCRETE BLOCKS FOR PROTECTING BAMBOO POSTS
Adapted from Ahmed, 1994

Walls: The strong wind could be easily resisted by woven bamboo or timber board sheathing and vertical support. Diagonal bracing should be used to strengthen the walls and to reduce the chances for corner failures; due to unequal pressures on two side wall during cyclones.

For construction technique and its details local people could depend on the expertise of local builders for spacing of vertical *Sundari, Goran* or bamboo post and fixing and tying of woven bamboo sheathing to the post.

Roof structure and roof cladding: Different experiments have shown that if the roof structure is secured firmly to the vertical support system there is little likelihood that the house will be damaged by cyclone (Huq, 1995). The suggestions focus on *Sundari, Goran*, bamboo and *Golpata* as building materials for roof structures and cladding.

1. Roof Structure: The roof structure should consist of horizontal *Goran/ Sundari*/bamboo support beams strengthened by Goran/Sundari/bamboo posts. The *Goran/Sundari*/bamboo beams support the rafters of split bamboo. In the roof structure system, the most important connections are between beams and vertical support and the connection between the rafters and beams. In order to make houses cyclone/storm resistant, these connections should be strong in order to withstand the strong upward force of the cyclone/storm. Metal straps commonly known as *hurricane straps* in hurricane prone countries, may be used in the connections, particularly for connections between post and beam (Huq, 1995). The local technology for connections details between and rafter is done by tying the rafter firmly to the beam by nylon rope after cutting a notch or 'housing' in the rafter and in a better constructed structure the notch in the rafter is securely fitted to the beam maintaining the required slope at the same time. To enhance strength of each joints and to make them more resistant 20 gauge galvanized metal strap should be used with nails, nuts, and bolts beside traditional use of materials like nylon rope etc.

2. Roof Cladding: In addition to the roof structures, the thatch roof cladding must be able to transfer the wind loads to purlins. Research results show that the eaves and ridges of the roof are particularly susceptible to wind load during cyclone. Purlins, therefore, are important structural members of the roof structural system.

Settlement pattern: In the study area 78.2% settlements belong to the categories of *nearly regular* and *complete regularity and regular* pattern which offer support and protection against cyclone. There is enough provision for air and light circulation, spacious road for better accessibility in such patterns of settlement. For random pattern of settlement the disadvantages should be offset by tree plantation and rear side gardening.

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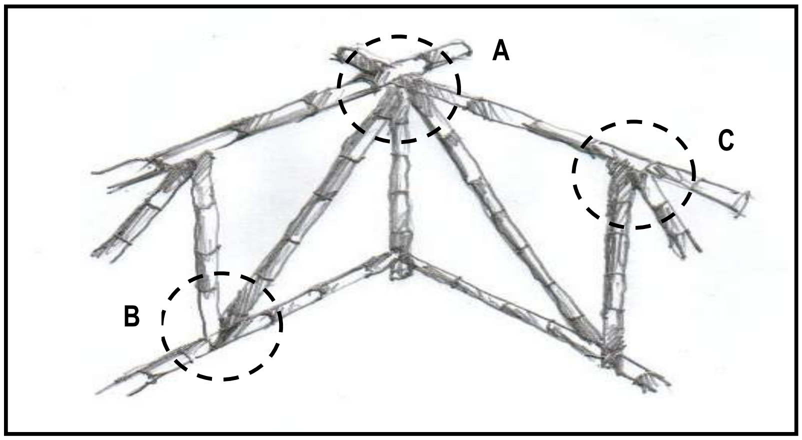
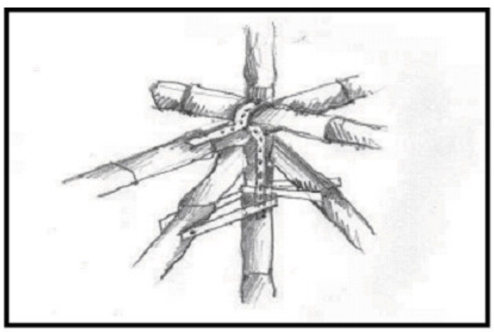
***Position of door and window*:** To cope with the cyclone, wall frame should be improved with the inclusion of cross bracings as shown in figure 7.





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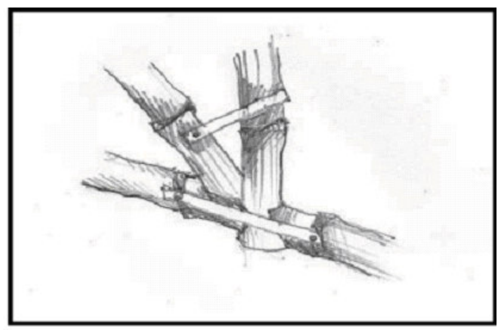

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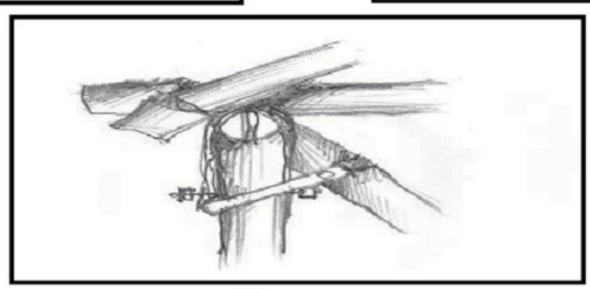

7C

FIGURE 7. CORNER BRACING

This cross bracing will distribute the total load, crated by the cyclone, to the four pillars of the house and it will be remained strong despite strong velocity of cyclone since depth and strong concrete foundation. To manoeuvre the strong wind walls and openings can be improved by placing door in the centre of the wall and placing small window opening in the rear wall (*see figure 8*).

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FIGURE 8. LOCATION OF DOORS AND WINDOWS

8. An affordability measure for cyclone resistant house

Many research projects have been carried out to construct cyclone and flood resistant house. In most of the cases the cost has gone so high up that they have become unaffordable to all income people (Hasan, 1999). This paper argues for a new model of cyclone and flood resistant house which is economically viable and affordable to all income people.

In the below section we have analyzed the economic feasibility of this new model with respect to the cost of existing house typologies and income of different group of people.

Cost of the proposed cyclone and flood resistant housing unit, having average size of 180 sq. ft, is 39.75 USD (table 5). Though the price is little higher (*detailed have been given in table 6*) than other house typologies, it not only offers a good resistance against frequently occurred natural calamities but also affordable to all income people. This new model of house offers the best price compare to per unit construction cost of other types (figure 9).

TABLE 5. COST OF PROPOSED CYCLONE AND FLOOD RESISTANT HOUSE

Proposed natural calamities resistant house	**Cost of main unit** (in USD) **Area:** 180 Sq. ft.
Roof- *Sundari, Goran*, Bamboo and *Golpata*	7
Wall- *Sundari, Goran*, Bamboo Mat and Bamboo	13.25
Floor- Mud	No
Labor	12
Transport	3
Accessories i.e., Metal Straps, Nylon Rope, Bitumen, Motor Oil, Concrete Foundation etc.	4.5
Total Cost	**39.75**

TABLE 6. A COMPARISON BETWEEN PER SQUARE FEET CONSTRUCTION COST OF DIFFERENT TYPES OF HOUSES

Type	Construction materials			Per sq. ft. construction cost (in USD)
	Roof	Wall	Floor	
A	Tiles	Mud & Date Leaf	Mud	0.16
B	Golpata	Mud & Bamboo Sticks	Mud	0.13
C	Golpata	Bamboo Mat	Mud	0.15
D	Coconut Leaves	Bamboo Mat	Mud	0.12
E	Golpata	Bamboo Mat	Bricks	0.46
F	CI sheet	Bamboo	Mud	0.19
G	Tiles	Mud & Bamboo Mat	Mud	0.22
H	Concrete	Bricks	Concrete	11
Proposed model	Sundari, Goran, bamboo & Golpata	Sundari, Goran, bamboo Mat & Bamboo	Mud	0.22

Source: Field survey, 2007.

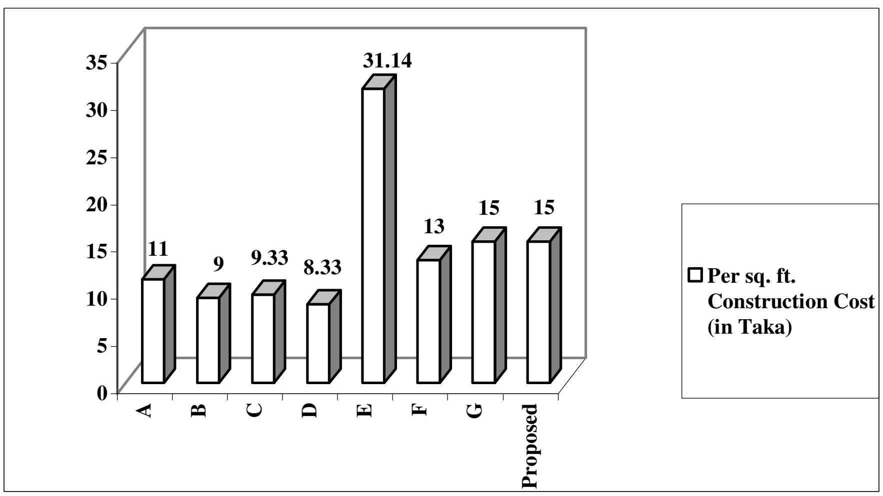

FIGURE 9. A COMPARISON BETWEEN PER SQ. FT. CONSTRUCTION COST OF DIFFERENT TYPES OF HOUSE

Most used housing type in the study area is Type-B and its construction cost is USD 0.13 per sq. ft. whereas per unit cost of proposed house type is USD 0.22 which is considered to be very reasonable.

If all the income groups adopt new house type, merely the low income people would have to enhance their expenditure for construction, which is a negligible figure compare to its potential output (Table 7). Since this is a disaster prone area, having average natural calamities 2/3 per year, certainly such natural calamity resistant house will minimize the cost of maintenance to a greater extent that will eventually compensate the extra expenditure for new construction.

TABLE 7. ECONOMIC FEASIBILITY OF THE PROPOSED HOUSE MODEL FOR DIFFERENT INCOME PEOPLE

Income Group	Yearly expenditure on housing (in USD)	Present expenditure on housing/year (% of income)	Expenditure on proposed house/year (% of income)
Low	18	5.10	11.39
Middle	94	11.57	4.52
High	115	12.65	3.75

Source: Field survey, 2007

From social acceptance point of view, the new house type is highly accepted as the construction mechanism is based on and modified from indigenous knowledge and techniques, is made of locally available materials and affordable to any income class in the society. This house type has also higher potential to be replicated in the areas of similar socio-economic, physiographic and climatic characteristics. Therefore, there is a need for a change in understanding the right knowledge and it needs to be applied in reality for a greater change in the society. As Stott et. al. (2006), University of London, rightly points out: ‘Climate is governed by millions of factors, from the flip of a butterfly's wing, through volcanic eruptions, the oceans and natural greenhouse gases, to solar activity and meteors’. If we really want to bring about a fundamental change and shift in all segments of society one has to look into this issue, as a systemic and holistic problem with no easy solution. We simply need to adapt to sustainable principles and to fundamentally rethink our current architecture, planning and urban design as well as to see what can be fixed in the best way to solve this.

9. Points to ponder on the use of resources and urban design principles

In the increasing concern of global warming, protection of environment is a big issue to be dealt with by the national and international communities. Due to sea level rising there is a dire possibility that half of Sundarbans mangrove forest will go under water by 2020 (Forest Department, 2000). Therefore, at the community level a preventive measure should be taken so that ecological biodiversity could be protected and frequency of natural calamities could be lessened.

For daily livelihoods the inhabitants are dependent on the resources from Sundarbans. They extract *Golpata, Goran, Gewa*[11]*, Sundari* etc. for constructing and repairing houses and to use as fuel as well. It is needless to mention here that the iterative cyclone cause a huge damage on house properties. There is a positive correlation between the extent of loss of house properties and dependencies on the resources from Sundarbans. Therefore, the frequent and higher intensity of cyclone is, greater the likelihood of resources being extracted from Sundarbans. In the near future, this resource dependency will cost a lot on overall natural environment, unless some actions are initiated at the community scale. This fact, in deed, leads to sustainable use of resources at the community level. This paper argues and presents findings in line with this statement that at the community scale a natural calamity resisting house (proposed house type) could minimize the resource dependencies on Sundarbans. There is a need, therefore, to adapt climate change through urban design principles. Forest department together with non-government organizations (NGOs) could take adequate steps to control resource extraction by introducing awareness program. The aim of such program should be to let them know the potential threats and its symptoms due to environmental degradation, their individual responsibilities in relation to this and to grow awareness and motivation to protect the environment at their immediate surroundings.

Effective strategies and new ways of foresight planning thinking should consider planning and regional development in a much more integrated and systemic way. Due to global warming, planning needs to identify, respond and influence the changes in the environment in this part of the world. We see a clear need to identify new and improved urban design principles in order to ensure that the priorities of urban design and climate change align successfully; otherwise the whole effort will be still born. There exist the urban design elements (people, place, space and objects) but there lacks an initiative to plan these in line with climate change and increasing need of climate resistant houses. Function, space (for living), perception (indigenous knowledge of house construction and environment) and practice are important elements in urban design. In this study, new model of climate resistant house was designed considering all these elements as pivotal factors to achieve sustainability.

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[11] Scientific name is Lespedeza cuneata

10. Concluding Remarks

We have to look more into and consider some of the difficult issues that lie behind future planning and urban design. Some of the issues brought up in our discussion are considered here as crucial ones for understanding the complexity and transformation of our society as risk and uncertainty grow systematically in vulnerable areas, thus making natural disaster mitigation, systemic approaches and sustainable urban design issues that are crucial. Undoubtedly, this is the right time to work together with the international communities despite the fact that some of the major powerful nation states are not that willing to curb carbon emission in an agreed rate and thereby to cooperate with others. Whatever the case is there is no spare time to wait for someone else to cooperate with as in every single moment this planet earth is heading towards a devastating and inhabitable future. In this paper, we have primarily highlighted what actions could be carried out at the community level focusing on housing in the coastal areas by applying micro climatic urban design elements. There is an urgent need to merge actions and initiatives at the global level together with the actions at the community level. Nevertheless, at this point of discussion we could argue that designing a new house type is a way, if not others, to adapt to changing climate at the community level.

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