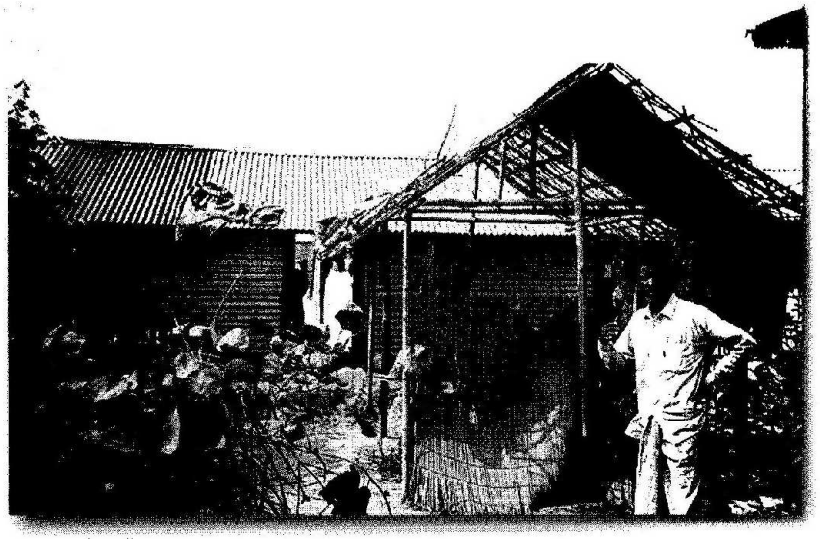



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## First Keynote Address

# DESIGN AND CONSTRUCTION OF HOUSES TO RESIST NATURAL HAZARDS

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### Introduction

From time immemorial, natural disasters have been causing the loss of millions of lives and resulting in colossal damage to the economy. In fact, the terms "natural hazard" and "natural disaster" were used almost synonymously. During the last few years, a clear distinction has gradually emerged between the two. A natural hazard is a "natural phenomenon or a combination of phenomena which threaten people or physical assets" while "a natural disaster is an event, sudden or progressive, which impacts with such severity that the affected community has to respond by exceptional measures" (Carter, 1991). Whereas it is extremely difficult to reduce natural hazards, developments in science and technology have now made it possible to reduce natural disasters, i.e. the impacts of natural hazards. This realisation is reflected in the change in nomenclature of the global efforts now underway to mitigate natural disasters it was originally named IDHR (International Decade for Hazard Reduction) when it was first proposed in 1984 by Dr Frank Press but, later on, when it was adopted by the UN General Assembly in 1987, its name was changed to the IDNDR (International Decade for Natural Disaster Reduction).

The housing situation in Bangladesh is extremely poor. According to the 1991 housing census, the backlog in housing was 3.1 million units, composed of 2.15 million units in rural areas and 0.95 million units in urban areas. By the year 2000, the housing shortage is likely to exceed 5 million (GOB, 1996). If we take into account the replacement needs of the rudimentary thatched houses, the target will be much more. About 90% of dwellings in rural areas and about 60% in urban areas are non-durable which implies that even if they are not subjected to extreme natural hazards, they would have to be replaced within 10-15 years.

Although natural hazards affect developed as well as developing countries, there is a difference in their impact. In the developed countries, improved mitigation measures have resulted in a dramatic reduction in the loss of human lives. For example, a magnitude 7 earthquake in a developing country may result in thousands of deaths but an earthquake of similar magnitude in a developed country (eg. California in USA) may kill only a few persons. However, the overall loss to the economy is much higher in the case of

developed countries. For example, in 1992, Hurricane Andrew caused an estimated loss of US$ 15.5 billion in Florida and the Great Hanshin earthquake in Kobe in 1995 resulted in an estimated loss of US$ 75 billion to physical assets (about 1.6% of GDP).

We have been fortunate that no major earthquake has affected Bangladesh during the last 78 years. The last major earthquake which had its epicentre within Bangladesh was the 1918 Srimongal earthquake which caused a lot of destruction in the Srimongal area and damaged houses as far away as Khishoregoni. A review of the damage statistics of the 1897 Great Indian earthquake shows that most of the brick masonry buildings in Dhaka collapsed or sustained major damage. The effect of a similar earthquake on the city (with a population 65 times more than in 1897), which has a large number of 3-5 storey brick masonry buildings with very little seismic resistance, would be catastrophic now. Moreover, many of these are on fills, with a possibility of ground failure during earthquakes. The traditional light-weight low-rise buildings in the north east part of the country (timber frame with thin bamboo mat walling) had excellent earthquake resistance but these are unfortunately being replaced by multi-storied brick masonry with RC floors and roofs which are extremely vulnerable to earthquake damage.

## Types of Natural Hazards

The various types of natural hazard may be classified as follows :

**Atmospheric Hazards**

- Tropical cyclones
- Storm surges
- Extra tropical cyclones
- Tornadoes/Thunderstorms
- River floods
- Droughts

**Geological Hazards**

- Earthquakes
- Tsunamis
- Volcanic eruptions
- Landslides
- Snow avalanches

**Other Hazards**

- River erosion
- Wildfires
- Locust infestation





It is estimated that about 3 million people around the world have lost their lives during the last 20 years due to natural disasters and around 1 billion people have been affected. The total damage during the period is estimated to be US$ 200 billion. Although all sectors of the economy are affected by natural disasters, destruction of infrastructure constitutes one of the major components of this loss.

## Natural Hazards in Bangladesh

Bangladesh is one of the most disaster-prone countries in the world. The major natural hazards which affect housing in Bangladesh are as follows :

- Earthquakes
- Tornadoes/Thunderstorms
- Tropical Cyclones and Storm Surges
- River Floods
- River Erosion

## Impacts of Hazards on Housing

The effects and consequences of some of the major natural hazards on housing are shown in Table 1.

## Engineered Housing

Buildings which are designed by competent engineers and supervised by them during construction are termed "engineered buildings". The design is governed by building codes which specify the loads, the design methodology and the details to be followed to enable the structure to resist the effects of natural hazards. In Bangladesh, efforts were initiated in 1973 to analyse the hazards due to extreme winds (Choudhury, 1974) and in 1979 to prepare an outline of a Code for Seismic Resistant Design (GSB, 1979) but it is only recently that a comprehensive National Building Code has been formulated (BNBC, 1993). The Code includes a wind speed map, seismic zoning map and a table giving the storm surge heights at different locations. The use of these values and the provisions of the Code should lead to construction of buildings which provide adequate safety against natural hazards. The Code also includes detailed recommendations for strengthening masonry buildings for earthquakes by providing horizontal as well as vertical reinforcement.

**Table 1 : Effects of Major Natural Hazards on Housing**

| Hazard | Effects | Impact on Housing |
|---|---|---|
| **Flood** (can be caused by unusually intense rainfall or by changes to earth's surface, such as deforestation upstream) | Inundation | Damage to human settlements ; walls may collapse, foundations may fail. Forces evacuation |
| **Tropical cyclone, Tornado, Thunderstorm** | High winds | Damage to buildings and other man made structures ; roofs blown away, collapse of walls & frames |
| **Storm surge** | Inundation and wave action | Collapse of walls due to inundation; foundation failure, collapse of walls and roof due to wave action |
| **Earthquake** | Tremors (ground shaking)<br>Liquefaction<br>Ground failure (horizontal displacement) | Damage to buildings, particularly unreinforced brick masonry and mud walled housing<br>Buildings on surface sink into soil<br>Damages buildings on the rupture lines |
| **River erosion** | Loss of ground support | Collapse of foundation |

## Non-engineered Housing

Most of the existing housing and houses which are going to be built in the next few decades are likely to be non-engineered, i.e. they would not have the benefit of being designed and supervised by engineers. Most likely, these are going to be designed and built by owners. These are the houses which are the most vulnerable to natural hazards. Our efforts should, therefore, be directed towards reducing the vulnerability of these non-engineered constructions. Fortunately, during the last few years, a number of projects have been undertaken in different parts of the world aimed at developing techniques for reducing the vulnerability of non-engineered construction against extreme winds and earthquakes (NBS, 1977 and IAEE, 1981).





These studies have identified the following four factors which have a strong influence on the vulnerability of housing :

- **Siting**
- **Design**
- **Construction Methods**
- **Materials.**

Taking all these into consideration, simple guidelines have been proposed for use by non-technical people and are presented in an illustrated booklet titled "43 Rules - How Houses Can Better Resist High Wind" (NBS, 1977). The International Association of Earthquake Engineering has prepared a manual for earthquake-resistant non-engineered construction (IAEE, 1981). By following these guidelines, it should be possible to reduce significantly the damage to housing due to natural causes, leading to a reduction in the loss of human lives and property.

The guidelines mentioned above have been available for quite a number of years. A question may naturally be asked : "Why are these not being followed in practice?". The answer is that the fruits of R&D are not being transferred into the field. As mentioned earlier, most of our houses are designed and built by owners or artisans who do not have access to these booklets. Obviously, there is a necessity for bridging this gap by transferring technology to the people, mostly living in the rural areas, who are actually involved in non-engineered construction. The lessons learnt from "agricultural extension services" may be used in this effort.

The following are some of the steps which may be used :

i Translating the guidelines into Bangla, including some modifications to reflect the conditions in Bangladesh.

ii Training of trainers
may be arranged by BUET and HBRI in association with NGOs involved in housing and banks providing micro-credit for housing (e.g. Grameen Bank).

iii Training programmes for artisans (masons, carpenters and other building-related technicians). These may be organised by NGOs.

iv Use of mass media (e.g. TV) to demonstrate good practices.

Experience of other countries shows that post disaster reconstruction provides an excellent opportunity for introducing improvements in housing technology. The experience of Tonga may be cited, where, following the 1985

typhoon, a few thousand houses were built using the help of BRE, UK. This has resulted in a dramatic improvement in the building practices in the island.

**Housing in Flood-prone areas**

The obvious measure which may be adopted for flood-prone areas is to raise the floor level above the level of flood-water. This may be achieved by

a. raising the level of ground on which the building rests
b. building on stilts
c. floating house with floor level rising along with the flood water

The first solution is very common in our rural areas where individual houses, clusters of houses or a whole village may be raised above the flood level by earth filling. However, adoption of this solution throughout the whole of the flood-prone areas does not appear feasible under the prevailing socio-economic conditions. Buildings on stilts are quite common in the coastal areas as well as along the river banks or roadside ditches. The major problem is that, unless properly braced, the unsupported lengths of columns may be excessive, leading to reduced resistance to lateral loads due to wind or earthquake. Floating houses supported on half-cylindrical ferrocement pontoons have been developed in Thailand but appear to be an expensive solution.

Houses on reinforced concrete stilts have been used in areas subjected to storm surge (e.g. Urir Char). However, the cost of Tk. 1 lac for a single room (around 10 ft x 10 ft) is beyond the means of most families. The use of precast prestressed space frames may lead to a reduction in the cost. Moreover, a structure which can be dismantled and re-erected at a new site would enable its use in areas subjected to erosion.

**Post-construction Repair and Retrofitting**

Mitigation techniques to reduce the vulnerability of housing to natural hazards can be incorporated most economically and effectively during construction. However, there is a large stock of existing housing which has already been built without adequate protection against natural hazards. Techniques for retrofitting have been developed, particularly for brick masonry and mud-wall housing. These include adding a ferrocement veneer, vertical corner reinforcement embedded in mortar, introducing tie beams and adding buttresses (IAEE, 1981).





**Concluding Remarks**

We are now in the seventh year of the International Decade for Natural Disaster Reduction, the major goal of which is to reduce the vulnerability of countries to natural hazards and to make disaster mitigation an integral part of national planning exercise. Although Bangladesh is the most disaster-prone country in the world, our national efforts during the last few years have not been significant. A large volume of literature exists and only some of the most useful and relevant ones have been referred to; what is now required is a concerted effort to transfer the know-how to people who are actually involved in the design and construction of housing. This Workshop has been organised so that participants from different countries can share their experiences in this field. The deliberations of the Workshop and the field visit should enable the participants, who represent a wide cross-section of professions, to formulate a strategy for achieving our goal which is to provide Hazard-Resistant Shelter for All.

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