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Traditional and Modern Disaster Resistant House Construction Techniques

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Abstract

A large portion of the wealth of any nation is invested in its built-up environment viz, housing, infrastructure, industrial and commercial facilities. The quality of this built-up environment, expressed in terms of durability, safety and functionality, is a determining factor for the quality of life and economic development of the society, and the competitiveness of its industry and services. Extensive loss of this wealth is caused by natural disasters that strike periodically. A natural disaster is an event of nature that causes sudden destruction, damaging the economy and social structure on a massive scale. The calamity results in a huge financial burden in terms of relief and rescue operations. All-round decline in production, unemployment, indebtedness as well as increased cost of goods and services are the other debilitating results of natural disasters. This research paper deals with the traditional as well as modern disaster resistant construction techniques to meet the aftermath of disasters. It examines the issue of damage to Reinforced Concrete Cement (RCC) buildings by underlying the necessity of adherence to building codes and standards. Some recent advances in housing technology are also highlighted.

Keywords: resistant, construction, strategies, mitigation, prevention and techniques

1. Guidelines for Disaster Resistant Construction

With its vast territory, large population and unique geo-climatic conditions, India is periodically exposed to natural catastrophes. Even today, natural hazards such as floods, cyclones, droughts and earthquakes are frequent phenomena in the country. While the vulnerability varies from region to region, a large part of the country is exposed to such natural hazards, which often turn into disasters causing significant disruption to socio-economic life of communities leading to a huge loss of life and property.

Concerned with the impact of natural disasters, the governments at the central and state levels are gradually evolving strategies, policies and programmes for natural disaster mitigation, preparedness and prevention. In response to the UN General Assembly Resolution declaring 1990-2000 as the International Decade for Natural Disaster Reduction, the Government of India has been taking several initiatives for strengthening disaster reduction strategies. An

Expert Committee was also set up in July 1994, after the Yokohama Conference, to examine disaster related issues and evolve suitable strategies. It is important to note that disaster resistant construction forms one of the core issues being addressed at the disaster mitigation and prevention policy levels. This aspect was dealt with in detail in the Report prepared by the Expert Committee.

For earthquake resistant construction, it is better to avoid hillside slopes and areas having sensitive and clayey soil. It should be preferable to have several blocks on terraces rather than one large block with footings at different clusters. The building as a whole should be kept almost symmetrical. Simple rectangular shapes behave better in an earthquake than shapes with multiple projections. Separation of a large building into several blocks is required for symmetry and rectangularity of each block. Restricting the width of openings, using bond beans and taking recourse to steel or wooden dowels as well as RCC band at plinth, lintel and roof levels are good disaster resistant techniques for buildings.

In case of cyclones, structures should be erected in areas, which provide a protective shield from high winds with natural firm level foundation. Flat roof arrangement should be avoided. So should be the projecting elements like antennas and chimneys, eave projections, sunshades etc. The construction should have adequate diagonal bracing, reinforced machinery, thicker plate glass, and anchoring of purlins to gable ends. As far as flood resistant housing is concerned, prohibited zones should be totally avoided. Layout of the buildings/ houses should be such that they do not block free flow of water. Construction should be done on raised mounds. Waterproofing treatment, adequate bracing, afforestation in catchment areas are required for flood-prone areas. The Expert Committee Report covered the following issues:

Identification of various hazard-prone areas

Vulnerability and risk assessment of buildings

Outlining the disaster damage scenarios

Technical guidelines for hazard resistant construction of buildings

Up gradation of hazard resistance of existing housing stock by retrofitting; and

Adoption of technical-legal regime.

2. Traditional Disaster Resistant Construction Techniques

Earthquakes are not new to India, as 55 per cent of the country is prone to seismic shocks. Thus, traditional earthquake resistant house construction techniques are as old as the earthquakes. Several earthquake-prone regions in the country have traditionally built houses that minimize the damage to life and property and stand up well in the wake of the quake. The traditional wisdom and attention to detail can be applied to modern material as well. These techniques are based on the use of traditional material e.g., timber and bamboo for building houses.

Avoiding compression structures like domes, vaults and arches is another option. The structural system needs to be tensile and the material should be flexible, as is the case with timber, steel and bamboo. It also helps if the structure is constructed in a way that it vibrates as one unit and sways together. Traditional constructions in India for example in the Northern Coast follow this principle, as also the tall skyscrapers of Tokyo. Traditionally built timber houses have proved to be the most effective in keeping the damage at bay. It would, however, be incorrect to say that the old-fashioned houses have survived just because of the material used. The construction techniques too have determined the amount of damage.

Most new constructions with heavy roofs (slate tiles or RCC) supported by weak walls (random rubble in mud mortar) have proven deadly. Older houses at higher elevations have timber roofs held together by timber and tie-bands, horizontal timber beams spanning across the entire building, connecting the entire structure and giving it the character of a cage. Such houses have suffered little damage despite the mud and stone masonry.

Quake resistant houses should have tie-bands just above the level of the floor, the level of the doors and windows, and another at the roof level. Corners are the most vulnerable and thus ought to be strengthened. Elasticity of the structure can be enhanced with flexible steel rods or wood batons at corners. Doors and windows should be few, small and symmetrically placed away from the corners. The house should be as light as possible. It should be noted that all houses designed by the renowned architect Laurie Baker remained intact during the 1999 Charnoli earthquake. Baker had laid emphasis on the use of local construction material coupled with traditional wisdom.

Some of the huge multi-storeyed building constructions in Garhwal Himalayas, known for high seismic activity, employ earthquake resistant traditional architectural design. A few building structures, five to six storeys high, have endured the ravages of time, weather and geo-activity for hundreds of years, These constructions are locally known as 'Sumer', 'Chaukhat' or 'Kothi'. These structures have withstood a number of earthquakes, including the recent ones. Let us now look at the nature of technology used in such constructions:

2.1 The Building Technology in 'Summers'

The Summers are ascribed to the Rajput families of Rajasthan in India. They built the Summers to function as watchtowers and to provide for the defence of all the families living in an area, rather than for the protection of a single family. Structures comparable to the 'Sumer', with some variations have also been reported from Pakistan, Afghanistan and Nepal, all in the Himalayan — Karakorarn earthquake-prone zone. The indigenously devised building technology, which is used to erect Summers, makes use of locally available resources such as long thick wooden logs, stones, slates and clay to specification. Typical. 'Summers' stand 15-17 mts high from the ground level and have 5-6 floors with 4 rooms on each floor. The ground area covered by the Sumer is 86 sq.mt. A foundation trench 3 mts deep and 70 cms wide is first dug and then refilled with well-dressed flat stones. This foundation is then raised above the ground in the fashion of a rectangular platform, to the height of 2.3 mts with the help of flat stones, clay and stone fillings.

The structure of the 'Sumer' rests upon this platform. To raise the walls, double wooden logs, are placed horizontally on the edge of the two parallel sides of the platform, which are opposite to each other. The width of the logs determines the thickness of the walls, which is 70 cms. On the other two parallel sides, the wall is raised with well-dressed flat stones to the surface level of the logs placed on the other two sides. The walls are further raised to 30 cms by placing heavy, well-dressed flat stones upon the wooden logs on the two sides and by placing another pair of wooden logs upon the stones on the other two opposite sides.

The four walls of the structure are thus raised using the wooden logs and dressed up flat stones alternately, up to a height of about 17mt. The structure is further reinforced with the help of wooden beams fixed alternately that run from the middle of the walls of one side to the other, intersecting at the centre. This arrangement divides the 'Sumer' into 4 equal parts from within and provides for joists supporting the floorboards in each floor of the building. On the fourth and the fifth floors, the 'Sumer' has a balcony with a wooden railing running around on all four sides. The fourth floor is also provided with a toilet-cum-bathroom on the balcony. Specially designed wooden ladders provide access to the different floors, which are located within the 'Sumer'. The roof of the 'Sumer' is laid with slate stones. These types of structures have proved to be quite resistant to earthquakes, and the design and technique behind them could be used in the present context.

2.2 Technology Used in 'Chaukhats'

The technology applied on the 'Chaukhats' or 'Kothi' is reininiscent of a machine stitch on a fabric that keeps a piece of cloth in shape. In like manner, the technology makes use of wood like a thread and keeps the entire structure intact against the ravages of weather and geo activity. Through-stones and flat-stones are used, and wood predominates the structures of whatever dimensions they are. Pairs of thick wooden logs, beginning from the base of any two opposite walls are used at every 30 inches alternately with heavy stones to raise the walls and run through the entire length of all the walls.

At the right angle where any two walls meet, the edges of the pair of logs on one wall are placed on the edge of the logs of the other and they are joined together by hammering thick wooden nails through them. This has an effect of turning the structure into a single piece construction. Any devices used for windows, doorways, ventilators or floor-joists are joined to these well-secured pairs of logs, which further strengthen the structure. The use of pair of logs gives to the wall a thickness of almost 70 crns. Such time-tested technologies for building quake resistant houses are still available in the Himalayan region in India. Let us now highlight some quake resistant technologies used in other countries such as Northern Peru.

2.3 Earthquake Resistant Housing in Peru

In the Grauniad San Martin regions of Northern Peru, over two million people are vulnerable to disasters including those caused by floods, landslides and earthquakes. Traditional 'Quincha' building technology results in a flexible structure with an inherent earthquake resistance. It has been used in parts of Peru for many centuries. Traditionally, a 'Quincha' house would have a round pole set directly in the ground, filled in with smaller wooden poles and interwoven to form a matrix, which is then plastered with one or more layers of earth. The structures performed well during earthquakes, but in May 1990, an earthquake struck the relatively isolated Alto Mayo region of Northern Peru and destroyed 3000 houses. It was then decided by the builders, householders and community organizations in Alto Mayo to introduce improved, earthquake-resistant building technology called 'Quincha Mejorada'. Improved 'Quincha' has the following characteristics over and above the traditional 'Quincha'.

2.4 Concrete Foundations for Greater Stability

Wooden columns treated with tar or pitch to protect against humidity, concreted into the ground with nails embedded in the wood at the base to give extra anchorage.

Use of concrete wall bases to prevent humidity affecting the wood and the canes in the walls.

Careful jointing between columns and beans to improve structural integrity.

Canes woven in a vertical fashion to provide greater stability.

Lightweight metal sheet roofing to reduce danger of falling tiles.

Nailing roofing material to roof beams; tying of beams and columns with roof wires.

Incorporating roof eaves of sufficient width to ensure protection of walls from heavy rains.

In April 1991, a second tremor hit the region damaging a further 9600 homes. However, the 70 improved 'Quincha' houses that had been built since May, withstood the tremor so well that a further 4000 odd houses have since been built along with several schools and community centres. Today, knowledge of this type of design as well as the building skills are so widespread in the local communities that the Intermediate Technology Development Group or ITDG, (An international NGO, which works with poor around the world to develop appropriate and sustainable technologies that will enhance the livelihoods, e.g., in countries of Latin America, South Africa, East Africa and South Asia) has been able to move on to 'Quincha' network.

Adobe brick is an inexpensive, readily available construction material used throughout Latin, America, especially in rural areas. Unfortunately, these solid and rigid bricks tend to crack and break apart during an earthquake, causing walls to collapse and ceilings to cave in. Much death and injury could be avoided if structures were made more secure in this earthquake-prone country. Researchers have designed a frame consisting of a grid of bamboo poles anchored at the top and bottom that allows the walls and roof to react to the vibrations of an earthquake as a unit, rather than breaking apart. The new design has been tested on a seismic table and has proved capable of resisting a force equal to that of Peru's strongest earthquake.

3. Stone and Brick Buildings

As against the concrete buildings as well as the buildings that use 'Sumer' and 'Quincha' type I of design, the stone and brick buildings have a bad track record. They normally do not perform well during an earthquake. It is important, thus, to know why we should avoid using solely stone or brick buildings.

Stone Masonry Buildings Such buildings are most commonly used in the hills of Western U.P, Himachal Pradesh, and Killari District of Maharashtra. These are single or double storey buildings with mud mortar or no mortar at all. The thickness of stonewalls is around 40 cm in two vertical layers. The roof generally consists of tiled stone slates. Such buildings suffer maximum damage during any calamity. The failure seems almost in the waiting in such buildings leading to heavy loss of human life and livestock.

1) Typical Failure Pattern is as follows:

Overturning of walls due to out of plane inertia forces

Separation of the two leaves of stone walls

Collapse of roof due to very heavy self-weight

2) The Main Reasons of failure are:

No mortar. to weak mortar in stone walls

No continuity at the joints of the walls in horizontal plane

Lack of through-stones between the outer and inner leaves of stone wall

Very heavy roof of stone slates

Lack of interconnection in roofs and walls

Brick Masonry Buildings

Brick buildings, if not constructed in adherence to the norms of symmetry, interconnections and reinforcement, perform rather badly during earthquakes.

3) Typical Failure Pattern is as follows:

Diagonal cracks through masonry units

Overturning of walls due to out of plane inertia forces

Vertical cracks in walls due to plane bending action.

Failure of wall connections

Collapse of roof

Unreinforced gable end masonry walls being unstable, the strutting action of purlins imposes additional force.

4) The Main Reasons of Failure in Such Buildings are:

Poor material workmanship

Long walls

Openings in walls to the extent of 50% of length

Openings too close to the corners of walls

Lack of structural integrity

Unsymmetrical plan of building

Poor soil or bad foundation

4. Damage to Reinforced Concrete Cement Buildings

A significant number of the mid-rise buildings suffered dramatic failure generally from loss of stability due to the soft ground storey during the January 26, 2001 Bhuj earthquake. Many buildings had only two to four columns at the ground floor. The size of columns on the ground floor varied from 230mrnX 230- to 230mrn X 900 mm, depending upon the storey height. The frames had weak column-strong girder proportions. Typical deficiencies included insufficient column ties, lack of cross ties, 90 degree rather than 135 degree hooks on the ties, splices with inadequate length and confinement and no staggering. Even the G+10 (i.e., ground floor and 10 more floors) storey buildings had isolated footings without interconnecting foundation beams.

Some of the buildings were located on in-filled soil without carrying out detailed geo-technical investigations. These buildings had used poor quality of concreting including no control on water-cement ratio, poor compaction and little curing. Fortunately, from amongst over 3, 00,000 buildings in Ahmadabad, only a very small fraction collapsed or suffered any major damage. The buildings that suffered damage were the newly constructed ones that had not followed any building byelaws and codes.

No building can remain entirely free of damage during a high density earthquake. Nevertheless, all houses, big or small, can be made safer or quake resistant. Structures can be made to withstand earthquakes of a particular magnitude by taking certain precautions. Buildings generally collapse as a result of inertial forces. During an earthquake, the lower part of a building tends to vibrate, as it is in direct contact with the ground. The forces of inertia, however, keep the -upper portions static. This conflict of forces leads to collapse. The magnitude of these forces is directly proportional to the weight of the building, the heavier the structure the greater is the damage. If the structure is light, lesser number of people die in case of a collapse.

It is necessary to provide horizontal reinforcement in walls for imparting bending strength in the horizontal plane against plate action for out of plane inertia load, and for tying the perpendicular walls together. It is provided in the form of following bands:

Plinth bad

Lintel band

Roof band

Gable band

A band is a reinforced concrete beam provided continuously through all-load bearing longitudinal and transverse walls at a given level. It consists of 2 or 4 longitudinal steel bars with links or stirrups embedded in 75 mm or 150mm thick concrete. The thickness of the band may be made equal to the thickness of / or a multiple of masonry unit and its width may be made equal to the thickness of the wall. The steel bars are located close to the wall faces, and full continuity is provided at the corners and junctions. The diameter of the bars may vary from 8mrn to 16mm depending upon the unsupported span of the walls.

5. Building Codes and Standards

Building codes are standards and guidelines for construction of buildings to ensure a minimum level of safety for the occupants. An appropriate building code incorporates a thorough understanding of the forces that natural hazards impose on the area governed by the code. Building codes are only one of the tools for increasing the resilience of the built-up environment in the face of natural hazards. Land use planning, emergency management, natural resource protection and infrastructure development policies play significant roles as well. Coordination j of these activities can be achieved through comprehensive hazard mitigation planning.

It is never possible through any building standard to lay down foolproof regulations for protection of infrastructure from earthquakes of all magnitudes. It is also not possible to build earthquake proof buildings. However, the design approach adopted in the building codes is to ensure that a building structure possesses:

Minimum strength to withstand minor earthquakes, which occur frequently, with some nonstructural damage.

Resistance to moderate-earthquakes, which occur once in ten years or so, with minor structural damage and some nonstructural damage; and

Withstanding capacity to a major earthquake, which is likely to occur once in a lifetime of the structure, without complete collapse.

Actual forces that occur during earthquakes are much greater than those specified in any building code. However, ductility (capability to undergo deformation), arising from inelastic material behaviour and detailing of reinforcement and over strength, arising from the additional reserve strength in structures over and above the design strength are relied upon to account for this difference in the actual and design loads. Critical facilities such as hospitals, telephone exchanges, powerhouses, schools, community centres, water tanks, airports etc., are designed for higher earthquake forces so that they must remain functional after the occurrence of earthquake. It may be noted that the cost of incorporating earthquake resistance features in a new building may be merely about 15% to 25% of the civil costs of the building.

The building regulatory system plays an important role in ensuring the quality of the built-up environment. But designing appropriate standards and mitigation programmes for natural hazards requires a sound understanding of the distribution, magnitude and frequency of those hazards. Also, it is equally essential to evolve an inspection mechanism that ensures adherence to the code and plans. Enforcement is generally the weakest part of the system, often due to lack of human and financial resources allocated to this function. It could also be due to political interference in the regulatory system.

The Bureau of Indian Standards (BIS) has initiated several pre-disaster mitigation projects to reduce the impact of natural disasters on life and property as well as bring down social vulnerabilities. It has undertaken standardization efforts in the area of earthquake engineering. The Himalayan-Nagalushai region, Indo-Gangetic plain, Western India, Kutch and Kathiawar regions in Gujarat are geologically unstable parts of the country. Hence, some devastating earthquakes of the world have occurred here. Strong earthquakes have also visited a major part of peninsular India. But these have been relatively few in number and of considerably, lesser intensity. Table 1 indicates the frequency, intensity and damage caused by earthquakes around the world in the past century. Taking cognizance of their frequency and intensity, it is, thus, all the more important to follow the building codes and earthquake resistant designs more rigorously.

Table 1.

S. No	Date	Place	Magnitude	Deaths
1.	April 4, 1905	Kangra, India	8.6	19,000
2.	August 17, 1906	Valparaiso, Chile	8.2	20,000
3.	December 28, 1908	Messina, Italy	7.2	100,000
4.	January 13, 1915	Avezzano, Italy	7.5	29,980

5.	December 16, 1920	Gansu, China	7.8	200,000
6.	September 1, 1923	Kanto, Japan	7.9	143,000
7.	May 22, 1927	Tsinghai, China	7.9	200,000
8.	December 25,1932	Gansu, China	7 6	70,000
9.	January 15, 1934	Bihar, India	8.1	10,700
10.	May 30, 1935	Quetta, Pakistan	7.5	60,000
11.	January 25, 1939	Chillan, Chile	8.3	28,000
12.	December 26, 1939	Erzincan, Turkey	7.8	30,000
13.	October 5, 1948	Ashgabat, Turk	7.3	30,000
14.	May 31, 1970	Peru	7.9	110,000
15.	February.4, 1976	Guatemala	7.5	23,000
16.	July 27, 1976	Tangshan, China	7.5	655,000
17.	December 7, 1988	Spitak, Armenia	6.8	25,000
18.	September 29, 1993	Latur, India	6.2	9,748
19.	January 26,2001	Gujarat, India	7.7	20,023
20.	December 26,2003	Barn, Iran	6.6	26,200
21.	December 26,2004	Sumatra, Indonesia	9.0	26,106
22.	October 8, 2005	Near Muzaffarabad (PoK)	7.6	7.6

Source: The United States Geological Survey (Cf The Hindustan Times, October 9, 2005).

Table 2. Worldwide Annual Frequency of Earthquakes

Description Magnitude	Great 8 & higher	Major 7-7.9	Strong 6-6.9	Moderate 5-5.9	Light 4-4.9	Minor 3-3.9	1 very Minor 2-2.9
Annual Average	1	17	134	1319	13.00	130,000	1,300.000

Source: ibid.

The damage caused by these major earthquakes has been very huge. In a bid to bring down the loss of life and property after disasters, there is a need to systematize and standardize the earthquake resistant design and construction of structures taking into account seismic data from studies of the past earthquakes. To serve this purpose, building standards have been formulated in the field of design and construction of earthquake resistant structures as also in the field of measurement and tests connected therewith by the Earthquake engineering Sectional Committee, CED 39. Let us now look at some of these building standards:

IS 1893 Standard — Deals with earthquake resistant design of structures and is applicable to buildings, elevated structures, bridges and dams. It also provides a map, which divides the country into five seismic zones, based on the seismic intensity.

IS 4326: 1993 — Provides for guidance in selection of materials, special features of design and construction for earthquake resistant buildings including masonry, timber and pre-fabricated constructions. It intends to cover the specified features of design and construction for earthquake resistance of buildings of conventional types. The general principles to be observed in the construction of such quake resistant buildings as specified in this standard are lightness, continuity of construction, avoiding / reinforcing projections and suspended parts, building configuration strength in various directions, stable foundations, ductility of structure, connection to non-structural parts and fire safety of structures.

IS 13827: 1993 — Deals with the design and construction aspects for improving earthquake resistance of earthen houses, without the use of stabilizers such as lime, cement and asphalt. It has been recommended that buildings should be light, single-storeyed and of a simple rectangular plan.

IS 13828: 1993 — Covers the special features of design and construction for improving earthquake resistance of buildings of low strength masonry.

IS 13920: 1993 — Includes the requirements for designing and detailing of monolithic reinforced concrete buildings to give them adequate toughness and ductility to resist severe earthquake shocks without collapse.

IS 13935: 1993 — Covers the selection of material and techniques to be used for repair and seismic strengthening of damaged buildings during earthquakes, and retrofitting for up gradation of seismic resistance of the existing buildings.

Despite, the stipulated building codes and standards, their adherence is still a rarity in the developing countries of South Asia. Lack of awareness on the part of community and inadequate training of masons and builders in earthquake resistant techniques could be the reasons for this. It is lamentable that no governmental or community monitoring mechanism exists to oversee the. implementation of the byelaws, legal provisions and sanctions.

We all have a very reactive approach to disasters. Crores and crores are spent on relief and rehabilitation while not even 1/41h of this amount goes into preparedness and proactive measures. The recent Earthquake in Muzzafarabad in Pakistan Occupied Kashmir (POK) is an eye opener. It has been the most devastating Earthquake of this century. It just seems that even today, in this age of massive scientific advancement and Information Communication Technology revolution, we are where we were centuries ago i.e., ever vulnerable to the wrath of nature.

6. Recent Advances in Housing Technology

Some of the technologies that are innovative and quake resistant. These need to be made use of in order to cope with disasters like the earthquakes and cyclones:

6.1 Base Isolation Technology

Reducing the forces transmitted to the building from the ground by placing the building atop a mechanical system of isolators, sliders and dampers is called 'base isolation technology'. This dampens the violent movements of the earth during a seismic event. By using isolators and dampers, the building is 'decoupled' from the ground motion of any earthquake and the transmission of seismic energy to the building is dampened.

This is done by lowering the vibration frequency, allowing the building to move or displace. It is also done by lowering the shock acceleration of the seismic event; thus, reducing the tendency for the upper floors to move faster than the lower floors. In general, buildings that have been isolated in this way are subjected to 113" to 115" of the horizontal acceleration to that of conventional structures during a seismic event. The isolator is a sandwich of alternating layers of 1/4th inch steel plate and 1/4th inch rubber, which are vulcanized to form a single integrated unit. It is able to displace horizontally in any direction by 24 inches from the centre.

6.2 Natural Disaster Resistant

Housing over the years, the National Association of Home Builders (NAHB), in partnership with the U.S. Department of Housing and Urban Development (HUD), has been funding major research and empirical studies involving the NAHB Research Centre and universities around the country to examine a variety of structural performance issues related to natural disasters. The research findings are being used to guide the future use of existing and new construction technologies and building systems. One of the Research Centre's activities is zeroing in on how well the houses using Insulating Concrete Forms (ICFs) are able to resist natural hazards such as hurricanes, earthquakes, tornadoes, floods and fires.

ICF construction is relatively new to the building codes and home building industry of the United States, ICFs are hollow foam blocks or panels that stack and interlock to create exterior walls of a building. Reinforced concrete is then placed inside the foam blocks, creating strong, insulated concrete walls. ICF construction is already noted for benefits such as energy efficiency and durability, but its structural performance when faced with natural hazards is largely undocumented, and that is the focus of ongoing (study at the Research Centre.

6.3 Reinforcing Concrete

Reinforcing concrete to keep it from cracking is nothing new. There are records to show that ancient civilizations used to make use of natural fibres to inhibit cracking in structures. Today, synthetic-fibre reinforcement is available to reinforce non-structural concrete applications with superior results. Currently, the most widely accepted form of reinforcement is Welded Wire Fabric (WWF). It is a mesh of thick steel wires that is placed in concrete. However, synthetic fibre reinforcement avoids the increased labour costs and difficulty in placement that are associated with WWE.

Small diameter synthetic fibres (nylon and polypropylene) are now being added to concrete in order reduce shrinkage and cracking by more than 80%, according to certain independent laboratory tests. Reducing the cracks lowers concrete permeability, increases its toughness and long-term exposure to weather. It also reduces callbacks in concrete slab floors, decks, driveways and walks. According to fibre manufacturers, the placement, curing or finishing characteristics of the concrete are not affected by the addition of fibrous reinforcement. Larger-diameter synthetic fibres (steel and polyolefin) added at higher content by volume (0.5% to 1.5% respectively) also enhance hardened flexural strength, but at an increased cost.

6.4 Cyclone Resistant Dwelling Construction

The Cyclone-ravaged Orissa is in the process of being rebuilt using disaster resistant housing technology. Modern building techniques, which help the dwellings to withstand intense storms like the one that lashed Orissa on October 29, 1999, are being made available to the people who have to rebuild their homes. The new technology has been developed by the National Building Construction Corporation (NBCC). It involves the use of pyramidal roofs so that the thnist area is reduced and the tile use to give the roof the required shape is made possible. The walls and foundation have been well-spaced to allow for flexibility when a building is buffeted by strong winds. Such building techniques are commonly used in quake-prone areas in Japan and along the Californian coastline in the United States.

6.5 Disaster Resistant Pier Systems

A good foundation of the house is of immense help in making it disaster resistant. For manufactured houses, one option is a disaster resistant pier system, with stout members rigidly connecting the house's classis to a slab, grade beam, or array of pads. Some systems incorporate lateral or diagonal bracing for greater resistance. Though often referred to as Earthquake Resistant Bracing (ERB) systems, these also resist high winds, frost heaves and floods. Not only are these systems cost-effective in reducing structural movement (compared to conventionally manufactured housing foundations); they can even save lives and property.

In earthquake-prone zones, disaster resistant pier systems are generally considered to be more cost-effective than ground anchor systems, which do not always perform adequately. The anchors are usually located on the longer sides of the house, which bear the greatest wind loads. However, earthquake loads can occur in any direction and additional anchors on the short sides increase costs. Because the piers are usually separated from the soil by pads, rust and deterioration are not such big concerns, as they are for ground anchors.

7. Agencies Involved in Disaster Resistant Construction

Housing and Urban Development Corporation (HUDCO). As we will also be reading in our next Unit, there are many agencies working in the area of housing technology for disasters. One of the most important ones is HUDCO. It is the only organization in India that has been working on the issues of disaster mitigation and use of disaster resistance technology in construction for the past several decades. Apart from its routine operations of techno-financing, housing and basic infrastructure, it promotes disaster-resistant technologies for human habitat. It adopts villages to demonstrate how to go about building shelters with simplicity and safety through simple illustration of 'Do s and Don't s' in disaster prone areas. It provides knowledge on spatial planning and design in disaster-prone areas keeping the traditional socio-cultural styles intact.

HUDCO imparts skills in improvising traditional building techniques using local materials to masons and artisans through its network of building centres all over the country. It conducts workshops to train engineers, architects, builders, administrators and project managers on the importance of using safe technologies for construction of buildings at its Human Settlement Management Institute in

Delhi. It funds rehabilitation projects that require reconstruction and extends financial help for retrofitting of housing and infrastructure. As on December 2004, HUDCO has funded reconstruction / rehabilitation of 1,911,368 dwelling units in the country with a loan amount of Rs. 1342.37 crores in disaster-affected areas. Its total operations in housing loan commitments have been around Rs. 17, 116 crores.

7.1 FICCI-CARE Gujarat Rehabilitation Project (FCGRP)

This Project has raised nearly 120 crores for relief and rehabilitation work in the worst-affected communities of Gujarat. The Project has successfully completed construction of over 3157 core earthquake and cyclone resistant homes. The construction of additional 2765 homes has commenced and the construction of community infrastructure is underway. These buildings incorporate important safety features such as steel reinforcing of all corners of the house and reinforcement of the plinth, beam and roof levels, the latter being an essential component for cyclone resistance, since the area is prone to high winds from the Arabian Sea. In fact, all construction is as per the specifications of the Indian Standards for Earthquake Safety 4326-1993, as provided in the guidelines issued by the Gujarat State Disaster Management Authority. Each core house covers an area of 30 square meters, and it takes into account the existing lifestyle of the beneficiaries. The design for the core house has been developed in consultation with the people and top architects, well-versed in earthquake and cyclone safety guidelines. There are many other agencies that are involved in disaster resistant construction.

8. Conclusion

The wrath of natural disasters could be reduced to a considerable degree with the adoption and implementation of improved design sitting and disaster resistant construction techniques practicable within the context of the cultural and socio-economic constraints prevailing in the given regions. When houses and buildings constructed through traditional methods, using conventional building materials, do not exhibit the necessary disaster resistant characteristics, new designs and nontraditional building materials and construction techniques need to be developed and put to use. Adoption of disaster resistant technology for constructions, therefore, an important consideration for the national programs and projects on disaster mitigation and prevention.

References

Dhameja, Alka (2003). “Disaster Risk Reduction through Disaster Resistant Construction Techniques,” in Pardeep- Sahni and Madhavi Malalgoda Ariyabandu (Eds.), *Disaster Risk Reduction in South Asia*, Prentice-Hall of India, New Delhi.

Guidelines for Building Reconstruction in Cyclone Affected Areas in Orissa. (2000, January). HUDCO.

Guidelines on Improving Earthquake Resistance of Housing. (1999-2000). Building Materials and Technology Promotion Council (BMTPC), Ministry of Urban Development and Poverty Alleviation, Department of Urban Development and Poverty Alleviation, Government of India, New Delhi.

IGNOU Certificate Programme in Disaster Management (CDM 1 and 2).

Mathur, G.C. (1986). Housing in Disaster Prone Areas, ESCAP, New Delhi.

Seminar Excerpts on “Earthquakes in Built Environment”. (2001). *Journal of Indian Building Congress*, 8(1).