Commonwealth Association of Architects Projects Unit

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HUMAN SETTLEMENTS AND DISASTERS

Series coordinator: Ian Davis, Principal Lecturer, Department of Architecture, Oxford Polytechnic, Oxford, UK

This series of five slide lectures and accompanying manual assumes a general knowledge of the effect of disasters, and applies this knowledge to the needs of buildings in the low-income sector both in their construction and siting. It is intended primarily for qualified architects, planners and engineers, as well as for students in these disciplines, working in disaster prone countries. It will also be of value to relief administrators, builders and military personnel. The talks are based on the most up-to-date information available at the time of publication and benefits from studies which the authors have undertaken with various bodies including UNDRO (Office of the United Nations Disaster Relief Coordinator), CIDA (Committee on International Disaster Assistance), voluntary relief agencies and governments.

Part 1 Defining an approach for designers by Ian Davis

The impact of disasters (earthquakes, floods and high winds), scale of casualties and damage particularly in the Third World; proportion of internal aid to external aid; need to uncover essential facts about disasters and to evaluate assistance programmes; eight vital steps for designers and builders concerned with improving low-income housing; essential involvement of survivors in the reconstruction process.

Part 2 Mitigation measures by Ken Westgate

Vulnerability analysis and mapping; large-scale preparedness measures, eg flood protection; modifying unsafe traditional building techniques; problems of moving vulnerable communities; particular vulnerability of poor sectors of the community, eg squatter settlements; educating for awareness of risk; community based mitigation policies.

Part 3 Simple techniques for making adobe houses more earthquake resistant by Everett M Ressler

Reasons for preponderance of mud brick construction in earthquake prone areas; incorporation of seismic-resistant principles into traditional building techniques; improved siting, spacing and shape of small dwellings; educating local builders.

Part 4 Making low-income housing wind resistant: a case study of Andhra Pradesh, India by Ian Davis and Everett M Ressler

The effect of wind pressure and suction on buildings; analysis of wind damaged structures; application of wind resistant principles to traditional pole beam construction common in south-east Asia; improved siting of buildings; planting barriers.

Part 5 Emergency shelter after disasters by Ian Davis

Strategies for emergency shelter provision; capacity of survivors for self help, improvisation and recovery; reasons for the failure of imported emergency housing and 'universal' solutions; conversion of temporary housing into permanent housing; need for long-term planning; alternative ways of using available funds; support role of donors in the local recovery process.

Slide lectures

Each slide lecture consists of a 20-25 minute cassette recording and 24 slides in a plastic pack. The tape is not synchronised and a pulse indicates each slide change. The reverse of the C60 cassette is

available for recording additional material or for a second language version. Suitable for group study with a standard tape recorder and slide projector, or for individual study by reading the commentary included in the manual and using a simple hand viewer.

Manual

The accompanying manual provides essential information in support of the slide lectures. In addition to the commentaries it includes: a description of the nature of hazards (earthquakes, cyclones/hurricanes, storm surges), a resource index of organisations and individuals able to provide assistance and a comprehensive bibliography. The bibliographical items are grouped for easy reference under the following headings: basic references, mitigation and preparedness measures, management of disaster relief and reconstruction, emergency shelter, medical aspects of shelter, refugee camp planning, sanitation/water supply, social/anthropological aspects, cyclone resistant housing, fire resistant thatch roofing, earthquake resistant housing, engineering studies of the earthquake resistance of low-income housing, laboratory techniques for testing the earthquake resistance of small dwellings, communication techniques in housing education programmes, historical studies of disaster reconstruction and the modification of house construction and siting, evaluations of housing performance/user satisfaction, reconstruction following disasters, appropriate technology, key relief periodicals.

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Price

£20 each separate slide lecture plus postage and packing. If the complete series of five slide lectures is purchased at the same time (£100), one copy of the manual will be included free of charge and additional copies will be charged at £3 per copy. If individual slide lectures are purchased, £3 will be charged for each and every copy of the manual.

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Overseas orders: all goods will be sent airmail (cheapest rate) unless otherwise specified.

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a series of five slide lectures

by

Ian Davis Dip Arch (co-ordinator)
Everett M Ressler
Ken Westgate BSc MSc

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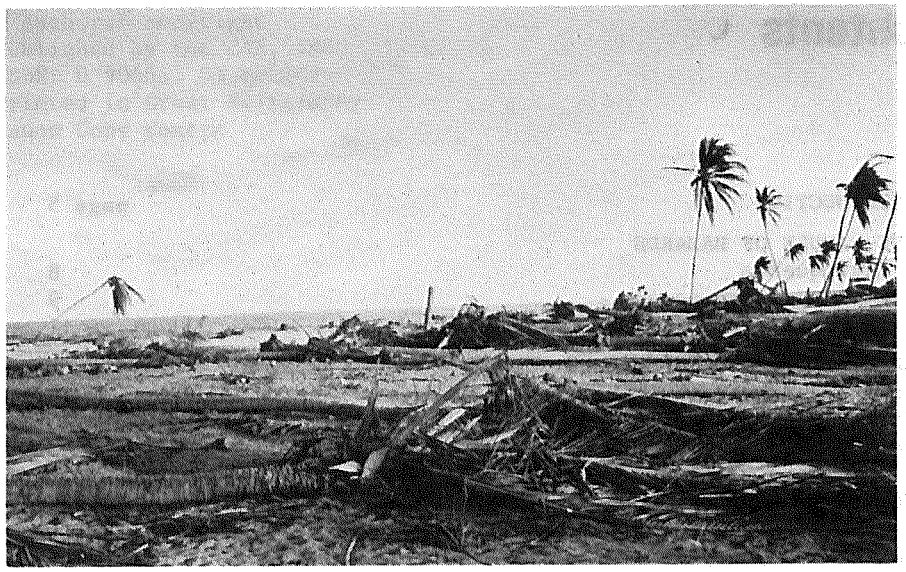


Above: Coconut palms in Sri Lanka provide shelter and income; after devastation, new trees take years to mature.
Below: Monsoons, the economic lifeblood of many Asian countries, can also have disastrous consequences; Calcutta floods in 1978.
(Photographs reproduced by courtesy of OXFAM)

1 Introduction

In recent years there has been a marked increase in casualties resulting from natural disasters with the annual death toll running at around a quarter of a million, about half of which occur in major castastrophes. Ninety-five per cent of these casualties are in the developing countries in which two-thirds of the world's population live.

The table summarises vulnerability to natural hazards and identifies the areas in which architects and planners can contribute their skills. It should be noted that although droughts cause the greatest number of casualties, they are not related to the design of houses or settlements and therefore this form of natural hazard has not been included in these slide lectures.

Column A Drought, tropical cyclones, floods and earthquakes together account for 90% of all natural disasters. The proportions indicated in this column are only approximate since, although earthquakes can be very easily detected by seismic monitoring devices, many floods and tropical cyclones in remote areas may not be reported.

Columns B and C Drought and cyclones cause most deaths, but floods cause the greatest physical damage. It is important to note that the siting of settlements in relation to the hazard is the main problem in areas subject to tropical cyclones and flooding, whilst in earthquake-prone areas the collapse of buildings is the critical factor. Thus the design of buildings is of primary importance in seismic zones. There are two approaches to the removal and reduction of risk: the ideal and the possible, that is the expedient. Both have significant social consequences which must be considered before any changes are carried out, and these are discussed at length in the slide lectures.

Columns D and E It is a cruel twist of fate that some of the most vulnerable areas are also the most suitable for habitation due to the fertility of the soil and work opportunities. Therefore, to propose the wholesale relocation of communities living in coastal areas subject to tropical cyclones, or on flood plains, or in seismic zones is rarely feasible. However, there may be local instances where relocation is possible. But against this must be set the key issue of social disruption caused by such moves. In practice, relocation is rarely carried out; where it has been attempted this has been against the will of the local community and

the resulting new settlement has not been successful.

Column F Practical measures to lessen risk are:
(i) Attempts to mitigate the force of the hazard by flood control devices or the building of windbreaks in cyclone areas.
(ii) Attempts to protect the vulnerable population by: effective warning systems for impending floods or tropical cyclones; evacuation policies to remove the population from the impending hazard; cyclone shelters; and modifying the structural form, shape and siting of houses in order better to withstand the extreme forces encountered in high winds, floods or earthquakes.

Column G Attempts have been made in several countries to modify unsafe housing, in particular in Bali, Guatemala, India, Mexico and Peru. The experience from these projects indicates that there are many obstacles to be overcome. These include: the cost of such changes (which may be critical for a poor family); conservatism in contemplating any change from local building traditions; and a lack of awareness of risk in the case of earthquakes because they may be infrequent in some areas, which is not the case with flooding or high winds which occur with greater frequency.

Summary
These slide lectures describe ways of considering the vulnerability of settlements and the reduction of risk. Four questions need to be asked:
(i) What are the risks facing communities from natural hazards? These should be established in order of importance.
(ii) How aware are the local population of these risks?
(iii) What local, regional and national resources are available to help reduce these risks?
(iv) What are the local priorities which may override any concern to lessen these risks?
The answers to these questions will clarify the basic issues, as follows:
(i) Whether modification is feasible. If it is, then
(ii) How to achieve this by devising structural techniques to make traditional housing resistant to extreme forces both in their construction and siting. There then remains the all important issue of
(iii) How to implement a housing modification programme with maximum effectiveness and minimum social disturbance.

Finally, it must be emphasized that the primary concern expressed throughout these lectures is the preservation of life with a far lower priority for the protection of property. Low-income houses and settlements can be relatively easily built if they are destroyed or damaged: lives cannot. The authors of these talks hope that architects and planners will recognize the challenge posed by the present scale of disaster casualties and will respond by focussing their creative skills and social concern on reducing the vulnerability of poor families living at risk from natural hazards.

HAZARDS	A	B	C	REMOVAL OF RISK		REDUCTION OF RISK	
				D	E	F	G
(descending order of mortality)	% of total natural disasters	Cause of death	Vulnerability of houses and settlements	Possible solution	Major difficulties	Feasible mitigation measures	Major difficulties
Drought	15%	Malnutrition resulting from lack of food/ water/resistance to simple infections	Overall location relative to food/water supply	Maintain supply of staple foodstuffs/ water	Logistics; market prices	Advance warning of crop failures (ie market price fluctuations in staple foods)	Resources to monitor drought indicators
Tropical cyclones	20%	Drowning/ exposure; injuries sustained when parts of buildings/trees/walls fall on people	Location of settlement adjacent to coastlines	Relocation of communities	Impossible in any general sense (may be possible at local level); location related to occupations and income levels	Cyclone shelters; evacuation policies; shelter breaks; stronger buildings	Economics, logistics, social consequences
Floods	40%	Drowning/ exposure	Location of settlements on low-lying ground in river basins/ estuaries	Relocation of communities	Impossible in any general sense (may be possible at local level); location related to occupations and income levels	Flood control measures; evacuation policies; stronger buildings	Economics, logistics, social consequences
Earthquakes	15%	Asphyxiation and injuries sustained from collapse of buildings	Lack of resistance of construction, shape or siting of house relative to earthquake forces	Relocation of communities	Impossible in any general sense (may be possible at local level); location related to occupations and income levels	Aseismic design; modification of house construction, shape and siting	Strength of local building traditions; economics; social consequences; lack of risk awareness
Other	10%	Various	Various				

2 The Nature of Hazards

1 EARTHQUAKES

Description

To design a house that will resist the forces of a major earthquake, we must first understand what an earthquake is and what happens to the earth during one.

The surface of the earth is composed of large land masses, called plates, which lie under whole oceans and continents, like North or South America. These plates are always moving (although only a few centimetres each year) and in several places they bump into one another. Where the plates meet, one will try to pass over the other. This causes a lot of pressure to build up over a period of years, and sooner or later this pressure will cause something to break deep below the surface. This breakage is an earthquake.

The point on the earth's surface below which the breakage occurs is called the 'epicentre'. The earthquake causes vibrations, known as 'waves', to go out in all directions from the epicentre. There are two types of wave which affect houses: the first make the earth move backwards and forwards along the same line; the second, which travel slower, cause what we call 'shock waves'.

How an earthquake affects a house

When an earthquake strikes and the earth begins to move, the foundations and lower part of the house which are attached to the earth immediately move with it. The roof, however, remains where it is. Gradually the upper part of the house tries to catch up with the lower part, but as it does so the earth moves in the other direction, thus speeding up the movement of the top. As the shock waves hit a wall, different parts of the wall begin to move in opposite directions and the wall will try first to crush itself, then throw itself apart.

The damage caused by an earthquake depends on the height and weight of the walls and the roof. The higher the walls, the greater the speed and force at the top, and thus the greater the damage. Therefore, in an earthquake zone, it is important to build low lightweight walls. Because the roof of the house sits on the walls, the height and weight of the roof must be added to that of the walls. Thus it is extremely important to build light roofs. Under no circumstances should tiles be used.

The force of an earthquake on a wall also pushes the walls into one another. If it pushes on one wall, much of the force and weight is

added to the walls to which that wall is attached. If the earthquake moves parallel to the direction of long walls, only the smaller end walls are likely to be damaged. But if it moves parallel to the short end walls, much greater damage can be expected. The long walls may fall through the entire length of the house and also push in the small end walls. A strong interior wall can help to hold the long walls up.

Shapes of houses

If the earthquake strikes the house at an angle, it will push the walls in opposite directions and the house will appear to twist on its foundations. It is therefore best to build square or rectangular houses to withstand these forces. An 'L'-shaped house is the worst possible design for an earthquake zone. If the site is small and additional living space is required, separate rooms should be built at least one metre apart.

While a square or rectangular-shaped house can best survive the forces of an earthquake, it must be built in a particular way. Since earthquake forces push on walls in opposite directions, it is very important for parallel walls to have equal weight, otherwise the earthquake will push more on the heavier wall and the building will try to twist on its foundations. It is therefore advisable not to have more openings on one side of the house than on the other. For every door or window in one wall there should be an opening of roughly equal size in the opposite parallel wall. It is preferable not to have openings in the small end walls, but if these are necessary, again they should be placed directly opposite one another.

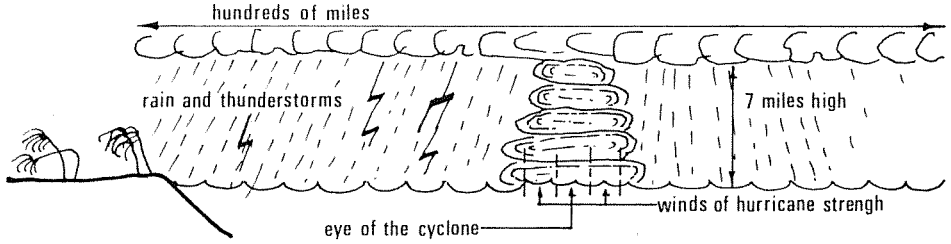
2 CYCLONES/HURRICANES

Description

Cyclones and hurricanes are identical events: they are often called hurricanes in the Northern Hemisphere and cyclones in the Southern Hemisphere. In this section, for simplicity the term 'cyclone' will be used. A cyclone is a tropical storm in which the winds develop extreme force and blow in a counter-clockwise direction in the Northern Hemisphere and clockwise in the Southern Hemisphere around a relatively calm low pressure centre. Cyclone (or hurricane) strength is defined as wind speeds in excess of 73 miles (117km) per hour.

The most severe winds occur in a circular band surrounding the centre or 'eye' of the cyclone. In this band, wind gusts of 120 to 150 miles (192 to 240km) per hour may occur. The eye of a cyclone is normally 10 to 30 miles (16 to 48km) in diameter and the lull in the winds, as the eye passes over the area may last for up to three hours. Wind speeds gradually diminish from the centre to the periphery, but the area affected by these winds is extensive. For example, surface winds of 40 miles (63km) per hour are common more than 100 miles from the centre.

The surface area within a cyclone where the winds will be 73 miles (118km) per hour or more will extend from about 10 miles (16km) to about 30 miles (45km) from the centre. These spiralling winds may rise to as high as 7 miles (11km) above the surface forming clouds that may extend out from the cyclone for hundreds of miles causing rain and thunderstorms over a wide area.



A cyclone's forward movement varies from 5 to 15 miles (8 to 24km) per hour. However, its movement is not constant; it may speed up for several hours, slow down suddenly, or pause without moving for days or even weeks. The reasons for this are not well understood. Cyclones also have very erratic paths, frequently changing direction and occasionally even doing loops.

How cyclones are formed

In order for a cyclone to form there must be a warm sea, above 80°F (26.5°C), and still air. The warm humid air rises, full of water vapour. Its place is taken by air rushing in from the sides and because of the earth's rotation this moving air is given a twist so that the entire system begins to revolve. As the warm moist air rises, it cools and the water vapour in it condenses to form water droplets and falls as rain. This releases a large amount of heat which helps the air ascend even higher. This system can continue to develop over the warm seas as there is a plentiful supply of warm moist air on the surface and cyclones thus become self-sustaining. For this reason they usually begin to lose their strength as soon as they cross over land.

Most damage to structures is caused by the winds of a cyclone, but many deaths are caused by the rain floods which accompany it. A cyclone may drop as much as 24 to 26 inches (600 to 900mm) of rain in a day causing general flooding in low-lying areas and flash floods in certain areas.

Cyclone storm pattern

Usually the storm will last for less than 24 hours with winds of hurricane force blowing for between 6 and 10 hours. The pattern of the wind and rain is important, and is as follows:

(i) There are likely to be thunder showers, heavy rainfall, and gusty winds for most of the 24 hours preceding the arrival of the highest winds and the eye of the storm. The area affected by the

rains will depend on the cloud formation.

(ii) Twelve hours before the eye reaches land, the winds are likely to be in gusts of from 20 to 30 miles (32 to 48km) per hour. These winds will gradually increase to 50 miles (80km) per hour over the next 6 to 8 hours. For the next few hours the wind speed will probably increase by about 10 miles (16km) per hour until it reaches peak force. However, the pattern of each cyclone varies considerably.

(iii) Near the centre of the storm the winds blowing at hurricane strength are likely to last from one to several hours before the eye arrives.

(iv) The approach of the eye will be detected by the sudden decrease in the wind to almost a calm, with virtually clear skies and no rain. This may last for as long as several hours.

(v) Once the eye has passed, the winds on the other side will very quickly increase from a calm to full hurricane force again, this time from the opposite direction.

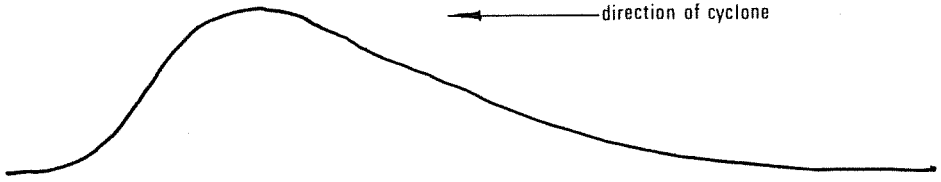
(vi) The decreasing wind pattern as the storm moves on will be the reverse of the increasing pattern that heralded its approach.

(vii) In areas adjacent to, but not directly in, the path of the eye, there will be no calm. The wind will gradually change direction, finally blowing in the opposite direction.

3 STORM SURGES

Description

A storm surge is a large mass of water which rises above the normal level of the sea and is pushed along by a cyclone. It therefore moves in the same direction as the cyclone and not in the direction of the wind. This movement of water creates a front or leading edge which may be many miles across and the high water behind it may extend backwards for many miles. Every cyclone has a storm surge; many are small, but a few in parts of the Bay of Bengal, for example, have been very large. As the diagram shows, a storm surge is more a hump of water than a giant wave; in fact, waves ride on top of it.



In popular usage, storm surges are often called tidal waves, but technically speaking, the term 'tidal wave' only refers to the wave motion of the tides. A storm surge usually moves at the same speed

as the cyclone itself. If the cyclone is moving forward at a speed of 12 miles (19km) per hour the storm surge will probably be moving at the same speed.

Causes

In a cyclone, the rise in the level of the sea is caused by two factors. First, the low air pressure in the eye of the cyclone which causes the water to rise upwards; the water level in the eye is higher than the normal sea level on the periphery and is maintained by the low pressure in the eye. Second, the friction of the wind on the water; winds blowing at hurricane strength tend to pile up the water.

The effect on the coast of this water build-up is largely determined by other factors. These include:

(i) The forward speed of the cyclone. The faster it moves, the more it tends to heap up water on the shoreline.

(ii) The angle of the sea bed near the shore. A long shallow sea bed near the shore prevents the piled-up water from returning to the sea, causing the water to surge over the shoreline.

(iii) The angle at which the cyclone strikes the coast. A cyclone which strikes the coast head on (at an angle of 90°) will produce more of a surge than one which strikes on a diagonal.

(iv) The shape of the coastline. A concave coastline, having large bays, tends to trap the water and accentuate a surge.

(v) The height of the normal tide. If the cyclone comes at high tide, the surge will ride that much higher on the coastline.

The height of a storm surge is determined by the same factors which cause its formation.

Effects of a storm surge

In addition to the risks of inundation by the rise in sea level, the effect of breaking waves on top of the surge can also be devastating. A storm surge will move inland until it reaches a point where the ground is as high above sea level as the top of the surge. Once it has stopped moving forward, it will begin to retreat to the sea. But its retreat may be slowed by the winds so that all the water is not likely to leave the area until the eye has passed; it may last from three to five hours in some places.

A storm surge can damage or destroy a house in many different ways.

(i) The speed and pressure of the water place great stress on the walls.

(ii) The currents and turbulence associated with the surge may destroy the foundations or walls.

(iii) The debris carried along by it, such as uprooted trees, fences and parts of houses will cause further damage.

(iv) Damage can be caused by water lifting up parts of a structure so that they float. This happens even to brick and cement structures.

Acknowledgements

The material in this section has been adapted from the following sources:

Earthquakes: from *Instructors' Manual*, INTERTECT, Box 10502, Dallas, Texas, USA.

Cyclones/hurricanes, storm surges: from the Sri Lanka Cyclone Study Technical Report No 7, *Sri Lanka Handbook*, edited by Everett M Ressler of INTERTECT working with PADCO (Planning and Development Collaborative International), under the technical assistance programme of UNDP. Published by the Ministry of Local Government, Housing and Construction, Government of Sri Lanka.

3 Slide Lecture Commentaries

Part 1 DEFINING AN APPROACH FOR DESIGNERS
by Ian Davis Dip Arch, Department of Architecture,
Oxford Polytechnic, UK

Slide 1
Title

This slide lecture introduces a series of talks which will deal with various aspects of human settlements which are prone to natural disasters. The impact of such disasters—earthquakes, floods and high winds—will be discussed and the scale and nature of aid and assistance both from outside and from within the affected area will be considered. Lastly, eight basic steps are suggested for any designer who may be working in such areas.

Slide 2
Earthquake, China

In 1976 the worst earthquake disaster of the last 400 years occurred in Tangshan, China, when 242,000 people died and 164,000 were seriously injured. The same year there were earthquakes in Turkey, Italy and the Philippines; hurricanes and typhoons devastated parts of the United States of America, Mexico and Japan; there were floods in Australia.

Although 1976 was an extreme year, it occurred within a broad trend of increases in casualties and damage. This trend is not due to any increase in the number of earthquakes, cyclones and other natural disasters, but rather to the vulnerability of human settlements to such hazards in their method of construction, siting and above all to the processes of population growth and rapid urbanization. To appreciate the scale of disaster casualties, during the ten-year period 1965-1975 deaths alone were equivalent to a city the size of Calcutta, while those affected were approximately twice the population of the United States of America.

Slide 3
Diagram: disaster assistance

A consequence of the widely publicized deaths, casualties and physical damage has been the growth of international concern. But it is important to note that the majority of financial aid does not flow from international voluntary organizations, or from foreign governments, but from within the affected countries themselves. For the years 1965 to 1975—the last period for which aid statistics were published—the proportion was $42 of internal aid for every dollar of external aid.

Numerous countries provide disaster assistance and large national and international agencies have been formed. There is also a special United Nations agency—UNDRO—to co-ordinate disaster relief and assist with mitigation measures.

Slide 4
Chart: gaps in our knowledge

Unfortunately the increasing involvement by outside agencies has yet to be matched by a corresponding concern to uncover essential facts about disasters. There are large gaps in our knowledge partly as a result of insufficient research and partly because the funding agencies—which spend vast sums of money on disaster aid—are only just beginning to recognize the need to devote funds to evaluating their assistance programmes.

Out of the total financial aid from all sources—some $8.8 thousand million between 1965 and 1975—it is unlikely that more than a minute fraction of 1% was devoted to research. We still know very little about the best way of assessing survivors' needs, the most effective ways of providing assistance (whether it be in cash or goods) or the long-term consequences of disaster assistance programmes.

Slide 5
Building, San Francisco

We may know why buildings collapse, but our knowledge is still primitive on appropriate ways of modifying their construction and siting them in less vulnerable locations. In the past, architects, planners and engineers have been involved in such modifications only in the case of expensive building types, for example hotels, factories or office buildings, such as this office building in San Francisco. Here we see triangulated cross-bracing being used as a protective measure against earthquake forces. In such cases owners are concerned to protect their investment, and the insurance companies reduce their premiums for houses built to aseismic standards.

Therefore such buildings are designed and built to comply with bye-law codes intended to protect them and their occupants against the abnormal forces encountered in earthquakes, high winds or floods. Not so the humble rural or urban dwelling.

Slide 6
Damaged house, Belize

Here is a timber house which was badly damaged in the hurricane which devastated Belize in the Caribbean in 1961. It is houses similar to this —low-income and probably outside bureaucratic controls—which are the primary cause of casualties.

The main purpose of this slide lecture series is to introduce these issues and to stress the importance of designers moving down the scale from the large investment project to the protection of the

occupants of small dwellings against the forces encountered in a disaster. This re-education is directed to students and practitioners—architects, engineers and planners—all of whom may work in countries which are vulnerable to natural hazards.

Slide 7
Protected housing, St Vincent

Incorporating adequate resistance against high winds into housing need not be expensive. The UK Building Research Establishment, which designed this house for low-income families in St Vincent, has shown that considerable savings can be achieved by good design and careful attention to connections.

The structural frame is of hardwood with galvanized brackets rigidly interconnecting all members. The foundations have to be strong enough to resist the high uplift forces in a hurricane, and special attention is also paid to the fixing details for the roof sheeting and the purlin/rafter interconnections, particularly round the perimeter of the roof. The design allows for variations in the size of the house, foundations and substructure as well as of the wall materials, and presupposes that builders have some skills which may not always be the case.

Slide 8
Chart: research conclusions

Some progress has been made in the past decade in research into post-disaster housing, and three broad conclusions have emerged. First, the capacity of disaster survivors to help themselves and satisfy their own needs. Evidence has shown that they are normally able to provide their own shelter.

Second, the need for external agencies and national and local governments to concentrate their resources of cash and manpower on mitigation measures. These will vary from small-scale activities, such as planting shelterbreaks in areas subject to high winds, up to vast river engineering projects for the purpose of flood control. Third, the need for post-disaster reconstruction programmes to implement mitigation measures both as regards the siting and construction of houses to minimize damage and save lives.

Slide 9
Map: incidence of disasters

We will now look at the context of natural disasters and suggest a basic approach for designers. From this map it can be seen that the majority of all major disasters occur in the developing countries, the exception being floods and high winds in North America. It has been estimated that over 90% of all disaster deaths are in the poor countries of the world. This situation is due to the direct correlation between casualties and the type of low-cost dwelling—its siting, shape and the quality of materials and skills used to build it.

Slide 10
Vulnerability diagram

As I have said earlier, this situation is not the result of any measurable increase in the incidence of the hazards themselves, but rather the result of the increased vulnerability of human settlements. This diagram brings together the factors which make up vulnerability. Once the relationship between living conditions and the cause of those conditions has been recognized, then the implications for a wide variety of individuals and groups becomes clear. This brings us to the need to define roles, a subject which we return to time and again in this series.

Slide 11
Relief officials, Guatemala

The two primary roles relate to the survivors and those who seek to help them. This picture shows the Oxfam Field Director, Reggie Norton, talking to a group of people in the immediate aftermath of the Guatemalan earthquake of 1976. This contact is a vital part of the post-disaster process, when the needs of survivors are made known to those who may have the resources to help. Such resources may include money, manpower and access to government officials and expertise. Frequently aid officials make the basic error of relying on preconceptions of what they think the survivors need instead of making a serious attempt to find out real needs, which may be very different from wants.

Slide 12
Chart: vital processes

The evaluations of post-disaster housing that have been conducted show that new housing provided by local architects, engineers and builders, as well as housing built by groups from distant countries has often been unsuccessful because some very basic factors were ignored by decision makers. The correct design approach is outlined in these eight vital steps.

They form a continuous process which begins with understanding the problem, next devising solutions and then evaluating their success or failure. The steps listed are all essential in the construction of new houses in disaster-prone environments, for post-disaster constructions and for modifying existing houses to make them more resistant to the forces encountered in high winds, floods or earthquakes. We will consider these steps in turn.

Slide 13
Hazards to one location

First, the nature of the hazard. It is essential for any designer to be aware of the types of hazard which may threaten the area in which he is working. This map of earthquake vulnerability was prepared by Turkish earthquake engineers. The information on these levels of risk has been converted into building codes so that, for example, structures are permitted in the capital city, Ankara (a safer zone), which would not be allowed in the more

dangerous site of Istanbul where aseismic construction is required. This information has then to be coupled with an examination of local house types if any attempt is to be made to assist the local population to strengthen their homes against earthquakes. Similar maps can be prepared for high winds and flood risk, and when overlaid composite hazards can be understood. Some areas may be subject to multiple hazards, Jamaica for example. Architects, engineers and planners need to know the force, frequency, characteristics of these hazards, and then design techniques to resist them.

Slide 14
Rural house, Turkey

The second step is to understand the normal living patterns of the community. Whilst working on a project to modify rural housing in Turkey to make it resistant to earthquakes, government officials have suggested that the most important change should be to do away with the heavy flat earth roof and substitute a pitched tile roof. On the face of it this seems eminently sensible. However, further thought and field observation reveal that the flat roof is a response to a highly complex set of social factors, and to change the roof would significantly and detrimentally affect the lifestyle of the house occupants.

Slide 15
Functions of flat roof, Turkey

First, the flat roof has specific functions. In hill villages it may be the only flat site for winnowing corn or preparing food safe from the animals which wander through the village. Second, it is a response to local climate. In a region with wide variations in climate, the heavy insulation of the roof is very effective against heat in summer and cold in winter. It is also a comfortable place to sleep in summer.

Third, it is a response to local materials and skills. There may not be a local sawmill or carpenters capable of making a secure roof truss. The roof seen here uses the plentiful supply of local poplar wood for beams, which are covered with brushwood and mud, a building process that does not require carpentry skills. Finally, it is a response to local income levels. It is most unlikely that the occupants of this house could have afforded the cost of clay tiles for a pitched roof.

Slide 16
Thatched house, India

The third step grows naturally out of an awareness of local living patterns; it is the understanding of local house forms. If we take this thatched village dwelling in Andhra Pradesh, India, which collapsed in the cyclone of 1977, and want to suggest modifications to its construction, we need to know a number of facts: Who lives in the house and how are the various parts used? Who builds houses in this village—owners or trained carpenters and thatchers? What are the local economics of housing? How much do

people pay for their homes relative to their incomes, and what materials are locally available? Finally, what priority does the community attach to shelter relative to other matters—land ownership, or the possession of animals, for example?

Slide 17
Rural housing, Guatemala

We now turn to the question of local awareness of disasters. It is vital that designers know how far a local community is aware of any risk, and also what priority they attach to such hazards. The families that live on the ravines of Guatemala city live in a highly dangerous location which is subject to landslides, earthquakes and flash floods. But—and this is the important point—it is the only available land close to their limited work opportunities near the city centre with its bus terminals and central markets. For the urban poor, their everyday fight for survival may mean living with numerous risks, and the risk of a possible disaster at some future date will probably weigh lightly against more pressing issues.

Slide 18
Western Samoa

Here is another example—from western Samoa. The families who live beside river estuaries or directly on the coast, such as this family, are in constant danger from flooding and cyclones. But their entire livelihood, probably derived from fishing, depends on their living close to water. To expect such families to move to a safe location—assuming one exists—could be unrealistic economically, quite apart from the social disruption of compulsory evacuation. Officials and designers need to assess the degree of local awareness of disaster risk, for this is an essential prerequisite to securing local support for any resiting or house modification programme.

Slide 19
Metro Manila

Closely related to the awareness of risk by the local population is the key factor—the actual vulnerability of any house or settlement to an earthquake, flood or high winds. The technical name for the process of analysing this risk is 'vulnerability mapping'. Analysis of risk is carried out at various scales, from the vast *macro* or regional scale to the small-scale siting of individual buildings in a given area.

A vulnerability analysis was undertaken by UNDRO as part of a study of the total vulnerability of Metro Manila in the Philippines to high winds, floods, tsunami and earthquakes. The area is gridded and a mathematical risk factor is calculated for each grid square as a composite factor combining the risks from various hazards. This simplified version of the map conveys the degrees of vulnerability that Metro Manila is exposed to:
White areas: indicate unrestricted development, since this is the

safest zone.
Red squares: (the most vulnerable): open space only is recommended.
Brown squares: no high or low-rise buildings, public places or industries are allowed.
Green squares: no high-rise buildings, industries or services vital to the community.
Black squares: no industries.
The process of vulnerability mapping is applicable for planning policies relating to new building work. As yet, the technique is largely irrelevant to existing settlements of low-income families.

Slide 20
Modification manual

By this stage the designer should have an understanding of normal house and settlement patterns and the extreme conditions which may occur only once in a lifetime. His next task is to fuse this knowledge together and make suggestions for the modification of a house or the siting of a new settlement. In making such proposals he will be weighing the everyday priorities which may be in sharp conflict with the need to adopt mitigation measures. These modification proposals should be in the form of manuals for use at different levels.

The one shown here, *How to Build a Safer House*, was prepared by Oxfam/World Neighbors for use by local builders in a reconstruction project in Guatemala. In putting forward his suggestions the designer will bear in mind the danger of advocating solutions, such as the Turkish pitched roof, which fundamentally change social patterns. He will also have to be constantly aware of the economic aspects. He may also suggest planning measures affecting the region as a whole, such as flood control measures or shelterbreaks along cyclone prone coastal areas.

Slide 21
Training class, Guatemala

It would be easy to stop at this point. However, two vital processes still remain. The first is implementation and the second evaluation. First, let us consider implementation. Here is a group of village builders in Guatemala being taught safe building techniques by a building adviser from Oxfam/World Neighbors. The application of safe housing techniques depends on total trust between teacher and taught as well as knowledge of how to communicate ideas. There is no point in producing plans for builders who cannot understand plans, or written instructions for illiterate carpenters.

Too often officials who are remote from the community concerned—both geographically and culturally—assume that once a clear safe proposal has been accepted, all that is needed is a manual or bye-law to effect the necessary changes. This is to ignore the basic conservatism of all local builders, as well as the vital need to educate people for quite abnormal risks which they may never have experienced.

Slide 22
Cyclone resistant housing

After implementation there is the all-important process of evaluation. An evaluation of this housing in India has revealed that the safe construction techniques have not been fully accepted by the local population. Ideally, officials, designers and builders need to return to the new housing one, two or possibly five years after completion to look at what has happened to each house and, very important, to listen to what the occupants have to say.

In practice, this very rarely occurs for a number of reasons—the cost involved, the high turnover of staff in agencies and their organizational structure in which administrators are frequently divorced from their field staff. The result is that the man who actually builds the house or lives in it may have little or no contact with those who conceived it in the first place. Currently a method for evaluating housing is being developed. Some key references are included in the manual accompanying these talks.

Slide 23
Aluminium framed structure

If a designer follows the eight basic steps described, many of the costly errors that have occurred in past reconstruction operations will be avoided. One fundamental mistake, the concept of a universal shelter, has been abandoned by many agencies, although many designers and some manufacturers retain a fascination with the subject. This aluminium framed structure was devised by a western relief agency to meet the assumed needs of disaster survivors. Inevitably, the complex variables of housing were over-simplified.

Major differences can occur from village to village even in localities which are very close to one another. These variables include available building materials and techniques, house forms and kinship patterns, all of which must be identified at the outset. The particular universal solution shown here was dropped by the agency concerned as a result of lessons learned from recent disasters where strong emphasis has been placed on the indigenous approach to shelter needs.

Slide 24
Andhra Pradesh poster

It must be recognized that the designer is unlikely to become a total designer concerned with the whole package from A to Z. His role will probably be concerned with designing or utilizing components, some of which may be unfamiliar locally; advising on the safe siting of future housing and, of course, on safe indigenous construction techniques possibly implemented within major upgrading of squatter settlements. This poster was used in Andhra Pradesh by a group of agencies to promote safe building techniques to withstand cyclones, and illustrates the importance of communicating any new technique to the local community in terms that will be fully understood.

To summarise: in this talk we have put natural disasters into context and have suggested a possible approach for designers. In the talks which follow we shall be emphasizing, first, that the primary resource for recovery is the survivors themselves; second, that any real contribution to the prevention of future deaths and damage to buildings can only be made with the fullest understanding of the *normal* local situation; and third, that the survivors must be totally involved in every stage of *their* reconstruction.

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PART 2 MITIGATION MEASURES

by Ken Westgate BSc MSc; and
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Slide 1
Title

Disaster mitigation is the term used to describe practical measures to reduce the long-term vulnerability of populations and settlements to natural disasters. Historically, mitigation measures have consisted of one or other of two courses of action—shifting development away from the existing hazardous areas to safer locations, or employing a variety of structural measures to resist more effectively the worst effects of disasters when they occur.

Slide 2
Thames barrage

The River Thames barrage, pictured here, is a good example of a structural measure. Because the width of the Thames is becoming narrower owing to the gradual encroachment of urban development on to its banks, severe flooding in London has become a distinct possibility. By building a barrage across the mouth of the Thames and developing a sophisticated early warning system, it is hoped that any future flood can be reduced in magnitude before it reaches the city or perhaps be eliminated altogether.

Slide 3
Ganges delta

Bangladesh also experiences flood problems, but they are more frequent and of a much greater magnitude. In the Ganges delta there are many islands where the land surface does not rise more than 20ft above sea level. This island, like many others, is open to storm surges from the sea during cyclones and to flooding from the great rivers that dissect Bangladesh. Protective measures such as barrages linking islands across the delta were begun, but because of the cost and the lack of technical skills, most of them remain incomplete.

On a larger scale, the use of embankments along the major rivers has been tried and the slopes of river banks afforested to reduce the run-off of surface water into the rivers after rain. But many of these embankments were breached during the 1970 cyclone with catastrophic results. Why, then, hasn't the vulnerability of the Ganges delta, with its far greater flood potential than the Thames, been seen as a vital priority? Part of the answer is to be found in prevailing assumptions about vulnerability.

Slide 4
Apartment block, Managua

Vulnerability is not merely, as some experts suggest, a function of the frequency and magnitude of the potential flood or earthquake multiplied by the probability of damage. Damage is most frequently expressed in monetary terms. By this criterion apartment blocks, like this one in Managua, Nicaragua, damaged and

unusable due to the 1972 earthquake, would be the most vulnerable because of their high capital cost. In most natural disasters observed over the past decade, it has been the poorer sections of the community which have suffered the greatest devastation.

Slide 5
Squatter housing, Guatemala City

The 1976 Guatemalan earthquake left the centre of Guatemala City relatively unaffected, whereas out on the periphery, among the squatter settlements on the ravine sides, the devastation was massive and the cost in human suffering and absolute loss was high. This is true vulnerability. Such vulnerability can also be intensified where buildings are not constructed according to anti-seismic or anti-flood criteria.

Because low-income dwellings are the homes of the poor, their form is determined primarily by the materials which are immediately available. These houses are of flimsy lightweight construction built of materials salvaged from city refuse dumps. It is no wonder that 90 per cent of all earthquake victims die in low-income housing.

Slide 6
City centre, Managua

Some entire cities, such as Managua, suffer from permanent vulnerability. The empty area in the foreground of this slide was once the central business district, which was destroyed in 1972. Earthquakes were not new to the citizens of Managua; three times in the past eighty-seven years the city had been subjected to earthquake activity, and forty-one years earlier—that is within living memory—it had been devastated. This is not merely bad luck or coincidence. Managua is built over a very active fault system.

Unfortunately, it is also a very large city and difficult to relocate. Its vulnerability is, therefore, permanent and the only way to combat future earthquake damage is to modify existing designs and structures and impose tight controls on new development. Some entire countries suffer from the same problem.

Slide 7
Coastal settlement, Bahamas

This coastal settlement in the Bahamas archipelago is courting disaster of a different kind. Hurricanes occur frequently during the summer months and the settlement is exposed to the full force of these great storms. Yet nowhere in the Bahamas does land rise above 200ft and most of the islands are considerably flatter. They are all part of an eroded limestone shelf, and inland the soil layer is almost non-existent, the vegetation scrublike and the water table very high and brackish.

The most equable sites are on slightly raised ridges along the coast with good access to the sea for fishing and with the only good soil for farming. So there is very little choice and the settlement is a highly vulnerable one.

Slide 8
Village, eastern Turkey

Vulnerability of settlements is also reflected in their planning. Many settlements are not planned in the conventional Western sense. Rather they develop according to custom or local cultural and economic criteria. At first sight this village in Turkey seems to have no planning logic. The buildings are very close together; they contain many additions in the form of store rooms or animal houses, and the streets that wind between them are narrow and tortuous.

Such a village is very vulnerable to, say, an earthquake. The buildings are so close together that they would fall on top of one another and there is little open space to which people can run to avoid falling masonry.

Slide 9
Vulnerability map, Mexico

Identifying the vulnerability of a region or country is an important step in the mitigation of future disaster. From this identification a map can be prepared which sets down all the factors which go to create vulnerability. One type of map, for Mexico, is illustrated here. It shows those areas which, based on historical and scientific data, are vulnerable to different types of natural disaster. This is important for identifying the areas to receive priority attention.

From a map such as this, smaller regional maps can be produced which contain additional information relevant to vulnerability—urban areas, areas of low-income housing, location of specific economic activity, important communications networks, and so on. With this information mitigation strategies can be devised to deal with the vulnerable areas.

Slide 10
Dam, Uganda

The most extreme and comprehensive set of mitigation measures is one which aims at preventing a disaster at some future date. A dam, such as the one pictured here in Uganda, or a series of dams, together with the regulation of stream channels and the zoning of land use on a flood plain, may prevent the occurrence of a flood of disaster proportions which is only expected to occur once in every hundred years. Such measures are really integrated development measures, because they aim not only to prevent flooding but also to conserve water, make channels more navigable and generally to improve the use of the river valley or flood plain.

Slide 11
Populated flood plain, Bangladesh

Comprehensive structural measures of this scale create their own problems. This slide is of a crowded settlement in one of the Bangladesh flood plains. An inevitable consequence of

making an area like this safer and more fertile due to better irrigation, actually encourages people to move into the area in ever-increasing numbers despite land-use regulations.

This means that they present a sitting target for the unforeseen flood that occurs perhaps once in five hundred years, which the flood control measures were never designed to cope with. Such comprehensive measures present two major problems: first, they may be prohibitively expensive for many Third World countries and second, the local population are no longer involved in the protection of their settlements.

Slide 12
Risk zone diagram, Nagoya, Japan

To return to the problem of urban areas—these can, of course, be redesigned if sections are destroyed in a disaster. The tools available to the planner are: scientific analysis, historical records and the kind of vulnerability mapping mentioned earlier. Soon after a cyclone devastated the port of Nagoya, Japan in 1959 the city authorities divided the region into the zones you see here. A different building code was given to each zone according to the level of risk and this was applied both during the immediate post-disaster reconstruction period and also to longer term development.

Slide 13
Old Lice, Turkey

At the opposite end of the scale from urban centres like Nagoya are small rural settlements. This was the town of Lice in Eastern Turkey which was destroyed by an earthquake in 1975. It was built in the foothills of a low mountain range, south-facing and sheltered, giving full access to the flat farming land that stretched out before it. Destruction of this kind can provide the impetus for some kind of regulation or relocation. Nagoya, as a partially-destroyed urban area and port, based its new siting regulations on the existing, undestroyed settled areas in order that the city should retain its functional usefulness. In the case of small rural settlements where the pressure on land may not be so great, more options are available. In this case, the Turkish government had no hesitation in relocating the settlement.

Slide 14
New Lice, Turkey

The rationale for planning the new town of Lice, illustrated here, is clear. The site of the old town was dangerous, rising as it did vertically into the hills and prone to landslides. The solution adopted by the Turkish government was to build a new town on the agricultural plain which stretched out in front of the destroyed settlement. Using earthquake-resistant prefabricated structures and better spacing between dwellings, the new town of Lice was built on flat land.

Unfortunately such policies often run counter to local needs and aspirations. Reconstruction on the plain exposed the new settlement

to the northerly winds from which it was previously protected by the steep hillside; it also reduced the amount of farming land available to the community. The factory produced houses, too, disregarded social and economic requirements, such as the size of room and provision of space for quartering animals.

Slide 15
Rebuilt Skopje, Yugoslavia

In both existing and new settlements careful planning and siting of buildings can only be successful in mitigating potential disaster if it is reinforced by legislation. The new city of Skopje, pictured here, was developed after an earthquake destroyed the city in 1963. It emerged out of a conglomeration of internationally produced plans and embodies strict regulations controlling new structures.

These regulations govern the height and horizontal shape of buildings to resist earthquake vibrations, the use of decorative elements and the spacing of buildings. Other regulations govern internal building elements, such as the provision of an adequate number of staircases and access to apartment blocks from opposite sides.

Slide 16
Damaged buildings, Gemona, Italy

Buildings which have survived intact and buildings which have been badly damaged in a disaster give rise to special problems in creating a disaster-resistant settlement. These old buildings in the Italian town of Gemona were damaged during the Friuli earthquake of 1976. When the town was reconstructed anti-seismic criteria were embodied in performance codes and damaged buildings were repaired only if they could be made to withstand future earthquake shocks.

The Friuli earthquake affected several historic towns with a flourishing tourist industry. The authorities therefore had to shore up damaged buildings before carrying out detailed restoration work incorporating aseismic measures. Tragically, a further earthquake in September of the same year totally destroyed all remaining buildings of historic interest.

Slide 17
Clayton building, Wellington, NZ

In the past, architects, planners and engineers have been involved in designing with aseismic techniques only in industrialized societies. This government office building under construction in Wellington, New Zealand, is situated near an active fault in a high-risk seismic zone. It will rise to four storeys and will be the first building in the world to be mounted on rubber bearings with lead energy absorbers to resist and absorb the energy produced by a major earthquake. This is the ultimate in sophisticated technology. It is important that both the principles and the technology fit the environment in which they are to be applied.

Slide 18
High-rise building, Tokyo

Japan is another industrialized country which is very prone to earthquakes. Over the years building codes and principles of design have been developed which, allied to traditional resources and knowledge, create a much safer environment within the social, economic and cultural context of the country. This office block in Tokyo is forty-three storeys high, steel-framed and with belt girders fashioned after bamboo joints at the eighth, twenty-first, thirty-fifth and forty-third floors. The building is also tapered outwards at the base to provide extra stability.

Slide 19
Internal detail, cross-bracing

No-one—in the most severe earthquake—will be killed in the Japanese building. Virtually all deaths in earthquakes occur when the unsafe homes of poor families collapse. Applying the identical principles to those used in the office building, small houses such as this one in Guatemala can be built to withstand earthquakes. In this slide several key features which make the house safe can be seen. First, a lightweight roof in place of heavy clay tiles; second, timber cross-bracing which is part of a complete framed house which will resist the powerful horizontal forces exerted in an earthquake; and third, the adobe blocks have been inserted into the frame and held in position by barbed wire to prevent them from falling inwards and crushing people.

Slide 20
Construction of roof

The new house resembles the traditional adobe house as closely as possible despite these important changes. The key factor is that a simple low technology constructional system has been introduced which is capable of being built by local builders and carpenters out of locally available materials. The building of these model houses in Guatemala was an opportunity to explain the techniques to local craftsmen. Proof of the success of this housing improvement programme is that four years later families are attempting to build in this new way without any help from Oxfam or other development agencies.

Slide 21
Squatter settlements, Lima, Peru

As we attempt to develop mitigation solutions for disaster-prone areas, it is worth considering an important fact about urban areas in the Third World. In these environments, the planned sector is decreasing while the unplanned, informal, low-income sector is increasing rapidly. Squatter settlements such as the one shown here set on an unstable hillside overlooking Lima, are frequently outside planning and building codes, which are in any event expensive to enforce. Therefore such communities are in danger of remaining outside the influence of official mitigation measures which could save both lives and property. This reality must be faced very squarely and creative ideas are needed to devise community based mitigation measures such as the Guatemalan house project which can be operated by the local population with the minimum of outside dependence.

Slide 22
Flooding near Trinidad, Bolivia

Extensive flooding is an annual hazard in the low-lying river swamps north of the Andes in Bolivia. Along the river banks very poor families subsist by fishing or planting their meagre crops on isolated patches of raised ground. A community based mitigation policy was introduced in 1974 by a local group who asked the local families whether they would be prepared to move their entire community to an area 100 miles away where the water table was lower and where there was less risk from flooding. They were unanimous in agreeing to leave their dangerous site and have now established a new community with some external support.

Slide 23
Cordon around centre of Managua

This barbed wire cordon illustrates a vital principle: there must be a willingness on the part of both the national government and international aid agencies to co-operate with, and even more important, learn from, the people whom mitigation measures are designed to serve. Unfortunately, for a variety of motives this precept is often ignored as will be seen from this and the following example.

The city centre of Managua was completely cordoned off and guarded after the earthquake of 1972 on the pretext that this would prevent looting. The former residents were forcibly expelled to nearby towns which placed considerable strain on their resources. All building activity was frozen while government planners devised methods for reconstructing a new safer city. Until the revolution of 1979 the former residents were not allowed back to their homes and did not participate in any way in the reconstruction of their city.

Slide 24
Prefabricated housing, Turkey

Lastly, here is a cautionary tale of a group of houses in eastern Turkey. The earthquake mitigation policy of the Government was to move the vulnerable population from their hillside homes into these new houses designed and sited to resist earthquakes. The inhabitants preferred the risk of a possible future earthquake and rebuilt their homes in the traditional unsafe manner. By doing this they showed very clearly that they preferred the risk of possible death or injury in an earthquake to the security of living in houses which were unsuited to their lifestyle and built without their co-operation. The lessons from this are very clear:

1 Work with people at every stage in developing a mitigation policy.
2 Introduce very gradually changes which respect local traditions.

3 Recognize that the perception of risk is a relative matter and that mitigation measures may weigh very lightly in comparison with normal survival needs, which are critical for the very poor.

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PART 3 SIMPLE TECHNIQUES FOR MAKING ADOBE HOUSES MORE EARTHQUAKE RESISTANT

by Everett M Ressler, INTERTECT, Dallas, Texas, USA

Slide 1
Title

Adobe is a building material which is widely used in the earthquake-prone regions of the Third World. It consists of sun-dried mud, formed into blocks, and sometimes mixed with a stablizing agent such as straw, ash or animal dung.

Slide 2
Damaged houses, Guatemala

This is an aerial view of San Martín, Guatemala, after the earthquake of 4 February 1976, in which more than 2,900 people were killed and the total housing stock was destroyed or severely damaged. This situation is often repeated in developing countries which are prone to earthquakes; for example, Chile, Nicaragua and Peru in South America; Iran and Turkey in the Middle East; Algeria and Morocco in North Africa; and Afghanistan, India and Pakistan in the Far East.

The statistics are sobering, particularly when it is realized that 95% of the fatalities occur when small unsafe houses collapse. It is estimated that 470,000 people in the developing countries will die in earthquakes alone in the twenty-five years between 1975 and the year 2000.

Slide 3
Destroyed homes, Guatemala

Analysis of past earthquakes reveals that the single family residence is the most vulnerable to damage and the most lethal. As illustrated in this street scene from San Martín, traditional construction made these homes vulnerable not to partial damage but to total collapse. The earthquake-prone regions of the world are well known and therefore earthquakes cannot be considered as unexpected natural phenomena against which nothing can be done to mitigate damage and to protect life. The extent of damage and loss of life depends on whether houses and other buildings are constructed to withstand earthquake forces.

Slide 4
House of adobe blocks

The majority of people in the earthquake-prone regions of the developing nations live in houses constructed of earthen walls—these may be of adobe, rammed earth, or field rock with mud mortar. These materials will continue to be used as primary building materials for decades; in fact, their use in house construction is increasing. This talk singles out adobe construction, such as is shown here, because it is the most commonly used of the materials mentioned. Adobe continues to be used for a variety of reasons, in particular availability, cost, ease of production, and because it provides better climatic protection than many of the alternatives.

Slide 5
Timber framed house

In this slide, an adobe house is being constructed using traditional skills but incorporating seismic-resistant principles such as cross-bracing. The key to safe housing is the incorporation of earthquake-resistant construction techniques into the normal building process. This means understanding local building materials, the variety of house forms in a given area together with local skills and traditions. If adobe is the most widely used building material, then the goal must be to seek ways of improving the performance of adobe houses.

Construction of damage-proof houses is not economic for the majority of the population, but adobe houses can and should be constructed in such a way that, although they may be damaged, they do not collapse causing injury or death. Damaged houses can be repaired.

Slide 6
Collapsed building

The extent to which an adobe house is prone to collapse in an earthquake depends on how the adobe is used. The use of an earthen building material does not automatically mean that the building is liable to collapse; nor does the use of concrete make a structure inherently earthquake-resistant. The collapse of this new steel-reinforced concrete building in Tecpán, Guatemala illustrates the point.

The purpose of this talk is to illustrate simple construction techniques which can be used to make single-family adobe houses more earthquake resistant. The principles described are general but it should be clearly understood that they must be adapted to the normal building process of the area in which they are applied. The illustrations which follow have been taken from educational material produced in Spanish for community craftsmen in Guatemala.

Slide 7
Diagram: building on slopes

First, the siting of a house plays an extremely important part in determining its safety. Flat, solid ground is obviously the ideal choice, but often this is not available. In selecting a site the aim is to ensure that the house is on firm soil which is not prone to slide or to be inundated by an earthquake-induced landslide or rock fall. The following rules of thumb for siting may appear obvious but are frequently disregarded: it is dangerous to build on the bumpy ground of a former landslide, on the edge of a cliff or a steep hillside, near landslide cracks, or on hillside land where trees are tilted. Tilting trees may indicate that the site is a former landslide.

Slide 8
Diagram: houses on a slope

However, if houses have to be built on a hillside, there are several principles to bear in mind. First, they should not be built with the downhill wall taller than the uphill wall, as is shown in the upper part of the slide; the difference in mass of the two walls will make the house prone to damage in an earthquake. Second, houses should not be constructed with one wall against the embankment as ground movement will cause the house to collapse. And third, houses should not be built on made-up ground which will certainly shift in an earthquake.

If a house is to be built on a hillside, it should be built on a levelled area, not including made-up ground, with adequate space between the embankment and the walls. Steep embankments of dirt should be terraced to minimize erosion and to prevent the bank from collapsing against the house.

Slide 9
Village housing, eastern Turkey

Here we see village housing in a seismic area of eastern Turkey which is poorly sited for a different reason. These houses would almost certainly be destroyed in an earthquake due to their close proximity to one another and unsafe construction in unreinforced adobe. Such vulnerability is of course accentuated when houses are built not on flat sites such as this, but on steep hillsides outside cities in Third World countries because the inhabitants cannot afford safer sites. If the authorities designate locations as unsafe, then they must provide safer sites at a cost which the displaced inhabitants can afford.

Slide 10
Diagram: spacing of dwellings

There is often a tendency in urban areas to build structures against one another. This should be avoided in earthquake-prone regions. Each building has a different shape, weight and design. During an earthquake these factors cause buildings to move and respond in different ways, which results in the buildings destroying one another, often with the smaller ones suffering the greater damage. This is also true of walls attached to structures, such as courtyard walls. Thus, a space should be left between buildings, and between buildings and walls.

Slide 11
Diagram: shape of buildings

The shape of a building is also a critical factor. Square houses are best because all wall masses are equal; one wall is less likely to destroy another. Although rectangular houses are not as well-balanced as square houses, they are generally acceptable. It is the L-shaped house which poses the greatest danger. Ground movement will cause the short walls to respond differently from the much longer walls. Hence, the house will not respond as a unit but will tend to twist, often resulting in collapse of the structure. For this reason, L-shaped houses should not be encouraged in earthquake-prone regions. If this shape is adopted, two independent buildings should be constructed with no common walls, as illustrated

at the bottom of the slide. This principle also applies to additions to the building.

Slide 12
Diagram: height of rooms

Another obvious consideration is the height of the walls. Walls should be constructed to provide a reasonable ceiling height of from 2100mm x 2400mm but not more. This is particularly important in traditional adobe construction because of the relatively weak bonding strength of the adobe mud mortar joints. The higher the wall, the more likely it is that any ground movement will cause the wall to collapse.

Slide 13
Diagram: vertical corner posts

Usually adobe houses are constructed entirely of mud brick with no vertical support columns. The roof rafters rest directly on the mud brick walls. This is true not only of Guatemala but also of almost all traditional earthen houses in the Middle East, north Africa and Asia. During an earthquake, the movement and momentum of the roof, resting only on the adobe walls, will tend to push out the walls, depriving the roof of support, thereby causing the house to collapse. A better design is one in which the weight of the roof is carried by vertical supports such as poles which are placed at the corners and on either side of doors and windows.

Slide 14
Diagram: ring beam

The bottom of the posts should be an integral part of the foundations, and the top of the posts should be securely attached to a ring beam, as shown here. The roof should be attached to the ring beam through which it is secured to the vertical columns. It therefore rests on top of the wall and the ring beam transfers the roof load to the columns. This means that the adobe wall is in the nature of an infill material rather than a load-bearing wall.

Slide 15
Diagram: cross-bracing of walls

Cross-bracing is one of the most effective means of stabilizing a structure. It prevents opposite corners from spreading and the walls from leaning, thus ensuring that the structure responds as a unit to any ground movement. All walls should be cross-braced, even above doors and windows. This slide shows the wooden framework into which adobe blocks will be inserted.

The effectiveness of cross-bracing depends on how well it is secured to the vertical posts. Care should be taken that the nails used to secure wooden cross-braces are of adequate size and do not split the wood. If wire is used as a cross-brace, it should be strong and wrapped around the corner poles. In Guatemala, the most widely available type is barbed wire. After the walls are completed, they are plastered inside and out to protect the adobe and the wire, and to bury the barbs.

Slide 16
Collapsed house with tiled roof

The roof is one of the most important components in building a seismic-resistant structure. It should be constructed of materials which are as light as possible. This building suffered total collapse due to the weight of the roof. The clay tiles which are used in many regions are very heavy and a tiled roof on a house measuring 3m x 5m can easily weigh over 2000 kilograms. The force generated by ground movement during an earthquake acquired devastating momentum with weight of this magnitude.

Slide 17
Collapsed house with thatch roof

Traditional thatch roofing is probably the most appropriate material, but other popular lightweight materials include corrugated iron sheeting and asbestos panels. Although the thatched roof shown here remained intact, it nevertheless destroyed the supporting walls which did not have vertical support columns and cross-bracing. This dramatizes the importance of all the elements of a building being made earthquake resistant.

Slide 18
Small wooden framed house

Here is a small adobe house under construction. The owner has used corner posts, with posts on either side of the door, cross-bracing, and adobe to infill the walls. In addition, a lightweight roof of corrugated iron sheeting has been used in lieu of the traditional heavy clay tiled roofs commonly used in Guatemala. Experiments are also being carried out in many countries with roofing materials made of pressed fibres and other local materials.

Slide 19
Diagram: roof trusses

The roof must be a monolithic unit, that is to say, the components must be well-secured together. For a pitched roof, trusses should be used as roof supports rather than relying upon rafters attached to a ridge pole. Trusses not only distribute the weight load but also play a significant role in making the roof an integral unit. The trusses should be well-secured to the ring beam.

Slide 20
Diagram: window and door positions

Another principle that should be observed in building seismic-resistant structures is that of balancing the walls. Facing walls must have the same amount of material or mass so that one wall is not heavier than the other. If there is an opening in one wall for a door or window, there should be a corresponding opening in the opposite wall.

Slide 21
Diagram: wall thicknesses

There is a common misconception that making an adobe wall thick will make it stronger. Thick walls are not good in earthquake-prone regions. During an earthquake, the increased mass only

adds to the momentum in building movement and increases the damage. As a rule of thumb, thin walls are safer than thick walls; however, thin walls must be constructed in such a way as to prevent them from collapsing, and the solution advocated in Guatemala was to insert thin adobe blocks inside the wooden frame.

Slide 22
Diagram: hanging of doors

Earthquake victims are often found near the doors of their homes. The ground movement and shifting of the structure which occurs during an earthquake causes the doors to jam. In the few moments when the residents are attempting to run out of the house, it is much more difficult to prise open a jammed door than to force it outward. For this reason, people should be encouraged to hang the doors so that they swing to the outside of the house.

Slide 23
Building under construction

No structure is earthquake-proof, but incorporating the principles described in this talk can make even the simplest mud brick house safer. This building was used as a model for training local builders. It incorporated seismic-resistant building principles, including lightweight roof, ring beam, vertical support columns, cross-bracing, and thin walls. Here a technical discussion is in progress between Pedro Guitz, the director of the housing programme, and a local builder.

The builders constructed the lower part of the walls by laying the adobes flat while the upper portion was constructed with the adobes laid on edge. Horizontally-strung barbed wire is also just visible; it was used to tie the adobe walls together. When completed the building will be plastered and painted.

Slide 24
Community hall

This community hall was built in adobe by Guatemalan carpenters to illustrate the earthquake-resistant principles described in this talk. All too often the construction of safe housing has only been considered after an earthquake has occurred while burying the victims, instead of as part of a long-term pre-disaster planning policy.

There are two pre-requisites for such a policy. First, it is necessary to educate the local inhabitants to accept the risks they face; and second, to persuade architects, engineers and planners to commit themselves to working within the local building process, using local materials and craftsmen and not relying on imported capital-intensive industrialized housing. Only thus, by fostering a better understanding of safe building principles at all levels, will it be possible to reduce the vulnerability of small dwellings in earthquake-prone areas.

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Part 4 MAKING LOW-INCOME HOUSING WIND-RESISTANT: A CASE STUDY OF ANDHRA PRADESH, INDIA

by Ian Davis Dip Arch, Department of Architecture,
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Everett M Ressler, INTERTECT, Dallas, Texas, USA

Slide 1
Title

The principles of wind-resistant construction apply to a wide variety of building forms and materials. Wind forces are well known and carefully calculated for engineered buildings such as high-rise structures, but as yet little has been done to apply these principles to single-storey family residences, particularly in the Third World. In addition, the high winds and torrential rains that normally accompany them can devastate crops and even cause wider ecological disturbance by eroding topsoils which may be carried off by flood waters.

Slide 2
Damage to a typical village

The illustrations in this talk relate to traditional housing in the wind-affected State of Andhra Pradesh, India, where the adoption of wind-resistant construction principles has been a major concern since the cyclone of 19 November 1977. In this cyclone at least 20,000 people died and the homes of two million people were damaged or destroyed. Although severe cyclones such as this, accompanied by a tidal surge, do not occur very frequently, strong wind storms may occur as often as four times in a single year.

Slide 3
Thatched house

The 1977 cyclone dramatized the need for an understanding of wind-resistant building construction principles. Although masonry buildings as well as traditional structures were destroyed, the examples used in this talk will be the simplest house type, the traditional pole beam construction with mud wall infill and thatch roofing. An organization called the Appropriate Reconstruction Training Information Centre (ARTIC) has devised simple modifications to such houses. Houses very like the one shown here can be found in other parts of India and throughout south-east Asia. In other areas of the world house types may be radically different, but the basic principles remain the same and need to be applied locally.

Slide 4
Wind pressure on walls

First of all, in order to be wind resistant, a house must be able to withstand suction forces as well as wind pressure. In this and the following diagrams, solid arrows indicate suction and hollow arrows pressure. It must be emphasized that wind forces in a cyclone or hurricane may rotate through 360°. Thus both kinds of pressure will be exerted on all surfaces in turn. The lower diagram illustrates wind pressure on walls, roof and floor. The walls facing the wind must be able to withstand the direct wind impact and, where the wind can enter the building through doors or windows, it will literally blow out the walls and roof.

Slide 5
Wind pressure from wall opening

If there is an opening in the windward wall, then the outside walls will be subjected to pressure from inside the building as well as from outside. Therefore people living in the path of a hurricane must be warned to close all doors and windows to minimize internal wind pressure, which will be intensified by external suction. It is also recommended that the windows be sealed with strongly built shutters.

Slide 6
Wind pressure on roofs

Wind directed round a building causes suction on the side walls and roof with increased suction on the windward corners as shown in the diagrams. This suction lifts off lightweight roofs, particularly if they are low-pitched and poorly connected to the walls. Some measures can be taken to combat this: better connections of roof to walls and a steeper pitched roof, which we will now consider.

Slide 7
Wind pressure on roof overhangs

Wind flowing over both flat and low pitched roofs creates severe uplift forces and causes the roof to act very much like the wing of an aeroplane. As can be seen in the left-hand diagram, these suction forces are greatest at the lower edge of the roof and they also increase towards the ridge. Only when the roof pitch approaches 30° (one metre in three) will the suction forces be at their lowest and the uplift pressure replaced with downward positive pressures. For this reason, steep roofs are much better than low pitched roofs. As these two diagrams show, roof overhangs are particularly susceptible because they are affected by both suction and positive pressure. Overhangs of more than 0.5 metres should be avoided.

Slide 8
House with damaged roof

If the roof of the overhang is made of small components such as tile or traditional materials like thatch, pressures may destroy it without affecting the remainder of the roof. The roof of this building was damaged in the Andhra Pradesh cyclone and the damage to the tiles corresponds to the areas subjected to high pressure, that is, the ridge and overhang eaves. Sheet materials, such as galvanized metal, will be more likely to cause the entire roof to be blown away because uplift at the eaves will allow the wind to get under the main roof sections.

Slide 9
House with damaged gable end

This brick-walled house had a gable end, and this contributed to its collapse since gable ends are extremely prone to damage from either intense suction or direct impact forces, depending on orientation to the wind. For this reason, hipped roofs are much less likely to be damaged in high winds.

Slide 10
Bamboo framework of house

An analysis of wind-damaged structures has shown that failure is not usually due to the failure of individual members but rather to connection details. Here is the bamboo frame of a half-completed house showing the numerous connections between roof and frame members. Without question, the most important construction principle for ensuring that buildings are wind-resistant is that all elements of the house must be securely tied together. the walls must be well anchored to the foundation and reinforced to ensure that they hold together as a unit. The roof must then be securely attached to the walls.

Slide 11
Twisted walls

One of the most common types of damage to buildings is racking or twisting of the building. Wooden frame buildings are particularly susceptible to this kind of damage, as can be clearly seen in this structure. This underlines the need for good connections, both between the corner posts and the wall plate of the roof structure as well as between the corner posts and the ground. It also illustrates the need for cross-bracing to make the walls rigid.

Slide 12
Cross-bracing

Cross-bracing is not part of the local building tradition in Andhra Pradesh, so the technique has to be taught. This model house was built to show local carpenters, by example, how to build a wind-resistant house. This education process relies primarily on visual material since some builders may not be able to read. As a further education aid a simple poster illustrating in easy steps how to insert cross-bracing is suspended from the rafters.

Slide 13
Corner junction

To prevent racking or twisting, diagonal braces were securely fixed across all corners. The sign identifies and explains the use of the diagonal brace. These braces are just as vital as the wall braces illustrated on the previous slide.

Slide 14
Joints

The joints themselves were reinforced with metal strips which were wrapped round them and nailed to the corner posts. This prevents the members from slipping over a dowel that traditionally holds the joints together.

Slide 15
Diagram: pole type construction

In pole type construction where corner posts provide the frame for the walls and the support for the roof, the key to the strength of the structure is mainly determined by the condition of the corner posts, including their size, how deeply they are buried, and whether they have deteriorated. A simple instruction booklet published after the cyclone illustrates the various techniques for preparing a corner post. Analysis of damaged buildings in Andhra Pradesh revealed that the corner posts were typically of untreated softwood and were often virtually destroyed below ground level by termites and wet rot. This meant that they were unable to withstand even the minimal forces of high winds.

Slide 16
Diagram: treating corner posts

The technique for preparing a corner post is to cut off the bark and lightly char the wood. In some cases, as an experiment, it was then wrapped in plastic sheeting. This was only a marginal improvement, and neither pressure treated nor chemically treated poles provided alternative solutions because of their high cost and limited availability. After preparation, the post must be securely fixed three feet in the ground to resist the upward pressures that will come with any high winds.

Slide 17
Creosoting corner posts

Another experiment in addition to charring, was to creosote the end of the post and then wrap it in polythene as a protection against termite attack. In spite of all these efforts, there was continual evidence throughout the area of the failure of corner posts at ground level due to termite damage. Both termites and rot caused by the high water table, therefore, continue to present a critical problem.

Slide 18
Reinforcing corner posts

A pilot scheme developed by EFICOR, an Indian Christian relief agency, was to manufacture and distribute concrete posts with internal bamboo reinforcement. Here the posts are seen being made in moulds. Although beyond the means of most rural households, the concrete post proved to be a more permanent solution to the problem of termite attack. Where families could not afford to buy the posts, distribution was subsidized.

Slide 19
Traditional pitched roofs

The traditional roof structures made of bamboo and thatch were found to be excellent adaptations of wind resistant building principles. As can be seen here, a four-sided roof is the normal form and the pitch is at least 30 degrees. This steep pitch has been a slowly evolving tradition probably in response to lessons learned through bitter experience of roof failures.

Thatch seems to have some distinct advantages over sheet materials in that its permeability prevents the pressures from building up as they would do on a sheet material. Where there were overhanging eaves and other high pressure areas, the thatch was blown off without damage to the roof superstructure.

Slide 20
Asbestos cement roofs

Throughout the wind affected areas, asbestos cement roofs were completely destroyed. Because of their brittleness they were highly susceptible to damage from either bending or the impact of foreign objects. This slide shows new government housing in which the asbestos roof was destroyed. Note the small pieces scattered about. Tile roofs, on the other hand, behaved much like thatch roofs. Damage largely depended on whether the tile was merely plastered on to the purlins or whether it was tied with wire or cord.

Slide 21
Hurricane seen from spacecraft

We will now turn from the problems of modifying the individual house to consider briefly the wider aspects of the protection of people and the environment from the effects of high winds. Unlike earthquakes where there is no warning, the development of storm tracking through such techniques as satellite photography means that there is normally several days' advance warning of impending cyclones and hurricanes. This photograph of Hurricane Gladys, taken from the Apollo 7 spacecraft, shows the typical conical cloud formations associated with hurricanes.

In addition to technological developments in monitoring the tracks of storms, the vast increase in the use of transistor radios (even amongst very poor families) has meant that warnings can now be passed on even to isolated communities. It is vital that all governments and local authorities prepare in advance for high winds by devising warning systems and evacuation routes away from vulnerable areas such coastal settlements to inland areas or higher ground where the force of the winds will be dissipated.

Slide 22
Cyclone shelter

When some families in Andhra Pradesh heard radio warnings of the impending cyclone they sought protection in schools and churches supposing them to be more secure than their lightly built homes. As a result 90 were killed when a church roof collapsed in the Guntur region. One response by the state government of Andhra Pradesh and Tamil Nadu, working closely with the Indian Red Cross, was to build concrete cyclone shelters in the most dangerous coastal areas. It is hoped that families will have adequate warning to take shelter in these buildings for up to three days.

This shelter near Madras can house about 500 people on its two floors, with the flat roof serving as an emergency area for helicopters to land food supplies. The problems that still have to be resolved are: what protection to provide for animals, and how to protect people who cannot be accommodated in shelters. There is also the fundamental question of whether the building of these shelters will engender a false sense of security so that families will not bother either to make their homes safe or to accept evacuation to a safe location.

Slide 23
Planting barrier

The correct siting of buildings can greatly help to reduce possible wind damage. Tight rows of buildings should be avoided as they are likely to offer too solid an obstruction and may even increase wind speed. Good practice assumes that the pattern of ground settlement is loosely permeable and allows an overall penetration of at least some wind over the whole site. The slide shows how this might be achieved with the help of planting barriers, in this case a grove of coconut palms flanked by bamboo. Depending on their height and permeability, such barriers allow a proportion of the wind to travel through them and to provide cushions of air on each side, which help lift the main airstream over the planting and create relatively sheltered zones (coloured yellow) within which buildings may be more safely sited. In this illustration the wind comes from one direction, although in a major hurricane or cyclone it will rotate through 360°.

Slide 24
Diagram: plan of settlement

As we have just seen wind damage in a cyclone may come from any direction. Therefore, to use barrier planting to best effect a circular pattern of settlement is desirable, with buildings generously spaced out in the sheltered yellow zones on each side of the green planting zone. This is an ideal arrangement which has, of course, to be adapted to local site conditions. In coastal positions, for example, settlements like this are often best raised up on earthen platforms to give protection from tidal waves and to provide a firmer anchorage for building foundations and tree roots. The area excavated can provide fish ponds to supplement the village food supply.

To summarise: architects and planners can do much to minimize casualties and damage from high winds. The first priority is to establish preparedness measures such as effective warning systems, evacuation procedures and the closure of any large buildings as potential places of refuge; the second priority is to instal flood control devices such as dykes and sea-walls; and the third priority is to devise appropriate methods such as those described in this talk to make local housing resistant to high winds.

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Part 5 EMERGENCY SHELTER AFTER DISASTERS

by Ian Davis Dip Arch, Department of Architecture, Oxford Polytechnic, UK

Slide 1
Title

When an area is devastated by a massive earthquake, flood or cyclone, thousands of people can be made homeless overnight. The rebuilding of their towns may take many years. In the meantime, what strategies for emergency shelter can be adopted? Let us look at the different options.

Slide 2
Ruins of Guatemala City

In February 1976, as soon as the Guatemalan earthquake victims had dug out the dead and injured from their ruined buildings, they began the reconstruction of their houses. Anything that could be recycled was rescued from the ruins for re-use. After the Turkish earthquake of November 1976, a BBC commentator reported: 'A serious obstacle to relief efforts has been the presence of newly erected tents within the ruins ... this has prevented the entry of bulldozers in their clearing operations.' In reality, this is probably the precise reverse of the facts. The obstacle to recovery was the bulldozer, not the tent, since it removed the rubble—the primary building material. The tent is the first poignant step towards full recovery.

Slide 3
Rebuilding in Guatemala City

Since it may take as long as nine months to build a house in the industrialized world, it is hard to grasp the speed of house building in the developing world. This skill may be as basic as cooking within industrialized societies and from start to finish a house may be built in a matter of three weeks. In some cultures, for example in Bangladesh, it may take as little as three days. This ability is the primary resource for shelter following disasters, and no official provision can possibly match its scale or effectiveness. This family may have rebuilt their home in Guatemala within a week of the earthquake.

Slide 4
Improvising shelter

Arriving in Guatemala City within three days of the earthquake, my dominant impression was of thousands of makeshift homes. It is estimated that 50,000 structures of cardboard, plastic and string were put together in blocked-off streets and city parks. One example of improvisation was this overnight shelter built on the back of a truck. A key principle for all aid givers is only to do what people cannot do for themselves. Clearly, if people can improvise on this scale it is pointless to fly in expensive tents and emergency structures from half way round the globe.

Slide 5
Winter tent

'But,' say the critics, 'what will happen when a major disaster strikes a population in an area of high exposure risk? Surely in this situation the life and death issues will demand an urgent response from outside sources.' In November 1976 they had a partial answer to their question. Turkey suffered its worst winter earthquake for forty years. Heated tents such as this one began to arrive with the unfamiliar sight of flue pipes poking through the canvas. But prior to the arrival of such winter tents the victims, as in Guatemala, improvised shelter in many ingenious ways. One technique was to interleave several tents inside one another to form a cellular, well-insulated construction.

Slide 6
Semi-subterranean house, Turkey

Some Turkish families dug holes in the ground to provide climatic protection, to provide shelter and to gain warmth from the ground below frost levels. This photograph shows the surface area of one of these semi-subterranean homes—a situation where disaster victims responded in a highly logical manner to their shelter needs. An important principle emerges from this; to understand the needs of victims after a disaster it is essential to grasp normal patterns of behaviour within the affected area. In this instance, the problem of coping with extreme cold was something that these families had to cope with each winter, and the disaster was only an extension of the familiar problem of winter survival.

Slide 7
Improvised shelter, Managua

Many improvised shelters will be progressively modified and improved into a state of permanence. These flimsy structures were built in Managua following the 1972 earthquake. We have seen in the earlier talks in this series that disaster victims are often the poorest groups in a city, and their poverty is shown in the dangerous siting of their homes, and in their flimsy construction. These homes are built on flat land and will be unlikely to kill anyone in the next earthquake. However, a characteristic of squatter homes in vulnerable towns and cities is that they are often built on waste ground which can be highly dangerous, for example, a ravine or a flood plain.

Slide 8
Emergency accommodation, Bolivia

Survivors may move into the homes of friends or their families, or they may find temporary homes in public buildings. This convent in Bolivia provided emergency accommodation for flood victims. Therefore, all public buildings in disaster prone towns and cities can fulfill this vital role (and also that of morgues or clinics). The obvious lesson is to make doubly sure that they survive a disaster. If the roof of a house collapses, it may kill six people; if the roof of a school collapses, it may kill a hundred.

Slide 9
Tents at Lice, Turkey

For many aid givers, a disaster shelter is another name for a tent. And this results in vast quantities arriving at any disaster scene. As in this istance—the Turkish earthquake at Lice in 1975—they can fulfill a vital role, provided they can be delivered quickly enough to be used by the victims needing immediate shelter. But in most cases, they take a long time to get from log-jammed airports to the victims. Further problems are their high cost. The winter tents in Turkey cost up to double the cost of a permanent home. But their most significant failure is that they make little contribution to the long-term development of a community. And this is the primary yardstick of all post-disaster shelter provision. With the money available, far better things can be done as we will see later.

Slide 10
Emergency camp site, Nicaragua

Often emergency camp sites are laid out by military personnel on rigid lines. This layout in Nicaragua is an attempt by Fred Cuny working with Oxfam and the Catholic Institute for International Relations (CIIR) to provide more humane, family cluster layouts. But if tents are used, it is probably the best course of action for them to be distributed so that families may remain in or near their ruined homes, and not on large sites, which are normally planned for administrative reasons.

Slide 11
Wooden houses, Nicaragua

The United States Government provided $3 million to build about 11,000 of these wooden houses in Nicaragua—a rather typical over-estimate of the number of post-disaster house units needed. Initially they were not well received by the intended occupants. Their objections were related to such issues as the siting of the units away from markets, with a poor bus service, and later to the absence of adequate drainage, roads, schools and shops. These defects were ultimately rectified, but serve as a reminder that housing, even after a disaster, is a far wider issue than an individual unit. And if the overall infrastructure is not considered, then low occupancy is almost certain to be the outcome.

Any official planning a settlement following a disaster may have in mind the immediate problem of shelter for survivors. But what he needs to consider is that he is planning a settlement that may last over 20 years. Therefore care needs to be taken over all planning issues, and this is a frequent area of failure.

Slide 12
Evolution of core unit

The process of providing shelter is organic, and the original core unit is certain to gradually evolve to suit the needs of the occupants. This slide shows the same housing as the previous

slide just a year after the disaster. The authorities have now recognized that the 'temporary' housing will become permanent, and they are extending each house with a concrete block linking unit. This also serves as a useful fire break, as well as providing additional living space.

Slide 13
Addition to core unit

Alternatively, the core unit may be changed by its owner adding a piece here or there to suit his own needs. In this instance on the same housing site in Managua, one family has added a second storey. If officials are involved in the post-disaster housing process, it is essential to recognize that the original basic unit will become the core of the final house. And in modifying the house form, the original unit can be structurally weakened. Therefore it is essential to ascertain that any post-disaster housing programme is built in a manner that will not only be resistant to disaster forces, but will also be capable of continuous modification.

Slide 14
Reconstruction, Bangladesh

After a disaster there will be a large number of unemployed people available. Therefore the usual dictum of construction in the developing world becomes all the more important. This is: 'Labour intensive—not capital intensive—using local materials and manpower, not imported goods and expertise'. One of the most successful reconstruction projects after the Bangladesh emergency was the housing designed by Peter McNee of the Evangelical Fellowship of India Commission of Relief (EFICOR). 1300 units were built using woven jute on a bamboo frame with a corrugated iron roof. The total cost of each unit was under $90.

Slide 15
Triangulated bamboo house

In many areas the local indigenous housing collapsed in the disaster. Therefore it is necessary to investigate the reasons for the failure and suggest modifications where possible. But to stand any chance of acceptance, such changes will have to be within the local range of skills and continue to use local materials. These approaches are considered in other lectures in this series.

Carnegie-Mellon University in the USA working with Fred Cuny have developed a 'modified' structure. This is an 'A' frame triangulated bamboo house, designed to resist the monsoon cyclones of Bangladesh, with a raised floor where housing is built on ground subject to flooding. The acid test of this (or any modified technique for that matter) is whether the local residents of the refugee camps adopt the new idea for their own housing when they build without external help. An evaluation of this housing showed that this did not occur.

Slide 16
Circular polyurethane igloo

Out of recent research within this sphere, evidence for one fact has emerged. This is the realization that there is no future in the idea of universal solutions. There have been several attempts to devise such a product. One of them was the polyurethane igloo developed by Bayer in Germany. This was used after three major disasters in Peru, Turkey and Nicaragua, and in each instance the units are still being occupied. The major problems are high cost (well over $1,000 per unit); the time for delivery (in Managua it took 4 months); the lack of local involvement since they generate little employment and use imported materials; and the all-important cultural issues. Questions, in fact, which relate to normal living patterns and how well they will adapt to an alien form of building.

Slide 17
Addition to igloo

In Nicaragua, the occupants of igloos in one village proceeded to make additions to their more familiar rectangular forms. This use of the igloos was their final appearance. It seems that they were abandoned by the manufacturers and the Red Cross on the grounds of high cost.

Slide 18
Hexagonal polyurethane igloo

Another venture in this direction was sponsored by Oxfam. This was to provide hexagonal polyurethane igloos. The product was used on one occasion only, following the Lice earthquake in 1975 in Turkey. As with the Bayer igloos, the major problems were administrative delays, high costs, cultural unsuitability and the risk of fire from the polyurethane.

Slide 19
Permanent reconstruction, Turkey

By the time 400 of these emergency units had been constructed, the Turkish authorities were completing the construction of 1500 permanent houses which were built in the amazingly short period of under two months. Subsequently Oxfam's emergency shelter programme was abandoned on cost grounds. If the designers and sponsors of 'universal solutions' were to adopt three principles, it is almost certain that they would recognize the irrelevance of their products to real needs. The first principle is to consult the homeless population to find out their shelter needs; the second is for the donors to make themselves accountable to these victims for what they provide (in effect, to depart from the customary 'take it and be grateful' approach); and the third is to evaluate the effectiveness of their relief programmes by returning to a disaster site one, two or possibly even five years after the event to observe what has happened to their products. Any cursory examination of the host of variables that decide house forms—climate, living patterns, local materials—will quickly show the designer that to find a universal solution for a small town

would be difficult; to attempt to do it for worldwide application is clearly ludicrous.

Slide 20
Prefabricated housing, Turkey

These principles are equally applicable when national governments erect housing following disasters. This prefabricated housing which was built so rapidly in Turkey was constructed with little active participation by the intended occupants. The design was devised many years before the disaster and was used in a variety of regions of Turkey. These houses had insufficient insulation for local climatic extremes, they were away from the town centre and, most important, there was no provision for the shelter of animals.

Critics of the suggestion that donors must ask victims what they need, and involve them in the design process, always raise the question of time. They claim that the urgency of making decisions precludes this luxury. However, current research has questioned this urgency. Even in areas of high risk there is still time to ask questions. Instead, donors prefer to make advance diagnoses of needs, which can be wildly incorrect.

Slide 21
Subsidized lightweight roofing

Earlier I referred to better ways of spending money than on tents. One possibility is to use the funds of the aid givers to subsidize—never give away—sheets of corrugated iron roofing. In Guatemala, one of the reasons for the high casualties was the very heavy tiled roofs which collapsed and buried families. Therefore most of the relief agencies mounted major schemes to distribute lightweight roofing.

Slide 22
Dual use of building materials

This roofing has been taken by the families and used as a form of temporary shelter, probably built over an improvised frame of timber. Then as a more permanent house is constructed, the roofing can be re-used. Thus it performs both an emergency and a long-term function. Since the key element in all housing is the roof, it is possible that governments in vulnerable countries could prepare for future disasters by contingency planning. To do this they could subsidize the cost of increased storage of supplies of corrugated iron, or possibly timber. This would then help to combat the massive depletion of stocks and rocketing prices which inevitably follow most disasters, when severe property losses have been sustained.

Slide 23
External/ internal shelter provision

There are two basic categories of shelter after disasters. On the left-hand side of the diagram we see contributions from external sources. Such shelter may be from the national capital city or from 6000 miles away. Then, on the right, we

have the wide range of local resources which come into play immediately. It is now known that the vast majority of all shelter needs is satisfied by local resources and that all external shelter and housing provision, even in a major disaster, will be unlikely to produce more than 20% of the total.

These local resources—to improvise, accommodate people within extended families, and rebuild rapidly—is the key process that has to be encouraged by all outside aid givers. In the past, their activities often had the effect of retarding local recovery. So, the role of outside personnel is clearly that of support to encourage a process already taking place. This is a difficult role: it means walking a tightrope between, on the one hand, not giving the help which may be needed, and on the other hand, being too active. If the latter takes place, it will establish a dependence which will ultimately be self-defeating—a sad legacy of many disasters.

Slide 24
Comparison of houses, Honduras

Finally, a key issue must be re-emphasized. This picture from a Honduran village rebuilt after Hurricane Fifi underlines the point that all forms of shelter must be within the range of local skills, life-styles, economy and materials. In the background there is an example of housing financed and constructed by an American relief agency. This uses concrete blocks and corrugated iron roofing. Then, in the foreground, there is another house made entirely out of local materials for less than a quarter of the cost of the concrete house.

But, as we have seen, the local form of dwelling may be unsafe. What then? As lectures on high winds and earthquakes in this series show, there may need to be changes in materials or technology. But if these changes are to have any permanent acceptance, they will have to be implemented by the local families themselves. If donors wish to involve themselves in shelter and reconstruction, they must recognize that they are intervening in a local process of recovery. Therefore, they must understand local resources and local needs. And, ultimately, they must become accountable to the victims, and not purely to some aid officials in the capital city or the relief agency headquarters who may be thousands of miles away.

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Slide 10: Fred Cuny
Slide 14: Tear Fund/Peter McNee

4 Resource Index

1 DISASTER INFORMATION RESOURCE ORGANIZATIONS AND INDIVIDUALS

American Council of Voluntary Agencies for Foreign Service Inc, 200 Park Avenue South, New York, NY 1003, USA

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Centre for Information and Research on Disasters and Natural Hazards (CIRDNH), Caulfield Institute of Technology, PO Box 197, Caulfield East, Melbourne, Victoria 3145, Australia

Centre de Recherche sur l'Epidémiologie des Désastres, Ecole de Santé Publique, Unité d'Epidémiologie, Université Catholique de Louvain, Clos Chapelle-aux-Champs 30, B-1200 Brussels, Belgium

Disaster Research Center, Ohio State University, 127-129 West Tenth Avenue, Columbus, Ohio 43201, USA

Emergency Preparedness and Disaster Relief Coordination (Dr Claude de Ville de Goyet), Pan American Health Organization, 525 Twenty-third Street NW, Washington DC 20037, USA

Institute for Food and Development Policy, 2588 Mission Street, San Francisco, California 94110, USA

International Disaster Institute (IDI) (Director: Frances D'Souza, PhD), 85 Marylebone High Street, London W1M 3DE, UK

International Society on Disaster Medicine, 10-12 Chemin de Surville, 1213 Petit-Lancy, Geneva, Switzerland

INTERTECT (Executive Director: Frederick C Cuny), PO Box 10502, Dallas, Texas 75207, USA

League of Red Cross Societies, 17 Chemin des Crêts, Petit-Saconnex, 1211 Geneva 19, Switzerland

Lewis, James. Research Programme in the Vulnerability to Natural Disasters, Centre for Development Studies, University of Bath, Bath, UK

Natural Hazard Research Program (Canada), Department of Geography, University of Toronto, Toronto, Ontario, Canada

Natural Hazard Research Program (USA), Institute of Behavioral Science #6, University of Colorado, Boulder, Colorado 80309, USA

Office of Foreign Disaster Assistance, US Agency for International Development, Department of State, Washington DC 20523, USA

Office of the United Nations Disaster Relief Coordinator (UNDRO), Palais des Nations, CH-1211 Geneva 10, Switzerland

Shelter and Settlements Unit (Leader: Ian Davis), Department of Architecture, Oxford Polytechnic, Headington, Oxford OX3 OBP, UK

United Nations Development Programme, One UN Plaza, New York, NY 10017, USA

United Nations High Commissioner for Refugees, Palais des Nations, CH-1211, Geneva 10, Switzerland

Volunteers in Technical Assistance Inc (VITA), 3706 Rhode Island Avenue, Mt Rainier, Maryland 20822, USA

This list has been compiled by INTERTECT

2 APPROPRIATE TECHNOLOGY CENTRES AND TECHNICAL AGENCIES

The slide lectures in this series emphasize the need to consider housing and settlement planning at very low technology levels. Assistance in these fields can often be given by organizations concerned with appropriate technology. This list identifies a number of key organizations throughout the world.

AUSTRALIA

Appropriate Technology Development Group (Gordon Innes), 20 Holdsworth Street, Woolahra, NSW 2025

BANGLADESH

Appropriate Agricultural Technology Cell, Bangladesh Agricultural Research Council, 130 C Road 1, Dhanmandi, Dacca

BOTSWANA

Rural Industries Innovation Centre, PO Box 18, Gaborone

CANADA

Brace Research Institute, MacDonald College, McGill University, Ste Anne de Bellevue 800, Quebec HOA 1CO

EGYPT

Transfer of Technology and Appropriate Technology Office (Prof Dr Mahmoud A Saleh), National Research Centre, El-Tahrir Street, Dokki, Cairo

ETHIOPIA

Women's Centre (Dr Marilyn Carr), UNECA, PO Box 3001, Addis Ababa

FRANCE

Groupe de Recherche sur les Techniques Rurales (GRET), 34 Rue Dumont d'Urville, Paris 75116

GHANA

Technology Consultancy Centre, University of Science and Technology, University Post Office, Kumasi

INDIA

Appropriate Reconstruction Training and Information Centre (ARTIC), Seshagirirao St, Manithinagar, Vijayawada 520 004 (AP)

Appropriate Technology Development Association (Executive Director: Mansur Hoda), PO Box 311, Gandhi Bhavan, Lucknow 226 001

Cell for the Application of Science and Technology to Rural Areas (ASTRA), c/o Indian Institute of Science, Bangalore 650 012

INDONESIA

Development Technology Centre, Bandung Institute of Technology, PO Box 276, Jalan Ganesha 10, Bandung

Proyek Teknologi Tepat (Anton Soedjarwo), Dian Desa, 11 Kerton Muju Muju 8, Yogyakarta

KENYA

Village Technology Unit, c/o UNICEF, PO Box 44145, Nairobi (Office at Phoenix House, Kenyatta Avenue; Centre at Karen)

MEXICO

Institute of Social and Economic Studies in the Third World, Corner Porfirio Diaz 50 and San Jeronimo Lidice, Mexico 20, DF

NETHERLANDS

Stichting, PO Box 525, Eindhoven

TOOL, Mauritskade 61a, Amsterdam

NIGERIA
International Institute of Tropical Agriculture (Dr Ray Wijewardene), PMB 5320, Ibadan

PAPUA NEW GUINEA
Village Development Task Force (Jean Kekedo), PO Box 6937, Boroko

PHILIPPINES
International Rice Research Institute, PO Box 933, Manila

RWANDA
Centre d'Etudes et d'Applications de l'Energie au Rwanda (CEAER), Université Nationale de Rwanda, Butare

SWITZERLAND
Schweizerische Vereinigung für Mittlere Technologie, c/o Latinoamerikanische Institut, Varnbülstrasse 14, 9000 St Gallen

TASMANIA
Intermediate Technology Development Pty (John McKean), 87 Riawena Road, Rose Bay, Hobart 7015

UNITED KINGDOM
Appropriate Health Resources and Technologies, Action Group Ltd (AHRTAG), 85 Marylebone High St, London W1M 3DE

Building Research Establishment, Overseas Division, Building Research Station, Garston, Watford, Herts

Hydraulic Research Station, Wallingford, Berks OX10 8BA

Intermediate Technology Development Group (ITDG), Panels on Health, Power and Transport, 9 King Street, London WC2E 8HN

ITDG Water and Agriculture Office, National College of Agricultural Engineering, Silsoe, Bedford MK45 4DT

Intermediate Technology Industrial Services (ITIS), Mysan House, Railway Terrace, Rugby CV21 3HT

National Institute of Agricultural Engineering (NIAE), Overseas Division, Wrest Park, Silsoe, Bedford MK45 4HS

ORT Technical Services, 12 Gloucester Place, London W1H 4EQ

Rural Communication Services, 17 St James Street, South Petherton, Somerset

Transport and Road Research Laboratory, Overseas Division, Crowthorne, Berks

Tropical Products Institute (TPI), Culham, Abingdon, Oxfordshire OX14 3DA

UPPER VOLTA
SRAT SAED (Amadou Traore), Section de Technologie Adaptée, s/c Oxfam, BP 593, Ouagadougou

USA
Volunteers in Technical Assistance Inc (VITA), 3706 Rhode Island Avenue, Mt Rainier, Maryland 20822

ZAMBIA
Family Farms Ltd (ITMA Unit), PO Box 42, Magoye

Technology Development and Advisory Unit (TDAU), University of Zambia, PO Box 2379, Lusaka

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Intermediate Technology Publications Ltd, 9 King Street, Covent Garden, London WC2, UK. A forum for the exchange of ideas among those directly involved in development work; technical articles, book reviews, readers' contributions. *Quarterly.*

Basics: a source of shared information on rural development
Rural Communications, 17 St James Street, South Petherton, Somerset, UK. Newsletter providing information on development problems in an easily understood form: settlements and housing; education and training; appropriate technology ideas and options. *Bi-monthly.*

Development Communication Report
Clearing House on Development Communications, 1414 22nd Street NW, Washington DC 20037, USA. Good resource for information on communications projects and technology. *Quarterly.*

Development Forum
Division of Economic and Social Information, United Nations, 1211 Geneva, Switzerland. Primarily devoted to development issues but includes some relief/reconstruction information. Excellent resource for publications and contacts. Articles on non-governmental organizations, UN agencies, technology, desertification, ecology-virology, development education. *Monthly.*

Disaster Preparedness in the Americas
Pan American Health Organization, Emergency Preparedness and Relief Coordination Unit, 525 23rd Street NW, Washington DC 20037, USA. Newsletter giving information on PAHO, WHO, UN and other agencies. Reviews publications, journals and newsletters on disasters. Excellent resource. *Monthly.*

Disasters: international journal of disaster studies and practice
Pergamon Press, Headington Hill Hall, Oxford OX3 OBW, UK. Edited by the staff of the International Disaster Institute. Articles and information on all facets of relief: pre-disaster planning and mitigation, disaster case studies, epidemiology. Excellent resource for publications and contacts. *Quarterly.*

Invention Intelligence
Department of Science and Technology, National Research Development Corporation of India, 61 Mahatma Gandhi Marg, Lajnagar III, Delhi 4, India. Includes articles on technology for the poor, rural-based industry, housing. *Monthly.*

Natural Hazards Observer
Institute of Behavioral Science #6, University of Colorado, Boulder, Colorado 80309, USA. Primarily aimed at researchers. Information on available studies and contacts; conferences and meetings; federal and state policies, regulations and forthcoming legislation; organizations and their projects; grants for research; recent publications. *Quarterly.*

Soundings from around the World
World Neighbors, 5116 N Portland, Oklahoma City, Oklahoma 73112, USA. Review of books, reports, periodicals, audio-visual training aids, etc produced by World Neighbors and other organizations throughout the world. Excellent resource for all aspects of development. *Quarterly.*

TAICH News
Technical Assistance Information Clearing House, 200 Park Avenue South, New York, NY 10003, USA. This Newsletter is an excellent source of information on US overseas development assistance projects, contacts and publications, forthcoming meetings and conferences. *Quarterly.*

TRANET Newsletter
TRANET (Transnational Network for Appropriate/Alternative Technologies), PO Box 567, Rangeley, Maine 04970, USA. Publishes lists of appropriate technology centres, low-cost and self-help housing groups, citizen planning; forthcoming meetings and workshops. Good resource for contacts and information about other organizations; fair resource for publications. *Quarterly.*

UNDRO Newsletter
Office of the United Nations Disaster Relief Coordinator, Palais des Nations, 1211 Geneva 10, Switzerland. Reviews recent disasters throughout the world and the response by UN agencies, other organizations and the national governments involved. Good resource for meetings and conferences organised by the UN, non-governmental and intergovernmental organizations, voluntary agencies and others. Also good resource for recent publications, articles, etc on natural disasters and related subjects. *Monthly.*

Unscheduled Events
Disaster Research Center, Ohio State University, College of Social and Behavioral Sciences, 128 Derby Hall, 154 N Oval Mall, Columbus, Ohio 43210, USA. Articles on studies and research projects, forthcoming conferences and meetings, recent publications. Good resource for contacts and references. *Quarterly.*

VITA News
Volunteers in Technical Assistance Inc, 3706 Rhode Island Avenue, Mt Rainier, Maryland 20822, USA. Articles on international information exchange, technology transfer/diffusion, rural development programmes, appropriate technology, recent publications, networks and contacts. Excellent reference. *Quarterly.*

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