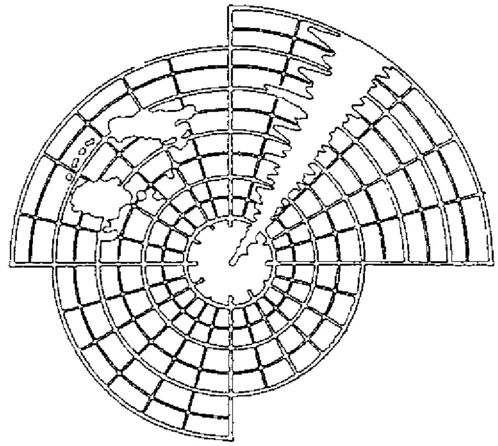


PART ONE COLLECTING THE FACTS

1 INTRODUCTION

The objectives of this study are to prepare a document containing technical guidelines for the repair and rehabilitation of existing educational buildings to withstand cyclone forces.

This often complex subject will be presented as simply as possible and will attempt to describe the problem, offer methodologies for rehabilitation and reinforcement of various types of building construction systems and will offer typical examples from a selected range of countries.

The study will include a section on the theory of wind action on buildings and explanations and tables of wind forces and diagrams of load areas.

It is also important to have knowledge of the resistance capacities of various construction details so that designers can incorporate these details and their costings in the preliminary design and budgeted stages of building development and, of course, repair and rehabilitation.

This follows the UNESCO work over the past decade where training courses and workshops have been held throughout the cyclone regions.

Whilst these and other international efforts at co-operation and co-ordination are offered to help establish standards for local governments and research groups, it should be understood that it is the governments of individual countries that are primarily responsible for the mitigation against disaster events and the establishment of criteria and standards in their own countries

Since 1970, and especially since 1985, there has been renewed interest in the mitigation of cyclone damages to buildings.

This has been caused by the increasing level of damages to buildings and communities by the effects of these high wind forces.

In the developed countries the economic costs of damages has escalated dramatically. In the poorer countries, and especially those with large populations at risk, the human cost and national disruption, despite significant improvements in countries like Bangladesh, continues to impact heavily on National and International agencies involved in dealing with post-disaster rehabilitation and recovery.

Skills have been developed in many areas to combat the problem and these skills are in a continual state of development and refinement.

The theory of how the winds blow, and their flow patterns around fixed objects and building shapes, is well known and readily understood.

The magnitude of the forces and the strength of the resistance mechanisms is less well known.

The practical knowledge of how many nails or screws to use in a typical construction detail, is not well known, nor is there an adequate understanding of the transfer of wind loads through the chain of construction links, from the roof and walls receiving the loads to the foundations where the loads are eventually dissipated.

Most countries now accept that the educational buildings, especially the town or village school are a focus in the community, known and recognised by the community and, since they are built by the government, they are expected to be safe from the effects of a disaster.

Failure of these buildings can kill or injure our children when they expect security therein.

This reinforces the responsibility of the government and its agencies to pay special care to the design of these buildings.

Retention of these buildings by better design initially, or by proper rehabilitation after damage, can enable these school buildings to serve a post disaster function, as shelter, meeting rooms and disaster co-ordination centres.

This is a further reason to treat school buildings as important structures

The inspection and evaluation process in the post disaster situation is an important phase and should be carried out by experienced personnel and agreed by a third party from the educational ministry.

The following steps should be recorded.

1. Cost estimate to demolish damaged building and its foundations including removal from site
2. Current replacement value of new type building similar to the damaged building, i.e total cost and cost/m^2.
3. Cost estimate to repair and rehabilitate damaged building, including structural upgrading to resist wind loads.

Inspection teams evaluating damages and recommending plans of actions need to be careful in assessing the condition of damaged buildings.

It is easy in the midst of damaged townships, with debris in all directions, to take decisions to demolish and rebuild.

There should not be an automatic requirement to demolish walls and foundations, remove them from the site and then to bring in new materials and build new work to replace that which was satisfactory.

Proper evaluation should be carried out before these decisions are taken.

The author believes that where buildings have been erected with a reasonable amount of integrity and are damaged in a disaster event but not destroyed, then after an assessment of its condition the cost of bringing the building back to first class condition can be done for between 25% and 50% of its current replacement value.

This factor could save a great deal of expense, both of the home country and also of any donor countries or agencies where thousands of buildings are involved.

Experienced architects with good engineering advice can produce design solutions that can rehabilitate damaged buildings after this positive evaluation has been made.

The author has lived through a major cyclonic disaster and has been involved in inspections, assessment and reconstruction of a community and its buildings in the post disaster period.

There is little more forceful education than the actual personal experience of being with one's family throughout the disaster event, where the strength of the forces is brought home.

Where one has the technical knowledge, the messages are even more relevant as the sight of failed construction details imparts a telling comprehension of the power of the forces and the need for better quality design, detailing, and construction throughout those parts of the world that are subjected to damage by wind forces there is a need to know.

Research is an integral part of the learning process and is an essential item if we are to continue to improve the quality of our built environment. The results of research enable us to reduce the factors of safety used in design and lead to economic savings.

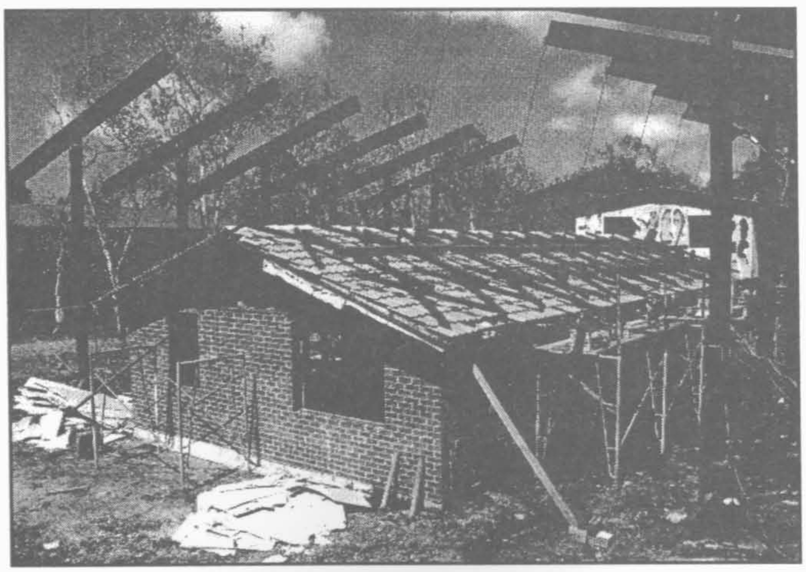
Support of independent research and evaluation by experienced teams should be sponsored by government agencies, academic institutions, private companies and commercial ventures.

Technical data banks should be maintained at selected epi-centres in the disaster regions so that expert advice can be readily obtained from people familiar with the region.

Testing stations should also be set up at selected research establishments in the region.

Full scale testings of buildings and/or building components, such as those currently being carried out by the Cyclone Testing Station at James Cook University in Townsville, Australia, are showing up the load-sharing capabilities of different building elements in resisting wind loads which offer cost savings.

The Cyclone Structural Testing Station
at James Cook University of North Queensland, Townsville Australia



A general overview should be determined so that overlap is avoided on major research projects.

Another prime need is for collation and dissemination of research done to date.

A great deal of research is lost once it is complete due to lack of publication and promotion.

The cost of reproducing research and technical data is a hurdle to be crossed. Perhaps support from product manufacturers or from the reinsurance industry and governments could assist in this regard, providing a suitable co-ordination body or council is set up to provide control.

A further major problem is to instil into the education courses for professional, technical and trade students the input needed to make these future leaders aware of the wind problem and its affect on construction details.

Unfortunately, too often schools do not upgrade their course material on a regular basis and the time lag in imparting new techniques is too slow.

With the growing demand for better buildings, the need to regularly update educational material is vital

In any case, architects, engineers and their clients have a need to re-examine the security and integrity of constructions in regard to resistance to high wind damage areas.

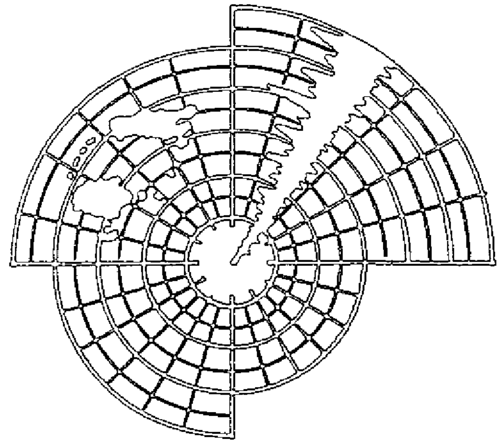
We must avoid letting theory alone dictate our responses in design and detailing to resist cyclonic wind forces.

There is a real need to understand the actual forces to be resisted by the actual construction details.

The architect must have a reasonable and practical knowledge of these forces as it is an integral element of the building design rather than leaving the whole problem to the engineer.

The rapid growth of population in many countries has identified the need to provide greater protection now that a large community is at risk.

The reliance on a limited number of experienced professionals and contractors is no longer satisfactory.



2 CYCLONES AND REGIONS AFFECTED

CONTENTS

2.1 WHAT IS A CYCLONE?
2.2 SEVERE CYCLONIC EVENTS
(a) Pressure and Frequency
(b) Wind
(c) Storm Surge
(d) Flooding
2.3 REGIONS AFFECTED BY CYCLONES

2.1 WHAT IS A CYCLONE?

The education process in the understanding of cyclone resistant construction must include a knowledge of the basic nature of cyclones themselves, the scale of a cyclone, the area it can affect, the speed of cyclonic winds, rapid fluctuations in the wind speed, direction and pressures exerted on building structures and, not least, the time the cyclone event takes to arrive and depart

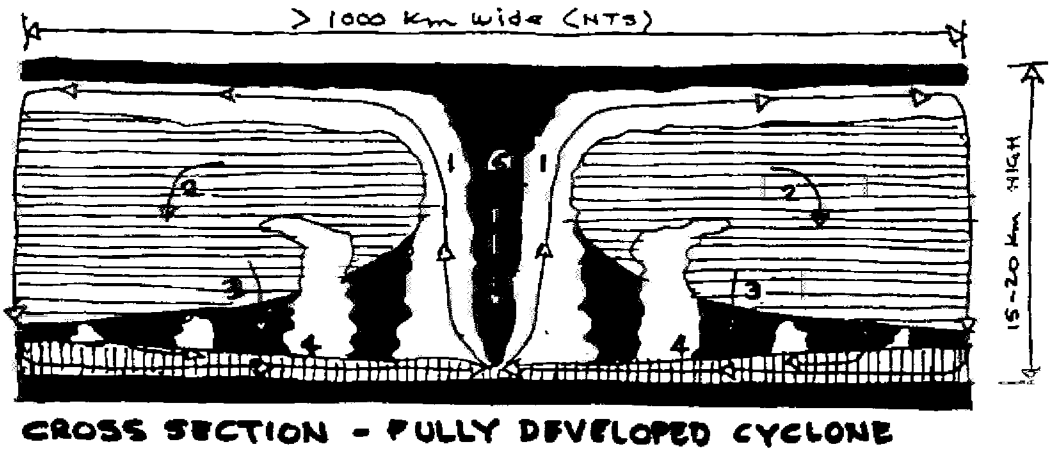
The principal Cyclone Season in the Southern Hemisphere is from November to April, and in the Northern Hemisphere from May to October, when warm tropical oceans and atmospheric conditions give rise to cyclonic events.

The area covered by an intense cyclone with winds in excess of 120 km/hr can have a diameter from 250 to 800 km and lesser wind affects to diameters of 1,200 km to 1,500 km.

A cyclone is a severe tropical storm of such magnitude that winds near the centre form a circular vortex or cyclonic whirl

If these winds exceed 120 km/hr (35 m/s, 75 mph), the storm is called a typhoon, hurricane or cyclone. The rotation of the Cyclonic Vortex is clockwise south of the equator and anti-clockwise north of the equator.

Close to the centre of intense cyclones is an area of windless clear sky known as the 'eye'. Around this eye of 1 to 50 km diameter is a large mass of cloud from which heavy rain falls The amount of rain that falls can be up to 350 mm and in extreme events over 1,000 mm.

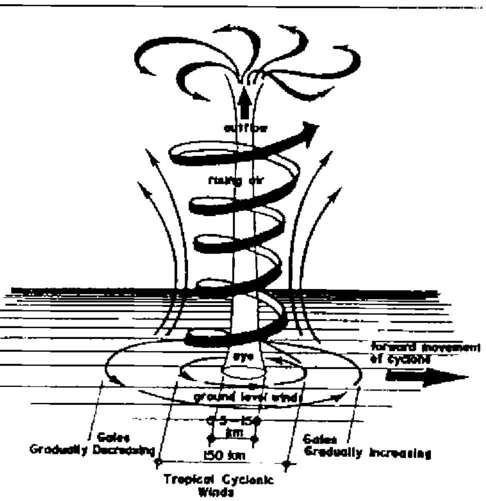


CROSS SECTION - FULLY DEVELOPED CYCLONE

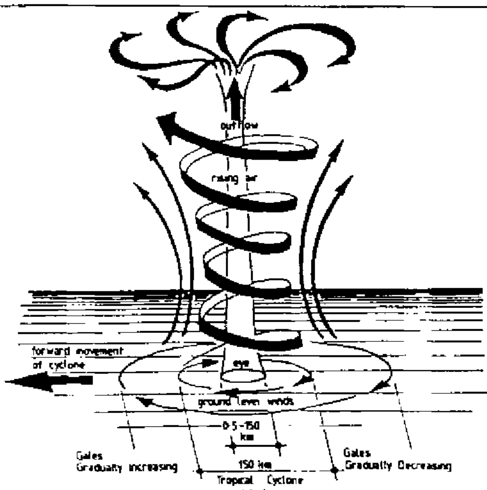
1	CENTRAL CLOUD BANK	- Substantial rising air violent precipitation
2	OUTSIDE CLOUD BANK	- Substantial rainfall.
3	TRADE WIND CONVECTION LAYER	- Rising moisture by convection
4	WIND FLOW OVER SEA SURFACE	Rising moisture from sea (fuel)
5	EYE OF THE CYCLONE	- Calm clear weather zone

The most important characteristic of a tropical cyclone in describing its intensity is the central pressure The strong upwards flow of hot air generated by the release of latent heat lowers the pressure at the centre which sucks in the low level air and thus creates the strong winds At the same time it acts like a giant straw sucking up the level of the sea above its normal level and creating a large mound of water which travels along with the cyclone and piles up against the coastline when the cyclone crosses the coast to form the storm surge Consequently in general the lower the central pressure the greater are the maximum winds and the higher is the storm surge

(Above diagram adapted from Munich Reinsurance, 1990).
(Diagrams below adapted from Trollope, Prof. D H 1972)



Diagrammatic Conception of the Structure of a **Tropical Cyclone** (North of the Equator)



Diagrammatic Conception of the Structure of a **Tropical Cyclone** (South of the Equator)

In association with the cyclone occurs a strong reduction in barometric pressure. This can cause a rise in the water level called a 'storm surge' Combined with wind driven sea water waves and astronomical tide, a rise of water level up to and often exceeding 10 metres can occur.

Consequently, damage to buildings during cyclones can consist of a combination of destructive high wind forces and widespread flooding.

"The most important characteristic of a tropical cyclone in describing its intensity is the central pressure. The strong upwards flow of hot air generated by the release of latent heat lowers the pressure at the centre which sucks in the low level air and thus creates the strong low level winds"

"At the same time it acts like a giant straw sucking up the level of the sea above its normal level and creating a large mound of water which travels along with the cyclone and piles up against the coastline when the cyclone crosses the coast to form the storm surge. Consequently, in general the lower the central pressure, the greater are the maximum winds and the higher is the storm surge" (Extracted from Munich Reinsurance, 1990).

Most people underestimate the effects and the power of a cyclone. It is therefore important to understand the magnitude of the forces and loads developed by severe events such as cyclones.

2.2 SEVERE CYCLONIC EVENTS

(a) PRESSURE AND FREQUENCY

Most cyclones have pressures between 950 mb and 985 mb with severe cyclones dropping to 920 mb or lower.

The lowest pressure recorded in a cyclone was 877 mb at sea level in Cyclone 'Nora' on 6 October 1973 over the Philippine sea by aircraft dropping a pressure recorder into the cyclone centre. The USA on Labour Day 1935 recorded 892 mb (Vickery D J, 1982:22).

The highest frequency of cyclones appears to be near the Philippines.

The areas where the greatest loss of life occurs are in the Bay of Bengal at the Bangladesh coast.

(b) WIND

Cyclone wind speeds normally vary between 30 m/s to above 60 m/s.

According to UNESCO records the strongest cyclone winds recorded were 320 km per hour or 90 m/s.

The areas with the strongest recorded winds caused by cyclone disturbances are in the Philippines in the western Pacific Ocean and around Mauritius in the Western Indian Ocean.

(c) STORM SURGE

Storm surges affect the Florida area of USA and the coastlines of the Gulf of Mexico, Bangladesh, and Vietnam most frequently and other countries in the cyclone regions from time to time.

A storm surge of 15 m in Cyclone "Mahina" (914 mb) (lat. 17°) in 1899 in Bathurst Bay, North Queensland, Australia, where a pearling fleet was destroyed has been well documented by the few survivors of that event.

The wave or storm surges that occur that cause such a loss of life in some areas are mostly 3 – 8 m above normal high tide level.

(e.g. Bangladesh: 1970 – 5 6 m with 400,000 lives lost; 1991 – 8.0 m with 140,000 lives lost).

(d) FLOODING

The worst flooding occurs in Bangladesh, with an area of 140,000 km^2, which has had 60% – 70% of the whole country flooded on a number of occasions.

China, made up of provinces, once had 85% of one province of 140,000 km^2 flooded in 1991.

2.3 REGIONS AFFECTED BY CYCLONES

Records taken over a 20 year period show that a global total of 2,000 cyclones have occurred in that period.

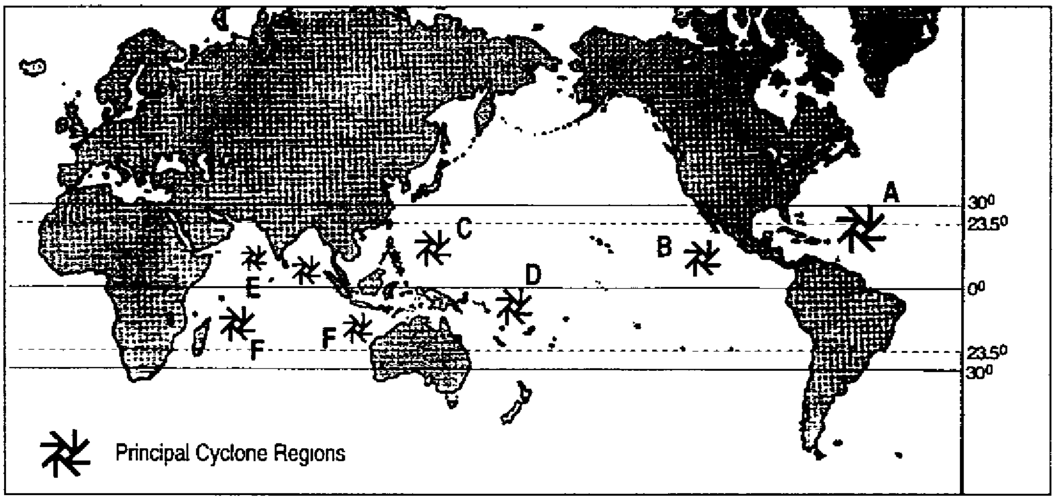
Distribution of cyclone events in the world's tropical regions is illustrated on the diagram.

Some 68% occur in the northern hemisphere and 32% in the southern hemisphere.

The regions affected with their cyclone season and the regions percentage of the total global events can be summarised as follows.

TABLE 1
CYCLONIC SEASONS AND TOTAL GLOBAL EVENTS

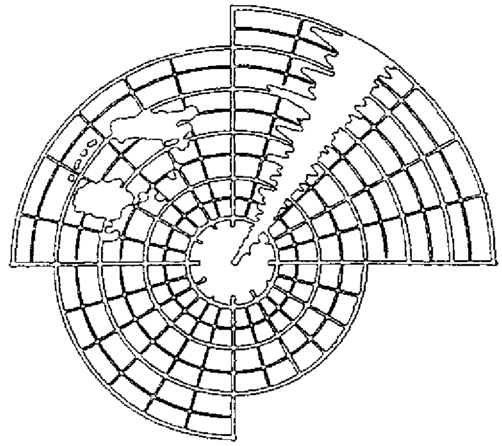
REGION	*SEASON*	*%*
North Atlantic – West	Aug – Oct	**12%**
East Pacific – North	June – Oct	**11%**
West Pacific – North	April – Dec	**30%**
West Pacific – South	Dec – April	**11%**
Indian Ocean – North	May – Dec	**15%**
Indian Ocean – South	Dec – April	**4%**



Distribution of Cyclone Events amongst the World's Tropical Regions

TABLE 2
CYCLONE AFFECTED COUNTRIES

REGION A North Atlantic - West			
Dominican Republic Bahamas Turks & Caicos Islands Dominica St Vincent Cuba Haiti Cayman Islands	Puerto Rico St Kitts & St Nevis Antigua Martinique Barbados Guyana Leeward Islands United States of America	Virgin Islands Anquilla Montserratt St Lucia Trinidad Tobago Colombia Venezuela	Jamaica St Martin Guadaloupe Grenada Netherlands Antilles Barbuda St Croix
REGION B East Pacific - North			
Mexico Belize	Nicaragua Guatemala	Honduras Costa Rica	Panama Hawaiian Islands
REGION C West Pacific - North			
Japan Hong Kong	China Philippines	Vietnam Guam	Thailand Micronesia & Caroline Islands
REGION D West Pacific - South			
American Samoa Tuvalu French Polynesia Papua New Guinea	Western Samoa Solomon Islands Cook Islands Australia - North East	Fiji Tonga New Caledonia	Kirabati Vanuatu
REGION E Indian Ocean - North			
Sri Lanka Pakistan	Maldives Myanmar	India	Bangladesh
REGION F Indian Ocean - South			
Mauritius Australia - North West	Madagascar	Reunion	Comoros Islands



3 DAMAGES CAUSED BY CYCLONES

CONTENTS

3.1 GENERAL DESCRIPTION
3.2 COMMONALITY WITH OTHER DISASTERS
3.3 CASE STUDY – BANGLADESH
3.4 SAFE SCHOOL PLAN IN BANGLADESH

3.1 GENERAL DESCRIPTION

Damages caused by cyclones are increasing as the world's population grows, as the poorer countnes develop to levels where their population is more able to purchase consumer goods and furnishings and live in better, more expensive accommodation.

In addition, the more developed nations see their population continuing to improve the value and quality of their possessions and insuring more.

Finally, more people are living in areas of risk, (e.g., valleys and coastal areas).

While economic losses in the decade 1980 – 1989 of $35 billion compared to $20 billion in the decade 1960 – 70 (a factor of 1.75), insured losses increased from $5 0 billion to $17 billion (a factor of 3.5) (Munich Reins. 1990:70).

Since 1990, the impact of disasters has continued to escalate greatly with cyclones in the Americas; the floods in China; the eruption at Mt Pinatubo in the Philippines; the earthquake in Kobe, Japan; and the 1995 floods in Europe among the major events.

The insurance companies are continually evaluating their position, reviewing the level and cost of insurance and identifying areas of high risk.

There are also sections of the affluent societies who rely on insurance and take less care in mitigating damages.

Some evacuate without adequate preparedness, thus increasing the risk and cost of damages.

Insurers will take steps to avoid these situations or place onerous conditions on these policies.

All governments are concerned with the mitigation of disaster events but their response is often mitigated itself by the nations ability to deal with the disaster events physically, technically, socially and financially.

For example, Bangladesh would have difficulty in fully responding to its 1991 flood, cyclone and storm surge disaster were it not for the donations and loans from the international community and national and international agencies technical assistance

Other countries with internal conflict find priorities re-arranged with protective measures deleted for more political reasons.

The full effects of the Kobe earthquake will set new standards of risk recognition and appreciation of the need to place mitigation action at a higher priority level

Cyclones and the storm surges and floods that accompany them have been responsible for the greatest loss of life of all disaster events.

Cyclones cause many affects on the environment and .community:

- Development of severe forces.
- Wind conditions dangerous to human life.
- Wind conditions that damage or destroy buildings.
- Under certain conditions, storm surges can occur.
- Very heavy rainfall and flooding.
- Denuding of vegetation.
- Damage to crops.
- Disruption of transport.
- Damages to services, power, sewerage, water supply, stormwater.
- Disruption to business and social life

The type of damages caused by cyclones to building structures can be summarised as listed hereunder The list is a summary of broad areas which will be dealt with in greater detail later in this paper.

- Removal of roof cladding, (sheeting and tiles).
- Removal of the immediate supporting framework, (timber roofing battens).
- Removal of supporting roof framing structure, (timber and steel trusses and beams).
- Removal of wall top plates
- Damage to walls, (brick, block, stone, timber), including demolition of same.
- Collapse of light framed and other building structures due to lack of bracing and stiffness.
- Serious damage to community infrastructure, (power poles, power lines, services).
- Serious damage to landscaping and environment by wind forces, violent rainfall, flood and landslides.
- Serious damages to communities by storm surge and wind damages.

The inability of the above structures to resist the wind forces emphasises the need for more education on techniques in building construction and design to enable all elements of building construction to resist these forces.

The examples of well designed structures which have survived should be better publicised and identification made of the reasons for their survival.

Broad policies should be adopted to provide:

- Better consideration by architects and engineers of disaster forces at professional level
- Better knowledge by professionals of a range of design details that resist wind forces
- Broader education of builders, inspectors and tradesmen at both technical colleges and at in-service training seminars.
- Better acceptance by manufacturers of their responsibilities to deliver better products and systems of passing on adequate fixing details

- Education of key individuals or departments at National, State and regional level in governments and non-government agencies.
- Education in basic knowledge of wind forces and preventative measures and preparedness to the general public and to school children.

3.2 COMMONALITY WITH OTHER DISASTERS

As various disaster events are studied, experts produce reports explaining the effects, the damages and the forces created by the event and list their recommendations and guidelines to be followed in construction to mitigate further damages. A study of the recommendations for damage mitigation to building construction for bushfires, earthquakes and cyclones reveals that at least 60% of the measures needed are common.

It is recommended that further studies into the commonality of recommended responses to various disasters be made which may save a large amount of money if proven common responses can be developed

3.3 CASE STUDY - BANGLADESH

In 1991 Bangladesh with a population of approx 116,000,000 suffered 233 km cyclone winds, an 8.0 m high storm surge and major inland flooding of the Ganges, Brahmaputra and Megna Rivers from prior heavy monsoonal rainfall.

Whilst the loss of life was reported to be as high as 140,000, the event deserves closer examination in comparison with previous events

The disastrous cyclone and storm surge of 5.6 m in 1970 caused 400,000 deaths when the population was approx. 58,000,000 to 60,000,000.

The enclosed diagram of statistics in 1970 and 1991 clearly show that the projection of loss of life from the 1970 event to 1991 in proportion to the doubling of the population from about 60 million to about 120 million would have caused about 800,000 deaths.

The actual loss of life at 140,000, painful to the nation as it was, showed a vast improvement below projections, indicating that 660,000 lives were saved.

Whilst this country is one of the poorest, it has shown remarkable progress in the two decades

Their satellite warning systems are vastly improved so that faster better warnings were available and people were able to move earlier to safer locations.

Some of the mitigation works in provision of better buildings were in place and helped save lives.

The government and its assisting agencies, both locally and overseas, may take some credit for the magnitude of its improvement in preparedness

Policies in place for the current decade 1990 - 2000 should show further significant improvements, especially if the "safe school" in each village programme is implemented.

The following diagrammatic sketches show one solution to overcome the wave surge problem adopted by government agencies

The provision of secure classrooms, with accessible concrete roof areas of the size shown can, in emergencies, accommodate 1,000 people in the rooms and balcony and 1,000 people on the roof, albeit in crowded circumstances, but safe until floods recede

The different designs shown are proposals for flood plains at different distances from the coastline, set at heights to be above the highest recorded storm surge heights at these locations.

Government departments have a number of school designs along these lines and implementation is proceeding.

The school could hold the normal village population of 2,000.

TABLE 3
FLOODS, CYCLONES, SEA SURGES IN BANGLADESH

ACTUAL 1970		*ESTIMATE 1990*	*ACTUAL 1991*
60,000,000	Population	120,000,000	116.000,000
400,000	Deaths	800,000	140,000
0.7%	Percentage of population killed	0.7%	0.12%
		SAVED	**660,000**
		EVACUATED	15,000,000

3.4 SAFE SCHOOL PLAN IN BANGLADESH

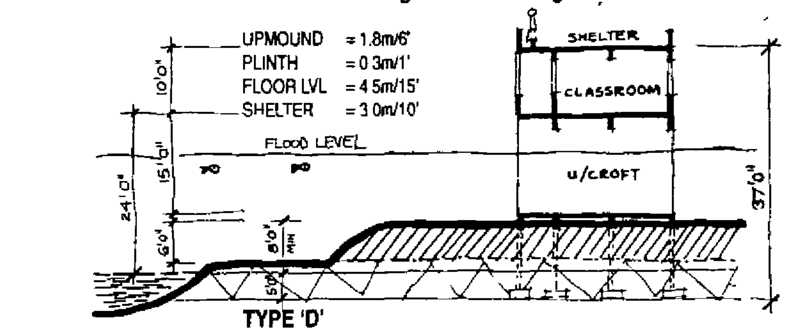
Current designs for schools aim to provide a secure school in each village of 2,000 people.

Depending on the proximity of the school to the coast and the risks of flooding by storm surges, the secure classroom block will be raised to safe nominated heights above the ground with open undercroft area at ground level of heights to allow design floods to pass under the classroom.

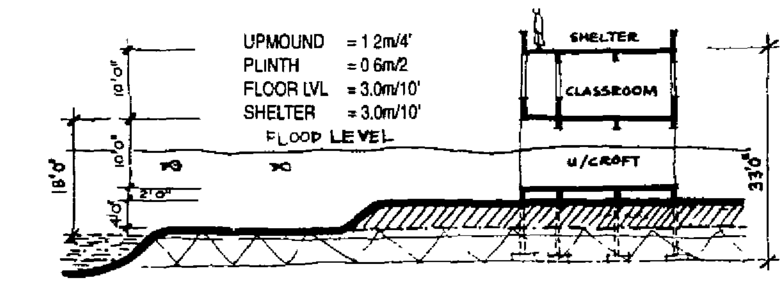
The classroom will provide access to a concrete roof with parapet.

In emergencies the village population could be given temporary accommodation in the school rooms and roof areas.

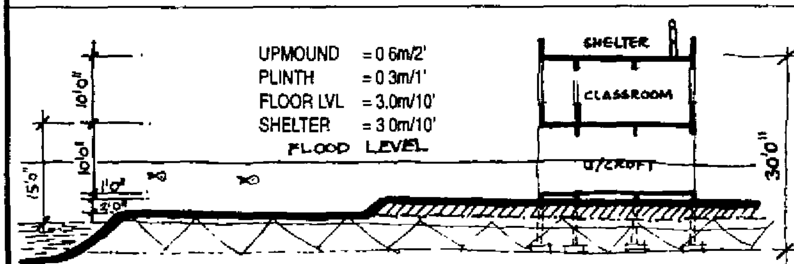
Coastal Schools – Recommended Height in Storm Surge Areas



TYPE 'D'
Within 15km/9 miles of coast

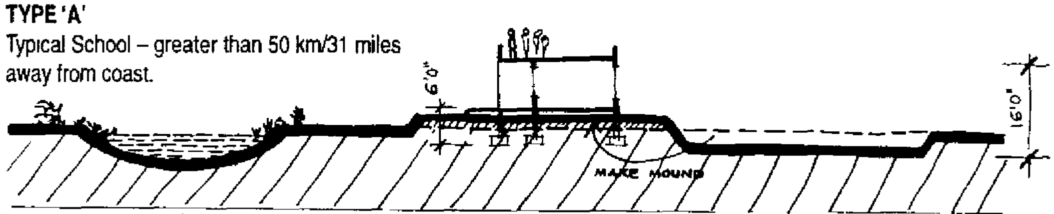


TYPE 'C'
Within 15–30 km/9–18 miles of coast

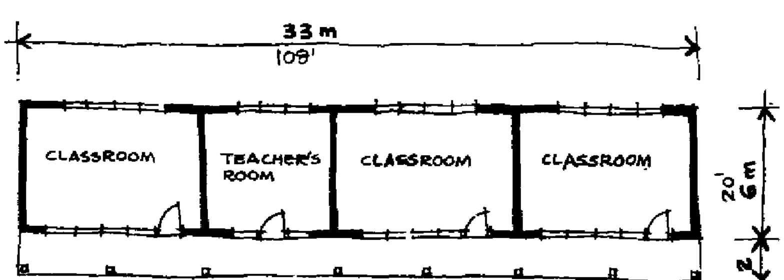


TYPE 'B'
Within 30–50 km/18–31 miles of coast

TYPE 'A'
Typical School – greater than 50 km/31 miles away from coast.

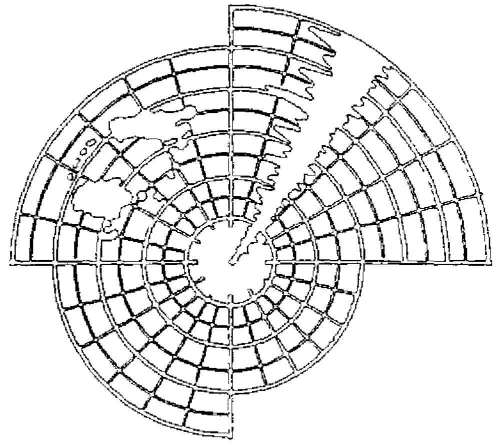


SECTION
Typical Bengali School



PLAN
Typical Bengali School for village of 2,000 population

Roof Area 270 m^2



4 SCHOOL TYPES IN CYCLONE AREAS

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4.2 WALLS, FLOORS AND ROOFS
4.3 TRADITIONAL CONSTRUCTION SYSTEMS
4.4 PRE-FABRICATION SYSTEMS
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4.6 SCHEDULE OF TYPICAL CONSTRUCTION TYPES
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- 4.7.1 Sri Lanka
- 4.7.2 Philippines
- 4.7.3 Vietnam
- 4.7.4 China
- 4.7.5 Bangladesh
- 4.7.6 Caribbean
- 4.7.7 Australia
- 4.7.8 Tonga

4.1 VARIATIONS

There are over 70 countries located in regions affected by cyclones

In the process of building construction and design of these school buildings it is noted that the methods of construction and materials used will vary a great deal, depending of a number of factors.

i	Country to country	Type of education system.
ii	Different climate zone	Tropics to temperate.
iii	Different types of terrain	Hills or plains
iv	Level of economy.	Poor to rich countries.
v	Political management.	Autocratic to democratic.
vi.	Sophistication.	Natural ventilation or air conditioning
vii.	Construction level	Technical and trade skill levels.

4.2 WALLS, FLOORS AND ROOFS

Floors will range from natural ground to crushed rubble and render to timber, to concrete floors in isolated slabs or in homogenous in situ slabs with concrete finish, natural or polished or with ceramic tile, terrazzo, sheet vinyl, vinyl tile or carpet on the floor.

Walls will range from concrete to stone or brick with face work or rendered finish, or concrete masonry block, reinforced or loosely laid, or to framed wall structure with concrete steel or timber portal frames and infill walls of brick or stud frame where walls are sheeted with sheet materials of fibre cement, metal cladding, plywood plasterboard or boarding.

Windows could be casement type, vertically sliding box frame, horizontally sliding box frame, horizontally sliding aluminium and glass, timber, metal or wooden louvre windows to awning type or pivot hung. Other windows are sheeted with galvanised iron casements and wrought iron grilles or still others are left open where climate demands prevail

Roof cladding and framing is sheet or tile on battens supported on rafters, or sheet roofing supported on purlins. Rafters are supported by beams or purlins which in turn are supported by trusses, beams or wall frames.

Prefab light weight trusses at close centres are also used to support batten and sheet or tile roofs. Still other have concrete roof structures with various methods of finish or waterproofing systems.

4.3 TRADITIONAL CONSTRUCTION SYSTEMS

Traditional systems of building have developed in each of the countries depending on the economy, materials and skills available.

For example a design for imported prefabricated steel truss frames in the hills of Papua New Guinea or Bhutan would soon be discarded when the cost of transport over long distances for days on poor narrow hilly roads is considered. Substitutions would be made with local materials such as log beams or locally made systems.

The above example of failed technology transfer points to the failure of the designer to properly consider the location of the building and the availability of materials, technology or of the local economy.

4.4 PRE-FABRICATION SYSTEMS

Similar problems with simple solutions to provide aid to developing countries such as delivery of sophisticated prefabricated schools of frames, panels and bolted connections may occur when the design, often made in a different climate zone, is delivered

Local personnel will mostly accept the school as a gift but often with one eye closed. When bolts rust, they are not replaced (none are locally available in that gauge or type), when panels are damaged they deteriorate without repair and the locals do not have the same feelings of responsibility to looking after the building than they would to one that they built themselves. The result is that the building can easily lose its structural integrity and fail in the next disaster.

4.5 DESIGN – UNESCO PRINCIPLES

The UNESCO general principles of educational building for classrooms in tropical areas are shown on the following diagram "Design Principles for Tropical Areas" which sets out certain recommended criteria for structure, orientation, ventilation, acoustics and seating arrangements for primary and secondary schools

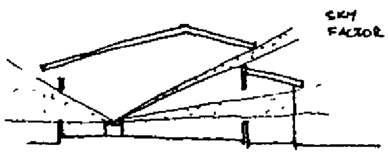
Desirable acoustics call for no student to be more than 6.0 m from the teacher and day lighting levels should illuminate the interiors to 100 to 300 lux.

Classrooms will vary in length from 7.0 m to 9.0 m and in width from 4.2 m to 7.0 m

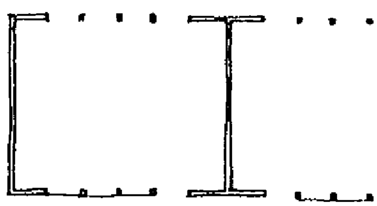
Most classroom buildings will be of single room width with a passage or open balcony along one side to allow maximum cross-ventilation.

DESIGN PRINCIPLES FOR TROPICAL AREAS

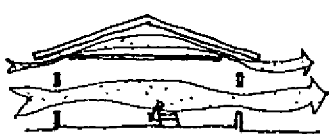
Source: Beynon, John (1986)· "General Principals of Good School Building Design which have relevance to schools in cyclone affected areas".



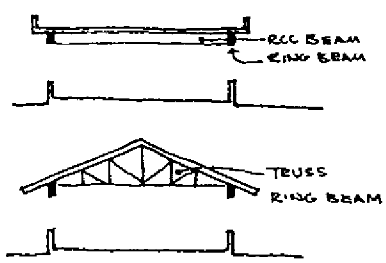
A. DAYLIGHT ILLUMINATION



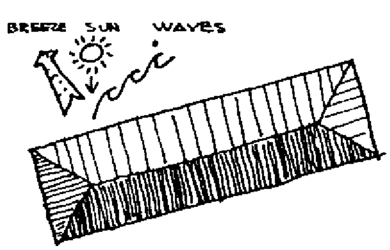
B. MAXIMUM OPENINGS



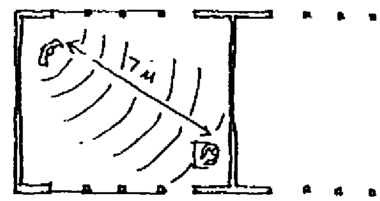
C NATURAL VENTILATION



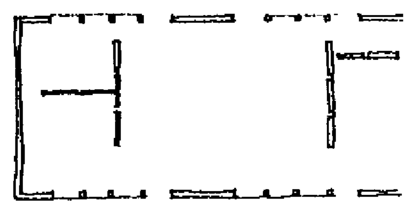
D. STRUCTURE



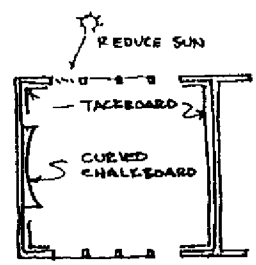
E. ORIENTATION



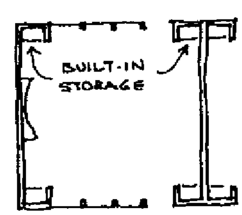
F. ACOUSTICS



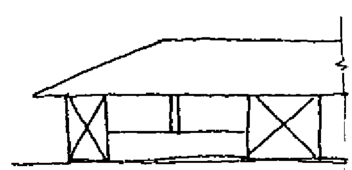
G. FLEXIBLE SPACE



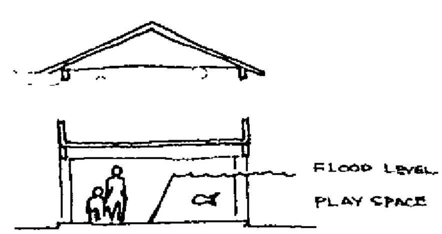
H. CHALKBOARDS/TACKBOARDS



I. STORAGE AS BRACING



J. BRACING



K. BUILDING ON STILTS J.B. 8.4.86