CHAPTER 3

THE CRITICAL NATURE OF HEALTH CARE FACILITIES IN DISASTER MITIGATION

3.1 RELATIVE IMPORTANCE OF HEALTH CARE FACILITIES

Most of the health services in the Commonwealth Caribbean Countries are provided by hospitals and health centres which are owned and operated by Governments. Hospitals normally provide emergency medical care, and secondary or tertiary medical care or both, whereas health centres deliver public health services and some basic primary medical care. Health Centres are called Polyclinics in Barbados.

Of the health care facilities, the acute care general hospital plays by far the most significant and pivotal role in disaster mitigation because of its primary function in treating injuries and disease.

The psychiatric and geriatric hospitals play a relatively minor role except where there is damage to their facilities, or there is a significant enough adverse psychological impact on individuals in the affected population to warrant their involvement.

As for health centres, their primary role is one of surveillance, even though historical evidence has shown that outbreaks of communicable diseases following natural disasters have been the exception rather than the rule[3].

Some health centres are also geared to treat persons with minor injuries, and this is extremely useful in relieving congestion at the acute care general hospitals.

(3) PAHO Disaster Report No.2 Jan.1983 - " Report on Disasters and Emergency Preparedness for Jamaica, St. Vincent and Dominica ".

STATUS OF DISASTER PREPAREDNESS - CARIBBEAN REGION

COUNTRY	HEALTH SECTOR DISASTER MANAGEMENT PLANS	HEALTH SECTOR DISTRICT PLANS ADEQUATE	HOSPITAL PLANS REVISION	DRILL	IDNDR NATIONAL COMMITTEE ACTIVE	HEALTH SECTOR COORDINATOR PART-TIME FULL-TIME	WORKING BUDGET NO=NO BUDGET NS=NO SPECIFIC BUDGET YES = SPECIFIC BUDGET
ANGUILLA	WEAK	WEAK	IRREGULAR	NO	NO	P	NO
ANTIGUA AND BARBUDA	SOME	FAIR	IRREGUALR	IRREGULAR*	UNDER DISC. + M.O.H.	P	NS
ARUBA	WEAK	WEAK	IRREGULAR	NO	NO	P	NS
BAHAMAS	SOME	SOME	ANNUAL	IRREGULAR	UNDER DISC. + M.O.H.	F	NS
BARBADOS	FAIR	SOME	IRREGULAR	IRREGULAR	UNDER DISC. + M.O.H.	P	NO
BELIZE	WEAK	SOME	IRREGULAR	IRREGULAR	UNDER DISC. + M.O.H.	P	NS
BERMUDA	GOOD	SOME	ANNUAL	IRREGULAR	NO	P	NS
BRITISH VIRGIN IS.	SOME	SOME	IRREGULAR	SOME AND IRREGULAR	UNDER DISC. + M.O.H.	P	NS
CAYMAN IS.	FAIR	WEAK	IRREGULAR	IRREGULAR	UNDER DISCUSSION	P	YES
CUBA	GOOD	GOOD	ANNUAL	IRREGULAR	YES + M.O.H.	F	YES
DOMINICA	GOOD	FAIR	ANNUAL	IRREGULAR	YES + M.O.H.	P	NS
DOMINICAN REPUBLIC	FAIR	SOME	SOME & IRREGULAR	SOME & IRREGULAR	YES + M.O.H.	F	NS
FRENCH GUIANA	GOOD	WEAK	IRREGULAR	NO	NO	P	NS
GRENADA	SOME	SOME	IRREGULAR	IRREGULAR	YES + M.O.H.	P	NO
GUADELOUPE	GOOD	SOME	IRREGULAR	NO	NO	P	NS
GUYANA	WEAK	SOME	NO	NO	NO	P	NS
HAITI	WEAK	NONE	NO	NO	YES + M.O.H.	P	NS

COUNTRY	HEALTH SECTOR DISASTER MANAGEMENT PLANS	HEALTH SECTOR DISTRICT PLANS ADEQUATE	HOSPITAL PLANS REVISION	DRILL	IDNDR NATIONAL COMMITTEE ACTIVE	HEALTH SECTOR COORDINATOR PART-TIME FULL-TIME	WORKING BUDGET NO=NO BUDGET NS=NO SPECIFIC BUDGET YES= SPECIFIC BUDGET
JAMAICA	GOOD	WEAK	SOME	PARTIAL	YES + M.O.H.	P	NS
MARTINIQUE	GOOD	SOME	ANNUAL	NO	NO	P	NS
MONTSERRAT	GOOD	SOME	ANNUAL	IRREGULAR	IN PROCESS	P	NS
CURACAO	YES	SOME	UNKNOWN	YES & NO	NO	P	?
BONAIRE	YES	-	UNKNOWN	NO	NO	P	?
SABA	YES	YES	YES	YES	YES	P	?
ST. EUSTATIUS	YES	YES	YES	NO	NO	P	?
ST. MAARTEN	YES	YES	YES	YES + NO	NO	P	NS
PUERTO RICO	FAIR	WEAK	IRREGULAR	IRREGULAR	NO	P	NO
SAINT LUCIA	SOME	SOME	IRREGULAR	IRREGULAR	NO	P	NS
ST. KITTS/NEVIS	FAIR	WEAK	IRREGULAR	IRREGULAR	NO	P	-
ST. VINCENT AND THE GRENADINES	FAIR	FAIR	ANNUAL	NO	NO	P	NS
SURINAME	WEAK	WEAK	NO	NO	NO	-	NO
TRINIDAD AND TOBAGO	FAIR	FAIR	SOME AND IRREGULAR	PARTIAL*	YES + M.O.H.	P	NS
TURKS AND CAICOS IS.	SOME	FAIR	IRREGULAR	IRREGULAR	NO	P	NO
US. VIRGIN ISLANDS	YES	YES	ANNUAL	YES	NO	P	NS

*FIRST AID TRAUMA
*USUALLY IN CONJUNCTION

May 1990

The Terms of Reference of the so-called Disaster Preparedness Committees invariably include the formulation of a formal Disaster Preparedness Plan, dissemination of its contents among staff in order to create an awareness and knowledge of the plan, the training of staff in the execution of the plan, and the conduct of drills and exercises to evaluate the appropriateness of the plan for the types of hazard envisaged. Plans are reviewed at frequent intervals.

(b) Buildings

Plans should include alternative arrangements for the case where there is serious damage to the hospital facility. The effects of hurricanes David, Gilbert and Hugo on hospitals in affected countries have clearly demonstrated that this is a serious deficiency in planning which needs urgent attention.

Experience has also shown that consideration must also be given in the design and construction of buildings to the safety, security and preservation of certain critical areas of the hospital such as the emergency department, the diagnostic facilities, the operating theatres, the pharmacy, the medical and food stores, and the utility backup services.

Emphasis in hospital design in the past was placed almost solely on provision of an optimum allocation of space, configured in such a way as to facilitate inter-related departmental functions and activities.

Because of the low cost of design and construction of the residential cottage type buildings, many of the older hospitals were built that way, and although this type of structure is highly resistant to damage by hurricanes and earthquakes, many of them were immobilised during hurricane Gilbert because of destruction of their open and fragile interconnecting walkways.

Capital Investments

Within recent times, much capital funds have been invested in hospital expansion and retrofitting, despite the fact that this capital is non-revenue generating, and will create an additional burden on governments in meeting the recurrent expenditures to run these facilities properly. This makes it all the more critical to make sure that these investments in social programmes in a time of economic stringency are secure and not subject to the vagaries of natural hazards.

Tourism

The case for the design and construction of new facilities and the retrofitting of existing ones to recognised engineering standards is further strengthened by recent shifts in the economies of these countries to a tourism base. This is because of the observed trend that the older wealthy tourists are holidaying in countries where the health services are good and available to them. In addition, there is a evidence that a fastgrowing component of the tourist market are visitors for educational and health purposes[6] .

Within the last two decades, tourism has become the industry that is making an increasingly significant contribution to the economies of most ot these island states. In some cases, it is the major source of foreign exchange earnings and the main support of economic growth.

It is a promising notion that the health care plant in the Commonwealth Caribbean can make a significant contribution to the economies of these countries through the medium of tourism . This is all the more reason for new health care facilities to be designed and constructed to withstand natural hazards, and existing ones to be similarly retrofitted so that this promise may be fulfilled.

[6] Alister McIntyre : "Developing Tourism" - Caribbean Affairs Vol.1 No.1 Jan-Mch 1988.

CHAPTER 4

DESIGN CONSIDERATIONS FOR NATURAL HAZARDS

4.1 GENERAL CONSIDERATIONS

Health care facilities present special characteristics of occupancy, complexity, critical supplies, hazardous items, dependency on utilities, and continuous interaction with the external environment. Too often, the admittedly infrequent cases of natural disasters are ignored in the planning and design of hospitals and related facilities - even in regions such as California where the risks are so well known. It is possible to accurately predict what may actually happen to an installation as a consequence of a hurricane, flood, earthquake or volcanic eruption, but given the variety of simultaneous activities which go on in a hospital, it is necessary to carefully analyze possible scenarios in order to avoid chaotic disruption.

An unsafe structure results in structural damage or collapse. If collapse occurs, there is major disaster and the hospital becomes a liability rather than a community resource. Major damage will result in evacuation and loss of service for an unknown time.

4.2 EARTHQUAKES

4.2.1 Seismic Design Requirements

Although this document is not intended as an engineering design manual, several problems of building design should be recognized by the health care facility owner, administrator, planner, architect or engineer as factors that may substantially increase the earthquake risk to their building, existing or new.

Seismic Hazard Evaluation

Proper seismic hazard evaluation, including local soil conditions, is of paramount importance. Although this is a general earthquake resistant design requirement, cases where this has been overlooked have led to catastrophic situations.

This means that the extent of damage to a building depends as much on its strength and the type of soil supporting it, as on the intensity and characteristics of the ground motion itself. Inadequate attention to foundation may give rise to differential settlements of footings. For instance, in extreme cases where liquefaction occurs, the building may suffer tilting, cracking and eventually non repairable damage, leading to a total loss. Settlements are also likely to occur if isolated footings of columns are sitting on different soil types. The same can be said if mixed foundations are used in the same building.

4.2.2 Seismic Performance Requirements

Design of new health care facilities in accordance with CUBiC is intended to ensure an acceptable level of safety. It is nevertheless recognized that for a large earthquake with a low probability of occurrence of intervals of several centuries, there may be some structural and non-structural damage, but life threatening collapse is improbable. This accepted risk criterion stems from the fact that it is not practical or economical to obtain absolute safety from any natural or man-made hazard. Nevertheless, the fulfillment of code prescriptions does not necessarily protect against many non-structural hazards.

Health care facility owners should also consider how to implement additional seismic performance requirements to protect the occupants and contents of their buildings. The basic strategy for reducing non-structural damage involves precautions in accordance with up-to-date requirements similar to CUBiC.

The following are suggested as seismic performance goals for health care facilities:

(i) The expected damage after an intense earthquake should be repairable and non-life threatening.

(ii) Patients, staff, and visitors should be protected during an earthquake.

(iii) Emergency utility systems in the facility should remain operational after the earthquake.

(iv) Occupants, and rescue and emergency workers should be able to circulate safely inside the facility.

These goals are intended to ensure that the facility will be available for its planned disaster response role after an earthquake.

Although some of these problems are addressed in seismic design building codes and performance requirements, their solutions reside moreso in the designer's understanding of the reported seismic response than in the specific code provisions. The problems are essentially concerned with site selection, building configuration, the non-structural elements, building ties, and non-structural issues.

4.2.3 Site Selection

For many years it has been known that local soil conditions have a definite influence on the characteristics of ground motions. Compacted hard rock-type grounds are likely to be accelerated with high frequency ground motions, in contrast to soft unconsolidated thick deposits where shaking tends to have longer period motions. More recently, it has been determined that topographic irregularities can significantly amplify the expected motions relative to flat terrain, and the topography of the basins which contain soil deposits may play an important role in the characteristics of ground motion.

Siting on top or close to active faults, or in tsunamic prone areas must be definitely avoided. Therefore site studies prior to the design and construction of a new facility are more than justified, and are normal procedures in the evaluation of the seismic vulnerability of existing installations.

4.2.4 Building Configuration

Engineers and architects have learnt that an important feature in the expected building performance is the regularity and symmetry in the overall shape of the building. All other things being equal, a box-shaped building is inherently less vulnerable than an L-shaped, a U-shaped building, a building with wings, or those with a tower rising from a lower structure. An irregular shaped building may twist as it shakes, thus increasing the damage.

It can therefore be concluded that :-

(i) simple rectangular buildings are the most desirable, the length being not more than about three times the width;

(ii) symmetrical buildings in plan and elevation are better than asymmetrical ones. Possible irregularities should be examined in both horizontal and vertical planes.

Effects of Non-structural Elements

This point has been mentioned with regard to possible damage which these types of components may experience or in fact cause. What this means is that certain non-structural elements may interact with the structure, somehow changing the expected dynamic response during the earthquake. This must be carefully evaluated in order to avoid unfavorable interaction.

Building Ties

Experience of past earthquakes has revealed that a frequent cause of distress has its origins in inadequate connections which tie the building or parts of its appurtenances together. Occasionally this can be due to lack of maintenance in corrosion prone areas. Particular attention should be given to the connections of precast facade elements.

4.2.5 Non-structural Issues

Beyond the mandated requirements of a code, the discipline to adjust to a code such as CUBiC requires a rational approach to design that focuses attention on a number of issues that are normally overlooked and can be avoided by rather inexpensive means.

For example, shelves that store medical supplies should be fixed to the walls to prevent them from overturning, or the containers from falling during intense shaking. Such reduction of nonstructural vulnerability may very well be the difference between a structurally safe, but useless facility, and a functional, operational installation in a post earthquake emergency phase.

4.3 HURRICANES

4.3.1 Design Criteria

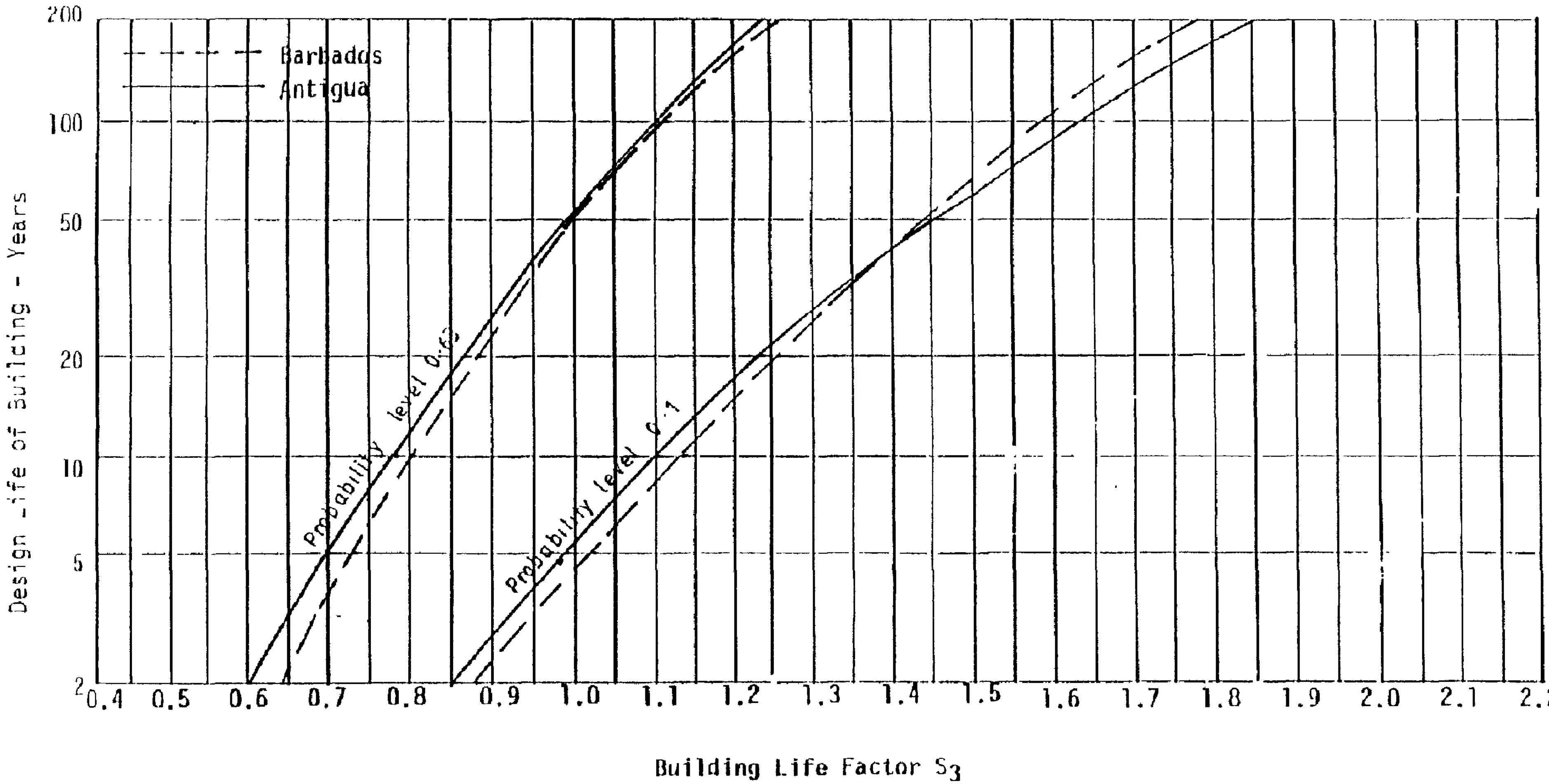
Some health care facilities and certain of their departments will be of more critical importance in the aftermath of a natural disaster than others. For example, acute care hospitals play a more critical role than health centres, and buildings which house life supporting equipment will require much greater levels of security than, say, those which house laundry facilities.

It is also worth noting that, with regard to intensity, hurricanes are an open-ended phenomenon. That is to say, there is no such thing as a maximum wind speed for all hurricanes. It follows, therefore, that one cannot economically design against the occurrence of every conceivable hurricane. It is therefore essential that at the time of the commissioning of consultants to provide designs for health care facilities, the brief is specific with respect to the criticality of the component hospital units and the wind design criteria to be employed.

The Saffir/Simpson categorization of hurricanes was set out in Chapter 2 of this booklet. The probability of the occurrence of a hurricane of particular intensity decreases with an increase in the category number. In other words, a Category 5 hurricane (catastrophic damage potential) is less likely to occur in any year than a Category 1 hurricane (minimal damage potential). In Figure 4.1, the building life factor, S_3 ,is plotted against the design life of the building for Antigua and Barbados at two probability levels. The S_3 factor is one of those used in the calculation of the design wind speed. It can be seen from the graph that the S_3 factor increases with the design life of the building for the probability of a particular wind speed being exceeded in any year.

The specification of design wind speeds must be done in relation to a particular averaging period over which the wind is measured. Typical averaging periods are 1 hour (Canadian Code), 10 minutes (Caribbean Uniform Building Code), 3 seconds (Barbados Association of Professional Engineers Wind Code) and fastest mile (USA Code).

FIGURE 6 - FACTOR FOR BUILDING LIFE



The following table lists the equivalent wind speeds for a 120 mph wind expressed for each averaging speed and shows clearly the need to specify the averaging speed:

Averaging Period	Wind Speed (mph)			
1 hour (Canada)	120	113	91	79
10 minutes (CUBiC)	127	120	96	84
Fastest mile (USA)	158	149	120	105
3 second (BAPE)	181	171	137	120

Designers often allow for security against Categories 2 and 3 hurricanes. It is advisable, though, that the most critical facilities be designed for Categories 4 and 5 hurricanes. Hurricane Hugo in 1989 was a Category 4 hurricane and Gilbert in 1988 was Category 5.

The determination of design criteria for health care facilities therefore requires firstly an assessment of their importance by health care managers, followed by the careful selection of design values in conjunction with the consultant.

The initial architectural brief prepared for the design of new health care facilities provides the best opportunity for health care managers to influence the safety of the completed structures with regard to natural hazards including hurricane force winds. Besides selecting the basic wind speed to be used in the design, other issues to be considered include the siting of facilities, building shape, and type of structure. These issues are addressed below.

4.3.2 Siting of Facilities

The intensity of hurricane force winds is modified by the topography of the surrounding area. Some examples are:

(a) Gently sloped valleys which act as funnels for the wind and accelerate its speed;

(b) Very exposed hill crests where acceleration of the wind is known to occur;

(c) Deep, steep sided, enclosed valleys which provide shelter from the wind;

(d) Heavy surrounding afforestation which provides windbreaks.

:count must therefore be taken of the effects of the nding topography when siting and designing structures.

Building Shape

)ome and polygonal shapes present fewer sharp edges to / adversely the flow of wind over the building. This leads wer areas of localised high wind suction and consequently an vement in security.

Most buildings, however, are rectangular in plan. Length to ı ratios of 3:1 or less are favourable with the most cient plan ratio for wind resistance being 1:1, which is a re. There is increasing vulnerability with increasing ratios /e 3:1.

L-shaped plan forms are also more vulnerable than square s. An increase in pressure occurs when the wind channels into junction between the two wings. In general, buildings which : asymmetrical in plan or elevation are more vulnerable to the :eral loads which winds generate than symmetrically shaped ildings.

Where lightweight roofs are employed on buildings, the shape : the roof will be the major factor in its proneness to ırricane damage.

.3.4 Lightweight Roofs

One of the most important elements of a building is its oof, the loss of which will result in much damage to the :ontents. The performance of roofs under wind loads is nfluenced by the materials used for construction. The best ;ecurity against high winds is provided by reinforced concrete ·oofs. Reinforced concrete slabs offer the best protection.

Throughout the Caribbean, lightweight roofs are commonly ısed for both private homes and public buildings. These are ;enerally constructed of corrugated metal sheeting on timber ›attens and rafters. Alternatively, the sheets, shingles, or ›ther cladding are supported on timber closeboarding on rafters.

In some cases, steel rafters and purlins are used. However, because of the relatively lower strength of lightweight roofing materials compared to reinforced concrete, lightweight roofs are inherently unsafe.

There are several measures which may be taken to improve the security of such roofs. The main ones are listed below:-

(1) Choice of roof shape. The order of preference for shapes is:

 (i) hipped (ie sloped on 4 sides),
 (ii) steep pitched gable,
 (iii) shallow pitched gable,
 (iv) monopitch,
 (v) flat.

 Experience has shown that pitches between 20° and 40° provide the best wind resistance.

(2) The use of heavier gauge sheeting, 0.5 mm minimum thickness for steel and 0.9 mm minimum thickness for aluminium. The thicker the sheeting, the less likely for it to fail under fatigue loading or pull through. Asbestos sheets are not recommended since these are brittle and more likely to suffer impact damage from airborne debris.

(3) The use of a closeboarded timber deck. This provides a second line of defence. The cladding then serves as waterproofing and its loss does not immediately lead to the failure of the roof structure.

(4) Screw fixings are less likely than nailed fixings to pull out under uplift forces and are preferred. A closer spacing of the fixings should be provided in higher suction zones adjacent to the eaves, gable ends and ridges. Fixings should be installed in the valleys of the corrugations as this will reduce the opportunity for flexure of the sheets and fatigue failure under the cyclical suctions generated by hurricane winds.

However, especially for sinusoidal sheet profiles, this may sometimes lead to leaking. If fixings are made to the ridges of corrugations, then spacer blocks should be placed between the sheets and the purlins.

(5) The use of short or no overhangs. If shading is required over windows and doors, separate canopies should be used. Failure of these would not endanger the roof.

(6) The provision of parapets to reduce uplift at the edges.

(7) The inclusion of ridge ventilators to reduce the internal pressure on the roof and walls.

4.3.5 Windows, Doors and Walls

Window and door openings are the next most vulnerable areas. Glass windows are particularly vulnerable and should be protected by using storm shutters. Where feasible, shutters should be fixed permanently to the building. This will ensure that they are always available and will eliminate the need for storage. Shutters may be made from timber, plywood or tongue and groove. Manufactured aluminium shutters are easy to install and are readily available in some countries.

External doors should be of robust construction and kept in good repair. It is not sufficient to rely on standard bolts to secure doors and large windows. The high pressures and suctions generated during a hurricane may cause bolts and hinges to fail at their fixings. It is recommended that braces be used to strengthen doors and window shutters. These braces may be secured in slots in the wall on either side of the opening or in brackets bolted to the wall.

The recent major hurricanes in the Caribbean have demonstrated that concrete blockwalls may be blown down by hurricane winds. Adequate reinforcement is therefore required for blockwalls.

4.3.6 Building Connections

It is imperative that all of the components of a building be securely interconnected. A well constructed roof will not stay in place during a hurricane if it is not attached to the rest of the building. The use of bolts and metal straps is recommended for connections. For timber to concrete connections, the bolts should be well anchored in the concrete members.

4.3.7 Summary

In summary, there are many measures which may be incorporated into the design of new health care facilities in order to ensure safety under hurricane conditions. Close communication should be maintained with the consultants during the design phase and the detailed scheme prepared with security against hurricane damage foremost in mind.

4.4 FLOODS

4.4.1 Design of Drainage Systems

In designing stormwater drainage systems for health care facilities, the level of design must be based on the relative importance of the facility. This relative importance can be determined by health care professionals.

Ordinary drainage facilities in the Caribbean are normally designed to accommodate runoff from storms having return periods of up to 20 years. However, on two occasions during the past twenty one years, in October 1970 and December 1977 respectively, Barbados experienced rainfall events that were estimated to have return periods in excess of 50 years[7].

Flood control systems for essential facilities such as health care facilities must have a higher level of design than non-essential facilities.

(7) Barbados Water Resources Study, 1977-78.

The following guidelines should therefore be used in arriving at criteria for the design of drainage systems:

(i) Pavements, especially vehicular accesses, should be free of excess stormwater in all floods having return periods up to 50 years.

(ii) There should be no ingress of water to main buildings in any event as a result of flooding.

(iii) Alternative travel paths for stormwater should be provided in case of blockage.

The time of concentration of the drainage basin, that is, the times used as the duration for the rainfall event, is small for such facilities, usually less than 10 minutes.

Rainfall intensities can increase significantly for small changes in duration for short duration events. As an example, in Bridgetown, Barbados, the intensity of a 15 minute storm having a return period of 25 years is 5.32 inches/hour, while the 10 minute storm having the same return period is 5.94 inches/hour, an increase of 12 percent. It is therefore critical that the storm duration is calculated accurately.

Since rainfall data from recording rain gauges are scarce for most of the region and totally lacking for many islands, recourse must be made to extrapolating existing data to arrive at values for higher return periods than available. In islands where there are no recording rain gauges, the records of the non-recording gauges can be used to arrive at rainfall intensity-duration-frequency curves by employing existing curves from a station in another island. In order to do this, the 12 and 24 hour records of the non-recording rain guages are used to determine return periods for these events. These figures are then plotted on the rainfall intensity-frequency-duration graph for the reference station, and the resulting curves are then extrapolated following the shapes of the curves of the reference station. Figure 4.2 shows curves for the Grantley Adams International Airport in Barbados which may be used as the reference station.

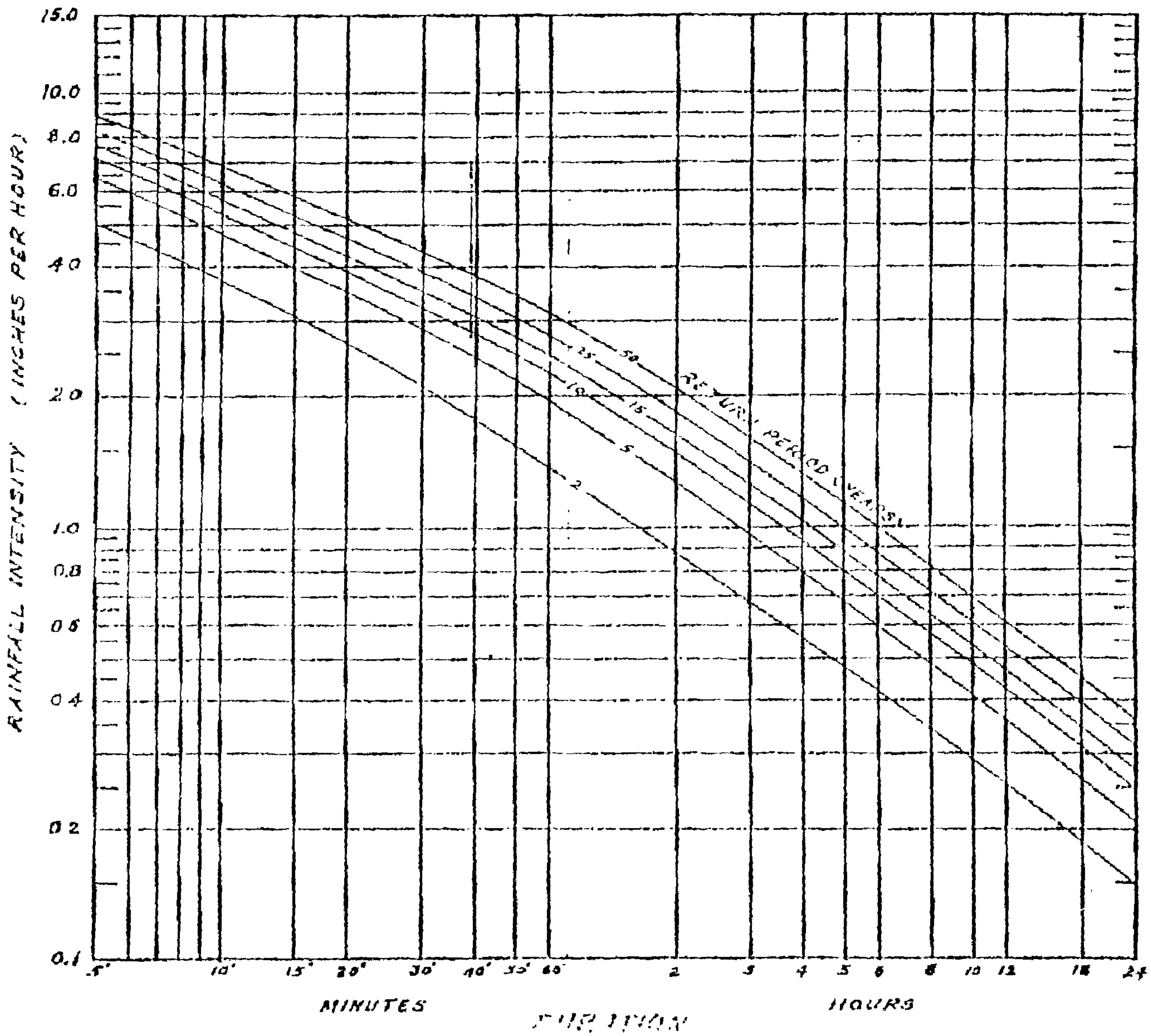


Figure 4-2

RAINFALL INTENSITY-DURATION-FREQUENCY CURVES

SEAWELL AIRPORT (X9)

Period: 1942-1970

Elevation: 183 feet above MSL

4.4.2 Siting of Facilities

Health care facilities located near water-courses, such as in valleys, or on flood plains are more susceptible to flooding than are those located on high ground or away from watercourses.

Conditions upstream of the facility influence the runoff to the facility. For example, dense vegetation reduces the peak rate of runoff by increasing interception of rainfall and by increasing the time of concentration whereas heavily developed areas increase the overall runoff as well as reduce the time of concentration, thereby increasing the runoff rate.

Facilities sited on high elevations are likely to have smaller catchment areas.

Subsoil Conditions

The type of subsoil conditions and ground cover as well as the method of stormwater disposal influence the volumes of runoff. For instance, in Barbados the coral limestone that lies [illegible] below the topsoil is very porous and fissured. This results in high absorption rates and also lends itself to subsoil disposal using suckwells.

In some of the other islands that are of volcanic formation, the soil is almost impervious and disposal must be by surface flow, usually in closed or open conduits, and eventually to natural watercourses or the sea.

Drainage Systems

The type of drainage system chosen has a significant effect on the overall performance of the system. Closed systems using pipes or box drains are more susceptible to blockage and are more difficult to maintain. On the other hand, earth swales and channels incorporated into the landscaping are easy to construct and maintain, and are also less costly and aesthetically pleasing. This type of system should therefore be considered whenever possible.

Maintenance of System

No flood control system can function effectively unless it is adequately maintained on a regular basis. Probably the single biggest cause of flooding of built facilities in the Caribbean is partially or totally blocked drainage systems or watercourses.

In designing drainage systems for health care facilities, engineers and designers should choose the system that meets all the previous requirements and is easiest to maintain in both the short and long term.

CHAPTER 5

DESIGNING NEW HEALTH CARE FACILITIES FOR MULTIPLE HAZARDS

5.1 CONCEPTUAL DESIGN

Conceptual design involves a series of decisions among which are:

(a) the siting of the building;

(b) geometry or shape or configuration of the building;

(c) the structural system;

(d) the materials of construction.

So basic are these issues that they must be addressed at the earliest stages in the development of a project. All parties should be involved at this stage - client, architect, engineers, constructors. Unfortunately, the present organisation of the building industry makes it difficult for constructors to be involved in design development. This places a greater obligation on architects and engineers to understand the construction process better, and be conscious of the implications of their design decisions on costs and facility of construction. Costs are affected by relative ease of construction, availability of materials, equipment and labour, and time for construction.

In some countries, the responsibility for monitoring costs is given to a separate discipline - the quantity surveyor. It would be better if the knowledge of costs resided in the minds of the designers. To take this argument to its logical conclusion, it would be better if there was one person (the conceptual designer) with the necessary expertise in architecture, engineering, cost estimating and construction. Such a person used to be the Master Builder. Arup described this notion succinctly: "Civilization is built on Specialization. Specialization may destroy Civilization."

5.2 THE DESIGN PROCESS

When engineers become involved in design, they take out their calculators too quickly. True design precedes detailed calculation. To be sure, some calculation is required in the process of design, but the principal calculations can only be done after the bulk of the design has been done. Mathematics is then a tool for refining the design and for determining the details of construction. This is not to downplay the importance of structural analysis and detailing. It is moreso to emphasize the proper chronology of these functions.

The building life cycle is as follows:

(1) Design (i.e conceptual design)

(2) Analysis

(3) Detailing

(4) Construction and Inspection

(5) Maintenance

(6) Demolition.

Each function is affected by each other stage in the cycle, but this is not at variance with the order of precedence given above. Good analysis cannot make up completely for bad design, and good construction can certainly not correct bad detailing.

5.3 COMPARISON OF DESIGN FEATURES FOR MULTIPLE HAZARDS

Designing against multiple hazards is more than doubly difficult, especially when those hazards are wind and earthquake. Many favourable features of wind-resistant design are unfavourable for earthquake-resistant design and vice versa:

(a) Heavy structures resist winds better. Light structures resist earthquakes better.

(b) Flexible structures attract greater wind forces. Stiff structures generally attract greater earthquake forces.

Both hurricanes and earthquakes impose horizontal loads on buildings. Earthquakes also impose significant vertical loads on a building overall. The vertical loading derived from wind is usually significant on those parts of a building which show certain aerodynamic characteristics.

There are however some similarities in the effective design and construction of buildings to resist hurricanes and earthquakes:

(a) Symmetrical shapes are favourable.

(b) Compact shapes are favourable.

(c) There must be a realization that there is a real risk that "design" forces may be exceeded. This is particularly so in the case of earthquakes where the design force is deliberately determined to be less than that expected during the anticipated life of the building. This leads to a requirement for redundancy in the structure and for "toughness" - the ability to absorb overloads without collapse.

(d) Connections are of paramount importance. Each critical element must be firmly connected to the adjacent elements.

There is a basic difference in the performance expectations in the event of an earthquake as opposed to a hurricane. A building is expected to survive its "design hurricane" with virtually no damage. Even a catastrophic hurricane should only lead to repairable damage. On the other hand the "design earthquake" is expected to cause some damage, hopefully repairable, and a catastrophic earthquake is likely to lead to a situation where the building cannot be repaired and must be demolished. In such an event, success is measured by the absence of deaths and serious injuries.

Table 5.1 summarizes the main differences between hurricanes and earthquakes as they affect structural design.

TABLE 5.1

Main differences between wind and earthquakes

		Wind	Earthquake effects
(1)	Source of loading	External force due to wind pressures	Applied movements from ground vibration
(2)	Type and duration of loading	Wind storm of several hours' duration; loads fluctuate, but predominantly in one direction	Transient cyclic loads at most a few minutes duration; loads change direction repeatedly
(3)	Predictability of loads	Usually good by extrapolation from records or by analysis of site and wind patterns	Poor; little statistical certainty of magnitude of vibrations or their effects
(4)	Influence of local soil conditions on response	Unimportant	Can be important
(5)	Main factors affecting building response	External shape and size of building; dynamic properties unimportant except for very slender structures	Response governed b building dynamic properties: fundamenta period, damping and mass
(6)	Normal design basis for maximum credible event	Elastic response required	Inelastic response permitted, but ductility must be provided; design is for a small fraction of the loads corresponding to elasti response
(7)	Design of non-structural elements	Loading confined to external cladding	Entire building contents shaken and must be designed appropriately

5.4 IMPLEMENTATION GUIDELINES

Structural configuration is the single most important factor in determining the performance of buildings subjected to earthquakes and hurricanes. The following recommendations are proposed and are particularly appropriate for non-engineered construction and for minimum-cost construction:

(1) Limit the height of buildings to two storeys.

(2) Use lightweight floors and roofs to reduce risks in earthquakes. Ensure that they are securely fastened to the walls to improve their performance in hurricanes. Alternatively, if concrete roofs are used as a hurricane-resistant strategy, ensure that the vertical elements (walls and columns) are conservatively built to carry the significant horizontal loads from earthquakes.

(3) The shape of the building should be, as far as possible, symmetrical. This symmetry also applies to the arrangement of partitions and openings. This would lead to a more balanced distribution of forces in the structure.

(4) Provide sufficient distance between openings to avoid narrow and slender piers. Keep the openings moderate in width to avoid long-span lintels.

(5) Link the heads of all walls together by providing a continuous collar or ring beam at floor and roof levels.

(6) Lightweight roofs should be not less steep than 20 degrees to improve their wind resistance. As a general rule, the steeper the better up to about 40 degrees.

(7) To improve their wind resistance lightweight roofs should have a hipped shape (sloping in four directions) rather than a gable shape (sloping in two directions) or a monopitch shape.

(8) To improve their wind resistance, lightweight roofs should have minimum overhangs at the eaves. In fact it would be better to have no overhangs and to introduce a parapet. The need to shade windows and doors from sun and rain may be met by separate canopies.

(9) The incorporation of ridge ventilators would reduce internal pressures and help retain lightweight roofs in a hurricane.

Clearly, the above recommendations are very restrictive indeed. But to vary significantly from them would require the conscious involvement of engineers to achieve safe construction. Today's technology permits almost anything to be done. In fact, it could be said that advances in technology are responsible for much bad design. Technology and the availability of funds permit badly designed buildings to be made safe. The aim is not to restrict design, but to sensitize people to those factors requiring caution.

5.5 IMPLEMENTATION CONSTRAINTS

The extensive loss of life and property caused by hurricanes and earthquakes can be avoided by the implementation of existing technology and without great financial strain. What is required is the will to do so. Because it would require about two generations to replace the building stock in most communities, as much attention should be paid to the retrofitting of existing buildings as to the improved design and construction of new buildings. At this time there are very few technical constraints governing the design and construction of most buildings against hurricanes and earthquakes. This is not to say that research and development should not continue. However, there are severe cultural, socio-economic, political and bureaucratic constraints to achieving success in this field.

Education and training programmes need to have a greater emphasis placed on the specific requirements of earthquake-resistant and hurricane-resistant design. At the higher educational levels, the subjects should be taught from the points of view of background studies and fundamentals. Experience has shown that the mere teaching of code procedures is not enough.

The lack of code enactment is a serious hindrance to progress in many territories. Of course code enactment would not be enough without enforcement. Funding agencies (loans and grants), domestic mortgage institutions and insurance companies could play pivotal roles in this regard.

5.6 PROCUREMENT, INSTALLATION AND MAINTENANCE OF EQUIPMENT

Not much attention has been given in the past to the procurement, installation, and maintenance of equipment in hazard mitigation, although there is ample evidence that this is an important factor, and simple, effective, and inexpensive measures can be taken at an early stage of construction or retrofitting to prevent costly damage at a later stage.

Where equipment will be exposed to the elements, it is important that, as far as possible, they should be protected against damage by hurricanes. Apart from ensuring the security of the plant itself, damage is prevented to adjacent structures from collapse of the plant or resulting airborne debris.

In earthquake prone areas, the specifications for and siting of utility installations are particularly important and must take into account subsoil conditions. Also, plant and equipment should be securely mounted and fixed to their foundations.

When ordering equipment, either directly or through a consultant, the design criteria for wind loads and earthquakes must be defined and specified in the tender document in relation to a particular code of practice.

Once equipment and fixings have been designed to withstand the specified criteria and delivered to site, it will next be necessary to ensure that installation is carried out in accordance with the manufacturer's instructions. Supervision of installation will be important.

Finally, there must be ongoing checks and timely maintenance of the fixings to equipment. Particular attention should be paid to the prevention of the corrosion of fixings. Whenever necessary, fixings should be replaced with no lesser specifications than those originally installed. The development of a maintenance manual is perhaps the best way to ensure that the above procedures are followed.