Reconstruction and mitigation programs in Jamaica post hurricane Gilbert

Prepared by:
Eng. Alfrico D. Adams
Consulting Engineer

Abstract

This paper briefly describes the island's exposure to hurricanes and earthquakes, and the impact of Hurricane Gilbert, 1988, on Jamaica.

It describes the then existing disaster mitigation strategies, and identifies the major areas of damage and failure.

It lists the steps taken immediately after the hurricane, to identify the deficiencies and set new strategies for repair, retro-fitting and mitigation.

Some damage observations and roof repair guidelines are summarized.

Comparisons are made between the costs of mitigation and the cost of repairs for low buildings, and recommendations are presented for improving mitigation measures in the future.

Prepared by:
Eng. Alfrico D. Adams
Consulting Engineer
Smada Consultants Ltd., Jamaica

1.0 Introduction

Hospital and health facilities play a critical role in the immediate post-disaster period for naturally occurring catastrophes, in particular, after earthquake or hurricane events.

Physical damage to these facilities affect their ability to provide for the emergency needs of their communities, at the time when their services are most needed.

Governments and relevant health-care professionals, have a duty to ensure that hospitals and clinics, not only continue to provide safe and effective facilities for the persons already under their care, but are in a position to make sudden increases in the scope and effectiveness of these facilities, during, and after disasters.

This paper describes Jamaica's experience from Hurricane Gilbert, 1988.

2.0 Jamaica's hurricane experience

Hurricanes are a constant threat to Jamaica. Year after year, tropical storms aim at the eastern arc of Caribbean islands, and appear set on a path through this arc to Jamaica.

Fortunately' few of these have actually impinged on Jamaica during the last 100 years of record. The frequency of damaging hurricanes has been low enough to ensure occurrence only once during the working life of the typical Jamaican adult. This has resulted in a rather casual attitude towards hurricane-resistant design and/maintenance, by both building maintenance officials and the lay-public at large.

Our Office of Disaster Preparedness, reported after Gilbert, that the population made poor response to appeals to the public, regarding long and medium term measures for hurricanes and for Hurricane Gilbert in particular. (Ref. 1)

3.0 Jamaica's most recent hurricane: Gilbert, September, 12, 1988

3.1 Maximum wind speed

Recorded 3 second wind speeds of 127-131 miles per hour (58m/sec) (Ref.3) were fairly close to the basic wind speed of 125 miles/per hour (56m/sec) recommended for design by The National Building Code, Jamaica and The Caribbean Uniform Building Code.

3.2 Damage estimates

Hurricane Gilbert caused severe damage in almost every sector of the Jamaican economy. Total damage (loss) to the Jamaican economy with its population of 2.4 million persons was estimated at between US$1.0 and 1.5 billion.

The national damage experienced in each of the sectors or utilities mentioned below, affected the health sector significantly, e.g., the level and quality of health care and emergency response were grossly affected by damage to water supply, sewerage, electricity, communications, and transportation systems.

The Health Sector

In the health sector, 23 of the 25 hospitals and half of the 377 health centres were damaged, mainly through the loss of roofs, roofbeams, ceilings and windows. Two of the hospitals were destroyed, while eleven suffered severe damage. The cost of repairs to this damage was estimated at US$13m.

Water Supply and Sewerage

Damage was estimated at US$12m. Over 50% of the water supply and sewerage disposal facilities, suffered damage varying from minor to complete destruction. Damage included Buildings and equipment, chlorinators, tanks, intakes, and pipelines.

Of the 40% of the system which depended on electricity, only 5% had stand-by generators. This further compounded the problems.

Electricity Supply

Damage was estimated at US$63m, and power supply islandwide was reduced by some 50%. Major damage was to the transmission and distribution network, with damage to wood poles being 20% and 30% respectively, and requiring replacement of 15000 wood-poles.

Telecommunications

Damage to local and international telecommunications was estimated at US$12m, and all forms of communication were badly affected.

Roads

Secondary and tertiary roads were estimated at a total repair cost of US$14m.

3.3 Buildings generally

Apart from Community and Public buildings, it was estimated that 25% of the total housing stock was damaged. 100,000 of these were low income houses, at a repair cost of US$100 million, and 35000 were middle and upper income, at a repair cost of US$225 million.

In general, buildings designed by professionals did well. Non-engineered buildings of the light-roofed variety, e.g. medium to low cost houses and generally poorly maintained light-roofs of all types, suffered badly.

Typical lightweight systems used on the roofs of both public and private buildings were:

> (a) Profiled aluminum sheeting attached to timber sheathing, or closely spaced wooden laths or on steel purling.
>
> (b) Wood or metal shingles on timber sheathing or battens.

4.0 Jamaica's earthquake experience

Jamaica falls in an earthquake prone region near to the edge of the Caribbean tectonic Plate.

Historically. the last devastating earthquake occurred in 1907. At the time, the lack of instrumentation meant that only Modified Mercalli Scale Intensity estimates of IX were available. Since then, moderate tremors of between 5.6 and 5.4 Richter Magnitude were felt in 1957 and 1993.

Local seismologists had recommended the use of effective peak acceleration EPA of 0.3g up to the 1993 event. Since then, however, the revelation that the 1993 event originated from a potentially destructive inland fault, and not offshore as previously anticipated, (Ref.6) has prompted a recommendation to increase the EPA value from 0.3g to 0.4g. This latter value is comparable with the maximum value recommended by the Structural Engineers Association of California for San Francisco.

Local seismologists have also advised that Jamaica is overdue for a major event. Jamaica is therefore in the position of being faced with the threat of a major earthquake, but with very few of its population with first hand experience of a this.

5.0 Hurricane and earthquake disaster mitigation strategies for buildings in Jamaica

It is important to recognize that Disaster Mitigation Strategies cannot be restricted to any one sector such as the health sector. Neither can it be restricted to one aspect of that sector, e.g., the proper construction of physical plant and buildings.

The strategy for hospitals and health care facilities must fit into the strategy for national disaster mitigation' otherwise, it would very soon be abandoned. Some of these strategies are, enforcement of Building Approval Standards and Codes, continuing education in the engineering profession, and the building industry and public education, which will influence the untrained sections of the labor force.

5.1 Building approval standards and codes

All Buildings constructed within given distances of the city limits, must be approved by The Local Building Authorities. This procedure is governed by Building Act Laws, applicable to individual urban centres or to parishes.

The Building Acts include Building Regulations which form the basis of Structural Evaluation of Buildings. Unfortunately, these are allowed to become out of date, with respect to design and material technology, mainly due to the lack of resources to ensure frequent and regular revisions. As a result, Building approval officers refer to the latest readily available international standard or code to supplement local documents, in approving Building designs.

In addition, during the last 12 years, two documents have been produced in Jamaica and the Caribbean, which, although they do not carry mandatory legal status, they have provided a valuable source of reference for local authorities and design professionals. They are:

1. The National Building Code, Jamaica, 1983 (Ref.4). Published with the status of recommended guidelines by the Government of Jamaica.

2. The Caribbean Uniform Building Code, 1986 (CUBIC). Published by The Caribbean Common Market under a project funded by The United States Agency for International Development and Caribbean Development Bank with Technical support from The Council of Caribbean Engineering Organizations.

These documents are now in the early and initial stages of review respectively before the issue of revised versions.

5.2 Continuing education in the local engineering profession and the building industry.

The Jamaican Institution of Engineers and the Council of Caribbean Engineering Organizations, have both gone to great pains during the last 20 years to educate local professionals on the rapid developments in design for disaster mitigation, particularly with respect to earthquakes and hurricanes.

This is essential, as these fields represent rapid changes in the academic curriculum of the engineer. There still remains the difficulty of disseminating such information to all engineers who should benefit from it.

5.3 Public education

It is recognized that trained professionals are generally engaged for the design and construction of significant buildings, but that the majority of building construction is still for housing and other small buildings. This category of buildings would not normally benefit from professional services. Various attempts have been made by the local office of Disaster Preparedness to educate the public through radio, television, and newspapers, on the essential elements of hurricane and earthquake resistance of buildings. This approach has also been extended to the print media with eye catching illustrations. (See Fig. 1)

This also helps the formal building industry, as it affects the site laborer whose training on site is normally restricted to his particular functions.

Courses have been planned and executed in conjunction with donor agencies, for small builders in both the formal and informal building sectors. Here too, the deficiency has been insufficient resources to fully saturate the public consciousness.

6.0 Reconstruction phase after hurricane Gilbert

6.1 Major causes of building damage identified.

Most damage to buildings was caused by lack of holding down capacity of the roof covering, or its secondary or primary supporting members.

Figs. 2(a) 2(d), 3 and 5, show photographs and illustrations of typical damage to roof elements. Figs 3-5 refer to hospitals. Jamaica was spared the worst excesses of total destruction of buildings by Hurricane Andrew in Florida in more recent years. The main reason for this was the Jamaican practice of using reinforced concrete masonry walls, even where roofing is light weight. This practice minimized both damage and casualties.

6.2 Post hurricane evaluation conference

Immediately after Hurricane Gilbert, the Jamaica Institution of Engineers, invited wind speed experts from Canada to join local engineers in evaluating the event and its implications for design and construction standards. Prominent among these were Mr. David E. Allen, Institute for Research in Construction, Ottawa, Canada, and Professor Allan Davenport, University of Waterloo, Canada.

An international conference was held five months after the Hurricane in February, 1989. This conference was attended by design professionals, national planning representatives, and managers of public utilities.

The conference concluded that the wind speeds recommended by the existing code, were appropriate. Later in 1989, the local Meteorological Office took a more conservative view of design wind speeds, and although not yet incorporated in the wind code, this has influenced design professionals in their selection of design speeds between 135 and 150 mph.

6.3 Measures taken to correct and mitigate damage

(a) ***A Review and Revision of Building Codes***

In the years following Hurricane Gilbert, the Government of Jamaica instructed the Jamaica Bureau of Standards to initiate a review of the existing local building code and standards, with a view to developing a new Building Code. This work has made slow progress, again, due to lack of resources. After much debate in committees, the review committee has acknowledged the good sense of adopting sections of the Caribbean Uniform Building Code wherever appropriate.

(b) ***Unofficial Decision to Avoid Aluminum Roof Sheeting***

In numerous instances of damage, the use of thin gauge profiled aluminum sheeting was found to be the cause of roof failures. Sheeting often tore around fasteners sometimes leaving fasteners intact.

A consensus developed among engineers and statutory bodies, to avoid the use of aluminum sheeting as a roofing material, and if used, to ensure 22 gauge minimum thickness.

(c) Every opportunity was taken, pending revision of the Building Code, to extend the concept of Importance factor used in earthquake design to wind resistant design. This concept applies a factor to increase design forces for buildings to be used for critical post-disaster facilities, such as hospitals health centres, police stations, schools to be used as shelters, etc.

(d) ***Retrofitting***

There is little in the way of statistics to suggest that undamaged buildings were modified ensure survival in future hurricanes. However, it was evident that damaged buildings which were repaired during the first year or 18 months tended to have modifications done, which would improve resistance to future hurricanes.

As time distanced us from the actual Hurricane experience, small buildings in the informal sector seem to drift toward the faulty designs based more on economy than hurricane resistance. It is clear that mandatory code provisions will be needed for this aspect.

7.0 Retrofitting measures for particular cases

Detailed information on the damage analysis of hospital structures has been unavailable, but the typical nature of hospital construction in pre-1988 construction, should justify the use of results of investigations on typical structures for other building applications.

The following analyses of damage and retro-fitting designs and costs, draws upon work done by The Urban Development Corporation (UDC), the Jamaican statutory body which was given the task of managing the reconstruction of the majority of the hospitals and schools damaged by Hurricane Gilbert.

Much of that information was summarized in a paper presented by John Pereira, former Deputy General Manager in charge of the Technical Services Department, UDC, to the Caribbean Disaster Mitigation Project Workshop, Trinidad, March 1995, and in presentation by others at the JIE/SCSE Seminar in 1989. As previously indicated, most of the damage was restricted to roofs.

7.1 Tabular summary of mechanism or cause of failures observed in typical roof systems

LOCATION OF FAILURE	PROBABLE CAUSE OF MECHANISM OF FAILURE	INCIDENCE
1. Sheeting to woodsheathing or laths	Tearing or rolling of sheeting. Static or fatigue (see fig. 2(a)	High
2. Timber Purlins/rafter connection	Pull out of nails (see fig. 2(a)	High
3. Rafter to wall plate connection	Poorly secured or missing strap (see fig. 5)	High
	Straightening of bent re-bar	Moderate
4. Wall plate held by 13mm wall rebar	Pull out of nail/screws (see fig. 2 (b)	Moderate
5. Connection of sheeting to Purlin	Failure of connection in uplift	Occasional
6. Truss support connection	Failure of dowel bars due to uplift (see fig. 3)	Occasional
7. Failure of edge beam		

7.2 Retrofit arrangements for damaged roofs

The following are some of the modifications made by the UDC in restoring damaged roofs.

DETAIL PRIOR TO HURRICANE GILBERT	DETAIL POST-GILBERT

1. Various types, thickness and lengths of profiled metal sheeting	Use of 26 gauge minimum steel sheeting with aluminum or galvanized coating in continuous sheets
2. Purlin Connection to rafters nailed	Sheet metal cleats for wood to wood connections
3. Rafters/Wall Plate Connections Metal, straps omitted partially or wholly, or connection nailed	Metal strap or cleat fixed to each rafter preferably to concrete belt beam.
4. Timber Wall- Plate held down by 13mm hold- down bolts at 1,35m centres	Wall plate hold-down bolts spaced at maximum 1,05m (42in) centres.
5 Timber Purlin spacing up to 1.2m (48in).	Maximum spacing 900mm (36in) centres
6. Screws to sheeting spaced at one per sheet or 900mm (36in)	Spacing of screws at 450mm (18in) centres. Spacing halved at eaves or overhangs
7. Open eaves for overhangs up to 900mm (36in) length	Boxed eaves used for overhangs exceeding 450mm (18in)

These are consistent with this writer's own practices, with the exception of item 6, for which the Building Code specification (See item 4) is more stringent.

7.3 Retrofit arrangements for combined earthquake and hurricane resistance

Perhaps because the only tremors in recent memory were moderate in magnitude at 5.4 to 5.6 on the Richter scale, there has been no attempt at retrofit for undamaged buildings.

On the other hand, in some cases where repair proved necessary, the opportunity was taken to improve resistance by:

(a) Introducing shear walls where possible (See Fig.4)

(b) Improving the strengths of damaged masonry walls by replacing with poured concrete, or introducing poured concrete stiffener columns.

7.4 Damage and retrofit to princess Margaret hospital

In the particular case of the Princess Margaret Hospital in Morant Bay, damage caused by Gilbert consisted of the total removal of the roof, damage to windows and doors, water damage to fittings, cupboards, work stations etc., and damage to wall finishes etc. (See Fig.3)

Subsequent to the hurricane damage, the building was vandalized and sanitary fittings etc.. removed.

Retrofit consisted of:

(i) Introducing shear walls to provide earthquake lateral resistance, and to compensate from the higher earthquake forces, expected from the new concrete roof - Approximate Cost US$55,000.

(ii) Replacing the original timber roof with a concrete roof to solve the problem of wind uplift; (See Fig.4) and non-structural works such as partitioning, windows, doors, plumbing, sanitary, and electrical installation and fitting, cupboards, workstations etc., cost a further US$1. 1 million

7.5 Costs of mitigation and repairs

An analysis of the added Costs in percentage terms of providing earthquake and hurricane resistant construction in Jamaica, was presented by John Pereira, and these can be rationalized and summarized as follows, for buildings of low rise (say 3-storeys). These relate to basic construction cost, excluding Mechanical and Electrical Services, fees, land and finance, and are mainly based on buildings repaired by the Urban Development Corporation, Jamaica.

These are consistent with the writer's own observations.

TABLE 7.5 COST OF MITIGATION AND REPAIRS (AFTER PEREIRA)

Element or Building System	Cost of Mitigation as % Increase on Overall Cost of Building	Cost of Repair or Replacement after a Major Event
Earthquakes and Hurricanes		
1. Bearing Wall (Reinforced concrete masonry)	8.0%	Up to 100%
2. Building Frame System (With some shear walls) 2 storey example	3.0%	Up to 100%
Hurricanes		
3. Roof System in single storey building	3.0%	15 - 30%

It is evident also, that the real costs of damage may be well beyond the values in column ' of the table if costs, such as damage to contents, and costs of temporary relocation of occupants are included.

8.0 Recommendations for improving mitigation measures in the future

8.1 Building code design forces for health facilities

Local building codes should be reviewed and revised regularly to:

> (a) Ensure ready availability of reliable design values, Examples of these are, basic wind speeds, seismicity (Zone Factors) and special provision for post-disaster facilities:
>
> eg. An Importance factor as recommended by the National Building Code, Jamaica, and the Caribbean Uniform Building Code, or the option of extending the recurrence interval beyond 50 years for basic wind speed, as recommended by the NBCJ. For the latter, the recurrence interval should be stated in the Codes. 100 years is a recommended interval (Ref.7)

8.2 The building approval and inspection system

The Statutory building approval and inspection system, must be strengthened and made more effective for all buildings, but particularly for health facilities.

8.3 Minimum thickness of profiled metal sheeting on roofs

At Clauses 4.6.11.4 (a) and 4.8.5.1 of the National Building Code, Jamaica, minimum, sheet thicknesses are recommended as 28 British Standard gauge (0.376mm) for steel sheeting and 24 British Standard Gauge (0.559mm) for aluminum sheeting.

These should be increased to 26 gauge (0.457mm) and 22 gauge (0.711) respectively.

8.4 Improved fasteners and connections to roofing systems

Deficiency in this respect caused the most damage during Hurricane Gilbert. The National Building Code Jamaica, requires minimum 3/16" (5mm) fasteners at 9" (230mm) minimum spacing for steel sheeting and 8" (200mm) for aluminum sheeting with 1/2 " (13mm) minimum diameter washers. If this had been observed, damage would have been vastly reduced. This needs to be adhered to. All timber ridge-joints - rafter bearings. and wall plates, should be connected by metal straps or bolts, adequately anchored to prevent uplift by wind.

It is vital also, that fasteners be spaced closer (a maximum of 150mm) at vulnerable roof edges, such as eaves, ridges, hips and gables.

8.5 Improved fasteners and connections to roofing systems

Research and Development work to counteract fatigue effects on sheeting fasteners. is currently being incorporated in the Standards Association of Australia, SAA Loading Code AS1170.

Part 2 : Wind Loads (Ref.8). This work should be considered for inclusion in local codes.

Simple illustrated manuals as companion documents to the code, would be useful to the small builder in this regard, as such requirements are only stated in general terms in the code

8.6 Vertical anchorage at beams, walls and foundations

For both Hurricanes and earthquakes, it is essential that vertical reinforcement be fully anchored from columns into foundations, and from columns into roof edge beams.

A major cause of the loss of the roof at Princess Margaret Hospital was the lack of anchorage c of the column reinforcing bars into the edge beams which supported the roof trusses. The concrete edge beams were lifted off with the roof and thrown to the ground.

8.7 Lateral bracing of lightweight framed buildings

As previously mentioned, the common practice in Jamaica of using reinforced masonry walls reduces significantly, the likelihood of lateral instability of our buildings. It is important however, to ensure that such walls are reinforced horizontally and tied together by reinforcement of junctions.

8.7 Roof Shapes and Vents

More stress should be placed in codes and public education on the advantages of tripped roof shapes.

8.8 Maintenance of Roofing Systems

Even. the best designed roofing systems are prone to deterioration due to weather and wear

Eg.
(a) Fasteners become loose due to shrinkage of lumber or vibration due to previous storms.
(b) Metal sheeting will corrode especially at fasteners
(c) Fasteners and their washers may degrade
(d) Timbers may rot, or may split due to shrinkage
(e) Leakage of water may accelerate any of the above.
(f) Reinforcing bars, metal straps and holding down bolts may corrode and lose their effectiveness.

All roofing systems should be inspected at least once per year, preferably before the start of the hurricane season, and repairs done immediately.

8.9 General

Whereas all the above mentioned provisions are important for specific roofing and building systems it must be realized that it is impossible to provide detailed provisions in codes or otherwise, for the many different systems that are available.

It is important therefore to:

(a) Ensure that design forces and the principles of hurricane and earthquake resistance are clearly set out and disseminated in codes for the benefit of trained building design professionals.

(b) Maintain mandatory standards for the quality of critical building materials eg. cement, concrete, blocks, steel, timber, profiled roof sheeting, fasteners.

(c) Strengthen and maintain the Building Approval Authorities and Building inspectorates to ensure that all designs are vetted for proper design and construction.

(d) Maintain a public education campaign to improve the understanding of all members of the public, of the general principles of hurricane and earthquake effects on buildings, and the precautions to be taken, both for the building and its occupants.

Jamaica has attempted each of the above, but none to the extent required.

(e) Develop summary guidelines or specifications based on existing or revised codes, which can be used by health administrators to instruct design and construction professionals engaged by them, on the more stringent requirements for hospital design and construction. E.g. Higher values of Importance factor, and/or recurrence interval for earthquake and wind respectively.

LIST OF REFERENCES

1. Seminar on Effects of Hurricane Gilbert on Buildings and Engineering Facilities in Jamaica. Presented by The Jamaica Institution of Engineers/Canadian Society of Engineers held on 16th February, 1989 in Kingston, Jamaica.

2. Disaster Report - Hurricane Gilbert Jamaica, September, 1988. Pan American Health Organization - Emergency. Preparedness and Disaster Relief Coordination Program. Report No.5 1989.

3. Design Values of Extreme Winds in Jamaica by Calvin R. Gray. National Meteorological Service, Jamaica 1989.

4. National Building Code, Jamaica, 1983. Published by Government of Jamaica as Recommended Guidelines.

5. Caribbean Uniform Building Code, 1985. Published by Caribbean Common Market (Caricom) under funding by United States Agency for International Development and Caribbean Development Bank.

6. Lessons from the Jamaica Earthquake of January 13, 1993. Seminar by Jamaica Institution of Engineers (JIE) Papers published in JIE Journal Vol.10 No.1 1992-1993.

7. A Guide to the Determination of Wind Forces by R.D. Marshall, US National Bureau of Standards 1975

8. Wind Resistant Low-Rise Buildings in the Tropics, by Mahen Mahendran. November 1995 Vol. 9) No.4 - Journal of Performance of Constructed Facilities - American Society of Civil Engineers - Technical Council on Forensic Engineering.