IMPROVING BUILDING CONSTRUCTION PROCEDURES IN THE CARIBBEAN STATES

A paper to be read at the International Conference on Disaster Mitigation Program Implementation

A. T. Wason, Prevention Adviser, Pan Caribbean Disaster Preparedness and Prevention Project

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By: A. T. Wason,
Prevention Adviser
Pan Caribbean Disaster Preparedness and Prevention Project

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IN THE CARIBBEAN STATES

1. NATURAL DISASTERS AND DEVELOPMENT

1.1 Records dating back to the sixteenth century show that
the Caribbean Region has been struck by a steady succession
of natural disasters including hurricanes, earthquakes and
volcanic eruptions.

1.2 In Jamaica from 1559 to 1951 the record of disasters has
been as follows:

<table>
<thead>
<tr>
<th>Disaster</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hurricane</td>
<td>69</td>
</tr>
<tr>
<td>Floods &amp; heavy rain</td>
<td>40</td>
</tr>
<tr>
<td>Earthquakes</td>
<td>12</td>
</tr>
<tr>
<td>Tornadoes</td>
<td>1</td>
</tr>
<tr>
<td>Landslides</td>
<td>3</td>
</tr>
<tr>
<td>Fire</td>
<td>10</td>
</tr>
<tr>
<td>Drought</td>
<td>5</td>
</tr>
</tbody>
</table>

The reported number of deaths from hurricanes and earth­
quakes in this period of 400 years is estimated at 9,600,
of which 3000 occurred in the 1692 earthquake and 1200 in
the 1907 earthquake. In addition, there were epidemics of
typhoid, smallpox and cholera accounting for significant
numbers of deaths and considerable suffering.

1.3 Most recently, the Caribbean has been affected by natural
disasters such as:

(a) **Hurricanes**

<table>
<thead>
<tr>
<th>Location</th>
<th>Hurricane</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barbados, Grenada</td>
<td>Janet</td>
<td>1955</td>
</tr>
<tr>
<td>Belize</td>
<td>Hattie</td>
<td>1961</td>
</tr>
<tr>
<td>Haiti</td>
<td>Cleo</td>
<td>1964</td>
</tr>
<tr>
<td>Dominica</td>
<td>David &amp; Fredrick</td>
<td>1979</td>
</tr>
<tr>
<td>Dominican Republic</td>
<td>David &amp; Fredrick</td>
<td>1979</td>
</tr>
<tr>
<td>St. Lucia</td>
<td>Allen</td>
<td>1980</td>
</tr>
<tr>
<td>Haiti</td>
<td>Allen</td>
<td>1980</td>
</tr>
<tr>
<td>Jamaica</td>
<td>Allen</td>
<td>1980</td>
</tr>
</tbody>
</table>
(b) **Volcanic eruptions**  
Martinique - 1902  
Guadeloupe - 1976  
St. Vincent - 1979  

(c) **Earthquakes**  
Jamaica - 1907  
Dominican Republic - 1946  
Antigua - 1974  

Most islands and Caribbean Basin countries have suffered from floods and landslides which have destroyed crops and added a significant long-term burden to the economy of the State.

1.4 The impact of the damage to a State caused by extraordinary occurrences such as hurricanes or earthquakes can best be judged on the basis of the State's ability to recover from the disasters. Recent surveys have shown that the ability of most Caribbean States to recover from natural disasters is perhaps currently at its lowest, while the value of destruction is increasing due largely to denser and more costly physical development. There is therefore an urgent need to recognise, in our planning of physical development, that disasters, (by definition), adversely affect the economy of a country, and that avoiding disasters is, in reality, a planning function.
The response to a disaster must lie in the state of the country's preparedness and in the mechanisms developed for mitigation of the disaster. Disaster preparedness is a national responsibility, but because of the close economic ties of the Caribbean States, the need to assist each State in its efforts to be prepared becomes a regional responsibility.

The Pan Caribbean Disaster Preparedness and Prevention Project (PCDPPP) was initiated in 1981 to provide regional assistance to each Caribbean State in developing preparedness organizations. The Caribbean Governments have traditionally responded to disaster threats by focusing on relief and emergency response at the time of the event, and in 1972, the Caribbean Health Ministers expressed concern about the effects of natural disasters in their region and urged the promotion of emergency preparedness in Caribbean countries. PCDPPP was born in 1981 out of this concern, and with the help of international relief and financing agencies which recognized the need for an effective regional body to coordinate all activities relating to disaster preparedness in the region.

The PCDPPP is sponsored by the following organizations:
- Canadian International Development Agency (CIDA)
- United Nations Disaster Relief Office (UNDRO)
- CARICOM Secretariat
- European Economic Community (EEC)
- League of Red Cross Societies (LRCS)
- Pan American Health Organization (PAHO)
- US Agency for International Development/Office of Foreign Disaster Assistance (USAID/OFDA)

The immediate objectives of the Project are to promote and facilitate the adoption of preparedness and prevention measures at the national and regional levels and, in particular, to provide technical cooperation, to the participating States, on request.
3. **HAZARDS MITIGATION PROGRAM, COMMONWEALTH CARIBBEAN**

3.1 In 1973, the regional organization of Engineers in the Commonwealth Caribbean, decided to develop a regional Building Code which would be adopted by each of the participating country organizations and which would be flexible enough to accommodate the environmental and social differences of the countries. This engineering organization, the Council of Caribbean Engineering Organizations (CCEO), had no mandate from the Governments of the CARICOM countries, and it was recognised therefore that the use of any uniform Building Code would depend on the voluntary acceptance of the Code by its users, the engineers and architects.

3.2 It was recognised that the Code has to address the major problems affecting building structures in the region and it was considered that the sections of significant importance to the region should be developed as soon as possible. By 1979 there were codes on Wind Loads, Reinforced Concrete and Masonry Structures, Electrical and Plumbing. The engineers and seismologists of the region were still debating the applicable seismic forces for each of our countries. These Codes were all developed on a voluntary basis and in fact the Wind Code which was developed in 1974 was and is being used as a teaching tool by the Faculty of Engineering of the University of the West Indies.

3.3 Historically, the regulation of building practices was accomplished through the various Public Health Acts which have had as their primary objectives the provision of sanitary living conditions. Other subsequent Acts such as the Factory Acts and later the Town Planning Acts included provisions designed to control not only the general layout of buildings but also the structure of buildings; but here again the objective was to ensure a suitable living and working environment.
3.4 However, significant advances in building regulations were made in Jamaica after the disastrous earthquake of 1907. The Kingston and St. Andrew Building Regulations of 1908 contain specific and detailed prescriptions for the design and construction of all buildings in the Corporate area. The Regulations prescribed detailed sizes of members, methods of connecting members, use of reinforcing steel, construction of roofs, floors and walls; and in fact the minimum construction details of all important parts of a building were described and made mandatory.

3.5 The 1948 Building Acts and Regulations of the other eleven parishes of Jamaica were patterned to a large extent on the Kingston and St. Andrew Building Regulations. Unfortunately, these Regulations containing as they do, prescriptions for building - using materials available in 1907, needed revisions to maintain their validity. The revisions were not made and the Regulations were more often breached than observed. It must be said, however, that the Regulations were designed to mitigate damage from earthquakes and provided competent design and construction practices based on the technology of the day.

3.6 There have been other Acts in the Commonwealth Caribbean which contained specific building instructions designed to mitigate damage from hurricanes. For example the Dominica Development Acts prescribed for the development of housing areas outside of the capital city of Roseau. These Acts were intended to control the planning of developments but also were intended to ensure that all buildings were constructed to specific minimum standards. It would appear that if the specifications laid down in the Dominica Acts had been followed, there would have been significant reductions in the housing failures even under the extraordinary forces developed by hurricane "David."

3.7 It should be noted therefore that before the formation of the Pan-Caribbean Disaster Preparedness and Prevention Project in 1981, there were in some States, Building Codes and Building Regulations
which, if properly enforced, could have been instrumental in mitigating some of the damage which occurred by the last two major hurricanes - "David" and "Fredrick" in 1979.
4. HURRICANE "DAVID"

4.1 On August 29th, 1979, Hurricane "David" attacked Dominica with winds of sustained speeds of 160 mph and gusts of 200 mph. The resultant death toll was 42 persons and the widespread destruction to buildings, public utilities, houses, infrastructure and agriculture was estimated to be EC $64.3 million as follows:

<table>
<thead>
<tr>
<th>Category</th>
<th>Estimated Cost of Reconstruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housing</td>
<td>5.3</td>
</tr>
<tr>
<td>Water &amp; Sewerage</td>
<td>2.3</td>
</tr>
<tr>
<td>Schools</td>
<td>2.4</td>
</tr>
<tr>
<td>Industry and Tourism</td>
<td>5.2</td>
</tr>
<tr>
<td>Public Buildings</td>
<td>1.4</td>
</tr>
<tr>
<td>Hospitals and Clinics</td>
<td>1.2</td>
</tr>
<tr>
<td>Port and Port Buildings</td>
<td>7.8</td>
</tr>
<tr>
<td>Telephones</td>
<td>3.0</td>
</tr>
<tr>
<td>Airport Buildings</td>
<td>0.1</td>
</tr>
<tr>
<td>Electricity</td>
<td>5.1</td>
</tr>
<tr>
<td>Agriculture</td>
<td>20.3</td>
</tr>
<tr>
<td>Roads and Bridges</td>
<td>10.1</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>64.3</td>
</tr>
</tbody>
</table>

The damage done (except to agriculture) is described briefly in the following paragraphs.

(a) Housing

It was estimated that of a total housing stock of 16,000, 8,000 houses or 50% of the housing stock, were seriously damaged. Of this amount 2,000 houses were completely destroyed, while 6,000 houses lost their roofs. Most of the damage occurred in the more densely populated southern part of the island which includes the city of Roseau, the capital of Dominica.

The housing stock before David was generally old, with about 81% of the houses being constructed of wood. The difficult terrain makes it particularly expensive for
services to be provided to all housing areas and a large percentage of the houses were inadequately served with water and electricity.

The main cause of the damage was similar for all houses - inadequate roof construction. The detailed problem areas recounted to the Consultant during interviews with persons whose dwellings were damaged were:

(a) Roof rafters and purlins were not properly nailed together;
(b) Galvanized roof sheets were not adequately fastened to purlins;
(c) Purlins too lights and spans too long;
(d) Rafters not properly fastened to roof plate;
(e) Where the buildings are of concrete, the lack of reinforced concrete ring beams and the lack of adequate fastenings of the timber plates to the ring beams.

The examination of failed dwellings also revealed that most of the dwellings which were badly damaged has lightweight roofing (26 gauge galvanized or bitumen fibre) on relatively shallow pitches.

The vernacular house, which by and large stood up remarkably well, is constructed of high pitch (40°) gable or hipped roofs of short spans, while the newer housing had low pitched roofs (15°) over relatively long spans. The shorter spans and steeper pitches allowed the traditional builders to use lighter roof structures with relative impunity. The modern builders continue to use the light structures but without recognizing the need for more careful detailing of the structural systems. This led to disastrous results under storm conditions.
(b) School Buildings

Nearly all of the schools were badly damaged, and necessitated urgent action so as to bring back some semblance of normality to Dominica social life. The Ministry of Education found that about $6 million was needed to rebuild or repair 64 schools.

The review of the damage showed that roof failure was the primary cause of problems leading, in some cases, to complete collapse of the walls. Most of the roofs were made of wooden trusses with 26 gauge galvanized sheeting. No roofs covered with aluminum sheeting survived. Some roofs remained partially intact, but the damage to windows, doors and internal partitions was significant. Some wooden structures were completely destroyed, partially by fallen trees and partially by being blown completely off of their foundations.

The response by the international community to the need for repair of schools was swift and generous and by November 13th, within two and a half months of the hurricane, sums totalling $6.07 million were pledged as follows:

Financial Assistance by Aid Agencies for Rehabilitation of Schools

<table>
<thead>
<tr>
<th>Agency</th>
<th>No. of Schools</th>
<th>Enrolment</th>
<th>Amount EC $ x 1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>British Development Division</td>
<td>4</td>
<td>1,486</td>
<td>322</td>
</tr>
<tr>
<td>Canadian International Develop-</td>
<td>10</td>
<td>5,016</td>
<td>348</td>
</tr>
<tr>
<td>ment Agency</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>USAID</td>
<td>41</td>
<td>12,900</td>
<td>4,172</td>
</tr>
</tbody>
</table>
Other local and foreign private organizations

<table>
<thead>
<tr>
<th>Agency</th>
<th>No. of Schools</th>
<th>Enrolment</th>
<th>Amount EC$ x 1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other local and foreign private</td>
<td>7</td>
<td>1,973</td>
<td>624</td>
</tr>
<tr>
<td>organizations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government of France</td>
<td>3</td>
<td>754</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>65</td>
<td>22,159</td>
<td>6,066</td>
</tr>
</tbody>
</table>

(c) Health Buildings

The maintenance of health facilities during and after a national disaster is of primary importance to the community, and the loss of any part of the existing facilities compounds the problems of providing basic health services to a battered community.

The major health building damaged was the Princess Margaret Hospital in Roseau. The hospital is constructed of a series of single and two-story buildings on sloping land. Construction varies, but is mostly of reinforced concrete block walls, concrete floors, timber roof trusses and sheeted roofs.

The hospital suffered primarily through the loss of roof sheets from nearly all of its twelve buildings with the exception of the laboratory building which has a concrete roof. Examination of the damage indicated that the roof structures were particularly vulnerable, having shallow pitches with large overhangs without adequate holding-down mechanisms. All walkways were virtually destroyed and a timber annex completely destroyed.

The building services - water, electricity, and telephones were also vulnerable. An emergency water
tank was not functioning due to a defective valve and the overhead telephone lines connecting the switchboard to the individual wards were also vulnerable to high winds. Electricity distribution within the hospital also depends partly on overhead lines, all of which should be underground.

There was significant damage to windows. The damage to the window frames showed that the frames themselves were not sturdy enough to withstand the pressures applied. They broke at about the midpoint. The aluminum louvre windows stood up fairly well but these windows leak under a driving rain and should be redesigned for use in exposed conditions. Many light timber doors were badly damaged, due partly to inadequate closing mechanisms, and partly to damage by flying debris.

Repairs to the roofs were given priority by the hospital management and the damaged timbers and roof sheets were replaced fairly quickly. There was evidence, however, that not enough care was taken to strengthen the construction, although some hurricane-resisting metal ties were used. This inadequate standard of reconstruction is understandable under the circumstances prevailing at the time. It is considered, however, that there should be a determined effort to install holding down ties, heavy doors with adequate bolts, and hurricane-resisting metal straps, and hurricane shutters to all windows.

The failures are typical for all buildings similarly constructed. They indicate the problems that must be dealt with in providing basic facilities that withstand hurricane force winds. The failures were generally caused by poor fixings of room sheets and
roof, purlins, and badly maintained windows and doors, some of which were torn off by the wind.

The other health facilities, including sanitary facilities in the rural areas and rural health centres, suffered damage to varying degrees and the estimated cost of repairs was EC $500,000.

(d) Ports
The main port in Woodbridge Bay was badly damaged, and required a major reconstruction effort costing about $10.8 million. The main damage was as follows:
- Destruction of the main retaining wall and collapse of part of the fill area;
- Collapse of a produce shed;
- Loss of roof sheets from storage warehouses.

The buildings suffered because of the loss of lightweight roof cladding, collapse of part of the fill and undermining of parts of the concrete floors. There was consequential collapse of some enclosing concrete block walls. In general, it appears that while some of the buildings were apparently designed to withstand hurricane winds of 120 mph (over an average period of 3 seconds), the design criteria were applied only to the building frame and did not include the secondary but important members such as roof cladding and external walls.

The causes of failures of the marine structures were the high seas which attacked the Woodbridge Bay Port and destroyed the rock protection. At Portsmouth, the banana jetty structure was in a dilapidated condition and collapsed readily.

(e) Other Buildings
Other major buildings which suffered extensive damage
were a 40-room hotel which lost most of its roof with consequential damage to windows, doors, etc., a major church in Roseau which lost its roof and suffered major structural damage to stone columns and supporting arches, and a twenty room hotel which was completely destroyed. The causes of failure were all similar - lack of adequate fixings for the roof and the use of lightweight roof sheets.

(f) Electricity

Before "David", eighty percent of the electricity supply was generated by hydroelectric plants located on the Roseau River about 5 miles from the City. The damage to the generation system occurred through major damage to the penstocks and pipelines which were broken by large boulders. One power station lost its roof and a turbine was consequently damaged. Outside line plant was almost completely destroyed, most of the damage being generated by trees and flying objects striking the utility poles and cables. It should be noted that the difficult topography makes large unprotected spans necessary, and it is not possible to prevent damage to the cables from falling trees. The cable system is designed in accordance with the relevant British Standard to withstand wind forces generated by 75 mph winds. The Electricity Company (Domlec) reports it appeared that there were very few failures due to wind loads on the cable system, but the failures were mostly due to objects striking the cables or poles. The Company is being encouraged to design the system to withstand winds of 120 mph.

There appears to be very little that can be done to abate the hazard from high winds except to ensure that the design standards be upgraded and that maintenance of the pole system be improved so that decayed poles
are replaced promptly. The emphasis therefore should be on ensuring that the recovery rate can be speeded up. This can be accomplished by having an adequate funding for labour and minor items.

(g) Telephones
The telephone system, both internal and external, is owned and managed by Cable and Wireless (W.I.) Ltd. The cable plant is mainly overhead and in the event of a storm, most of this plant will be lost as was the case in St. Lucia during hurricane "Allen".

During hurricane "David" 85% of the line plant was destroyed. By April 1, 1984 about 90% of the pre-David service had been restored. The Company has pointed out that there are remote areas in Dominica which, prior to "David" had telephone service, but because of low demand and high costs, are uneconomical to service.

The telephone poles used are of imported pine. The system is guyed at each angle in the route and at about every six poles in a straight run. It is recognized that the cable systems are completely exposed and vulnerable. The Company has a back-up system for its overseas links and while the internal system generally failed, the overseas link was always open and overseas service to those subscribers who were on the underground network in Roseau was possible.

As with the electricity system, it is not possible (at reasonable cost) to secure the telephone line plant from serious damage and interruption to service. One small substation was destroyed and this could have been averted, but the other telephone buildings remained intact. The microwave links go a long way towards reducing the vulnerability of the trunk routes.
However, except for those areas served by the U/G system within the main city, the junctions from the microwave receivers switching stations to subscribers will be largely unprotected.

(h) Roads and Bridges
Damage to the road network as a result of Hurricane "David" was remarkably light. Four short sections of the West Coast road were undermined, and some other sections of the main roads suffered some damage. The roads in Dominica have been deteriorating for some time and the hurricane, which would be expected to lead to significant damage, did not add appreciably to the poor condition of the roads, except for small sections where landslides and trees blocked the road or where wave action undermined the pavement.

The major bridges in Dominica are, with very few exceptions, more than sixty years old and most bridges need replacing. The capital programmes now in hand will replace some of the bridges but those not being replaced add to the vulnerability of the system. It is presumed, therefore, that the road system will continue to have elements of vulnerability which can only be removed by a planned investment program for replacement of the bridges.

(i) Water Supply
The hurricane caused disruption to 19 of the 33 water systems on the island. Damage consisted of broken pipes, clogged intakes, and loss of reservoir roofs. Within 2 months of the disaster, all but 6 systems had been restored to service. As was the case with the electricity services, the completion of reinstatement works depended on the financial ability of the Central Water Authority to undertake the work required. The work is now completed but because of lack of material
in Dominica, the project took about 18 months or nearly six months longer than was scheduled.

The water system will remain vulnerable largely because of vulnerability of the intakes located in river beds. During floods, boulders of up to one metre in diameter are transported down the river to lodge in the intakes and become cemented with clay and sand. The clearing of blocked intakes is a difficult and time-consuming operation. In some cases, intakes may have to be abandoned and new ones constructed. This is a feature of topography and cannot be easily averted. Recovery depends on the severity of the problem and the manpower available.

The other areas of vulnerability as revealed by hurricane "David" are the treatment plants and suspended pipelines. The treatment plant buildings can be made secure by carrying out the standard precautions of tying down the roofs and using concrete roofs rather than timber roofs. Where pipelines have to cross streams, it is difficult to be completely secure against rampaging waters carrying large boulders. It may be possible in stream crossings, where the pipes cannot be buried, to construct a suspension system which can carry the pipes above the level of the flood waters.

The cost of recovery of the water systems was in fact relatively small, and if the Central Water Authority were better equipped financially to deal with the emergency, full service could have been restored considerably sooner. It is therefore recommended that the Central Water Authority be encouraged to stock an adequate quantity of pipes and fittings at all times, that special attention be paid to treatment plants to ensure that the buildings are secure, and that supplies of chlorine and other chemicals needed
for water treatment be adequate for emergency purposes.
5. VULNERABILITY ANALYSIS

5.1 The basic problems found in the review of the impact of hurricane "David" have been recounted in some detail to convey a picture of the causes of the damage to the buildings and infrastructure systems. Very fortunately, the rainfall which accompanied these hurricanes was light and caused only minor damage.

5.2 The main causes of building failures were:
- Decayed timber;
- Inadequate holding-down mechanisms for roofs;
- Corroded roof sheets;
- Inadequate holding-down mechanisms for prefabricated buildings; and
- Use of light gauge aluminum or galvanized iron sheets.

It is fortunate that the centres of administration of Dominica are housed in concrete buildings constructed within the last 35 years. Damage to these buildings was limited to windows and peripheral attachments. The older Government offices which are generally housed in timber buildings, which in most cases show signs of decay, are completely vulnerable to high winds. It would be difficult, without complete rebuilding, to design an economical program to reduce the vulnerability of these buildings.

5.3 The water systems failed because of silted intakes, pipelines damaged by landslides, and pumping systems not functioning due to lack of power.

5.4 The power systems failed largely because trees and other objects fell on conductors, and, in a minority of cases, because of pole failures. In St. Lucia the failure of a power station roof led to the failure of a generator.

5.5 The telecommunications systems suffered as did the electricity systems, from falling trees and flying debris.

5.6 Roads were blocked by landslides and falling trees, but because rainfall was light the road damage was not severe.
5.7 Damage to ports was mainly to the buildings which lost their roofs. In Dominica however, major damage was sustained by the port structure due to high seas generated by the hurricane winds.

5.8 The failure to school buildings was widespread. Schools constructed from about 1950 onwards followed a simple design principle. The buildings are rectangular with exterior corridors, generally on the leeward side, protected by cantilevered roofs or floor slabs. Windows on the windward side are louvered jalousies and on the corridor side are steel mesh or open block-work. Under hurricane conditions the wind direction shifts, and the openings normally on the leeward side, may then be on the windward side. This new condition, in which the louvered jalousies are closed and the fixed openings are on the windward side, leads to increased internal pressures which add to the uplift forces on the low-pitched roofs. For these reasons, and where additionally the construction details were faulty, or the building maintenance deficient, the roofs failed.

5.9 A Survey recently carried out in four Eastern Caribbean States for PCDPPP has suggested remedial measures to reduce the vulnerability of the school buildings. Such measures include providing hurricane shutters, retrofitting roof ties and straps, increasing fixings of roof sheets. Until these measures are put in place fully, most of the school buildings in Dominica must be considered vulnerable to hurricanes, and should be examined very carefully to ensure that all roof fixings are in place, that doors and windows can close properly, and that decayed timber is replaced promptly. Such inspections should be repeated at regular intervals.

5.10 Houses, especially those of low income families, present the greatest challenges. In Dominica, under conditions of extraordinary hurricane severity, there were 8000 houses badly damaged including 2000 that could not be repaired.
In fact, a little hamlet near Pichelin in the south of Dominica was completely destroyed.

5.11 The failures which have been described earlier, were in many cases, due to the fact that the older timber houses, generally occupied by working class persons, were decayed. It is indeed surprising that some older timber houses constructed in the traditional design concepts, are seriously decayed, but are still standing. However, the newer houses whether of timber or concrete block which failed did so because of improper construction practices.

5.12 The traditional working-class house design of small spans, high roof pitches and hipped roofs has been forgotten in favour of a new aesthetic with low pitches (in some cases a mono pitch) and larger roof spans. Unfortunately it is apparent that the new aesthetic did not bring with it improved use of materials, and the same traditional rafters and lath construction was used for the new, flatter roofs.

5.13 It is difficult to state precisely what caused the failure to these small buildings, but bad construction and unfortunate design concepts were certainly factors which contributed to the failure of newer dwellings, while decayed timber and corroded roof sheets contributed in large measure to the failures of the older houses.

5.14 The principles of providing hurricane-resistant housing are fairly well established, and there have been many seminars and illustrated papers on the topic. It is apparent, however, that the principles are not understood by the builders of low-income housing; nor, as evidenced by the construction techniques used in some Government building projects and schools, by builders of medium sized, important buildings.

5.15 In as much as the majority of low income housing is still being constructed privately, it would appear that the lessons to be learnt from the hurricanes should be taught to the
artisans in their villages, using practical methods as far as possible. The Government of Dominica is in agreement with the idea of mounting practical workshops in the five or six major population areas in Dominica, and the program now is for the PCDPPP to assist Dominica and other States in organising and financing these workshops.

Some low-income and middle-income houses under construction in Dominica were examined by a Consultant to PCDPPP and the building techniques being used were discussed with the builders. It was apparent that the builders of middle-income homes were conscious of the possible effects of hurricanes, but were very unwilling to change from the "new aesthetic" of low pitched roofs, wide overhangs and exposed glass-louvered windows. The education programme for this group of builders, who in many cases are also the designers, has to be specially tailored. A program of developing minimum building standards should ensure the use of safe construction procedures and it is intended to assist the States in producing manuals of building procedures.

The damage to the telephone and electricity systems was largely a function of the topography of the countries and of the exposed nature of the systems. It is considered that it would not be feasible to construct a "fail-safe" system, and it is suggested that the authorities concentrate on improving on the recovery rates which were achieved after the recent hurricanes. This can be achieved by ensuring that:

(a) There is a Disaster Unit trained to respond to disasters.

(b) The Unit should be equipped with the necessary personnel, tools, equipment and telecommunications equipment.

(c) There is an adequate stock of spare parts for vital equipment and outside plant equipment such as cable, poles, insulators, transformers, etc., to effect early reinstatement of service to vital areas.
(d) There are underground service connections both for telephones and electricity to the main Hospital, Administration Building and Police Station.

(e) The power station and other important buildings housing vital equipment be constructed with materials that would not be damaged by flying objects during a hurricane. The building structure should be resistant to hurricane wind forces.

(f) Electricity transmission and distribution systems be upgraded where feasible, to 120 mph (measured over a 3 second period) design standard by introducing more frequent guys and shortening the spans.

(g) The pole systems be examined systematically and decayed poles replaced.

5.18 In summary, buildings of all types can be less vulnerable by following simple principles of design and construction. Retrofitting with holding-down straps for roofs, hurricane shutters, etc., may be costly, but should be done for important Government Buildings, hospitals and designated shelters, which would be needed during and after the hurricane. Utility systems are vulnerable because of the terrain. Vulnerability of these systems cannot be reduced significantly at reasonable cost but recovery of service to vital areas can be improved through proper planning and preparedness.
6. CURRENT MITIGATION PROGRAM

6.1 The background to the present hazard mitigation program has been recited in the Introduction. Briefly, the main thrust of the program being developed by the Governments is centered on the completion of the Caribbean Uniform Building Code Project (CUBIC). This project was put on a sound footing in 1982 with financial assistance from USAID/OFDA and the Caribbean Development Bank. The document which will be produced early in 1985 will contain sections on:

(a) Administration and Enforcement
(b) Dead loads and live loads including Wind and Seismic loads
(c) Occupancy, Fire Safety, and Public Health Requirements

Electrical and Plumbing Codes have already been completed.

The Government of Jamaica has recently published a Jamaica National Building Code as a policy document. This Code will apply to all building in the State and enforcement procedures are now being worked out to ensure that the Code, when made mandatory, can be adequately enforced. Also, the Government of the Bahamas has developed a Building Code (based on the Florida Code) which has been in use for the past six years.

6.2 Training Programs

The survey of the damage caused by Hurricane "David" has shown that the persons who suffered the greatest, are ill prepared to prevent similar failures in the event of another hurricane. It was noticed that bad construction practices were being repeated generally for lack of knowledge. As stated earlier, the PCDPPP is discussing with Governments of the Region, the development of outreach training programs for the rural house builder. The Training will take place in the villages and at times convenient to the villagers. In one State, it appeared that the most appropriate
time for the training would be on Sundays after Church, and that the local priest would make the appropriate announcement during the Church service.

It is considered that the outreach program, which will deal only in basic construction methods for small timber and masonry houses, will be the leading edge of the mitigation program. The results should lead to a significant reduction of failures of roofs due to inadequate holding-down mechanisms, and to ensuring that small timber houses remain upright during a hurricane.

It is considered that the training of the village contractor and artisans would best be done by the Government Building Inspectors who are charged with the responsibility of ensuring that buildings are properly constructed. It is considered also that these Building Inspectors should be trained in this task and special workshops are being developed for this training.

Implementation of the training programs is now starting, and it is envisaged that after the pilot project has been evaluated, programs can run concurrently in participating States requesting such assistance.

6.3 Building Procedures Manuals

In nearly all of the PCDPPP participating States, most of the housing is designed and constructed by persons who are not qualified architectural or engineering designers, but who depend on their experience and on tradition to produce an acceptable dwelling. Unfortunately, many of these houses are structurally inadequate and cannot withstand the forces of a hurricane or earthquake. A building procedures manual containing illustrations of construction procedures and minimum material sizes, would be of great assistance to this group of builders.

The PCDPPP is assisting the Governments in organising and financing workshops for builders and designers with the aim of producing such a manual. The workshops will be held generally in each State, as building procedures differ
slightly from State to State. Some of the differences are significant, and building procedures must relate to the environment and normal building patterns of the society. It was considered also, that building procedures, to be effective, must be understood and accepted by the persons who will be expected to use them. The workshops will examine with representative groups of builders and professionals in each State, all of the important elements of construction, and determine acceptable safe procedures for construction.

6.4 Training of Engineers and Architects

The Caribbean Council of Engineering Organizations (CCEO) and the Caribbean Association of Architects, have shown continued interest in upgrading the skills of its members in the design of safe structures. It appears that traditionally, it was difficult to encourage architects to recognise that safe structures are developed most often by a planning concept which takes into account the resistance to, or avoidance of, the forces generated by natural hazards. However, the two professional bodies have agreed that they have mutually supporting roles in the design of buildings, and are planning the first Caribbean Conference on the design of buildings to resist hazards. This conference will be supported by the PCDPPP and it is hoped to have participants from each State. The Conference being planned will also involve faculty members of the Faculty of Engineering, University of the West Indies. The training of professionals is particularly important, as many multi-storey buildings are now being constructed to house the low income worker, and the pressure on producing inexpensive housing, forces the designer to look for savings which do not necessarily appear on the accommodation being offered.

The impact of training programs on the safe design and construction of buildings should be seen relatively quickly, provided the training programs can be sustained, and provided the University Faculty of Engineering and practising Architects are
also sensitized to the need for this training. There are still, however, many buildings and important developments in the Caribbean States which have not been designed to mitigate damage from natural disasters. The PCDPPP has suggested to the Caribbean Insurance Conference held in Jamaica on September 9 - 12, 1984, that there should be an urgent examination of all major buildings to determine their structural and other weaknesses and to take the appropriate steps to encourage building owners to improve their buildings so as to prevent disasters. We are pleased that our recommendations are being actively considered, and we would urge that such hazard abatement exercises be instituted in all States and that special attention be paid to schools, hospitals, and other important buildings that would have to be functioning during and after a disastrous occurrence.

6.5 Maintenance

The review of the impact of Hurricane "David" showed that most building structures that failed were in poor repair. In many cases, timber buildings were almost completely rotten and nailed connections were useless. Galvanized roof sheets developed rust very quickly around the edges, taps and fixings. In most of the buildings the rusted roof sheets were easily blown off leaving the building structure to its fate.

In terms of mitigation of hazards, the need for maintenance of building structures is as important as the need for proper design of structures, and while it is perhaps easy to recognize and develop training programs for safe design, it appears to be difficult to encourage State authorities and building owners to agree that maintenance of existing assets should be a priority call on the budget. There is always the pressure, in our societies, to provide funds for employment generating enterprises at the expense of funds for maintenance; and new building construction is a useful way of providing immediate employment for many. It is in recognition of this "fact of life" that we
recommended to the Insurance Companies that they look seriously at the condition of buildings they insure, and put pressure on building owners to maintain the buildings properly so that the value of the asset is not reduced below its normal insured value.

6.6 Prevention and Preparedness

The PCDPPP is a relatively new organisation and is now in the process of establishing with its participating members, the level of assistance required by each State, while encouraging with financial and/or organizational support the development of training programs in long term preparedness, emergency response, and handling of mass casualty and other major emergencies.

Prevention is a long term exercise. It is now recognised that most natural disasters can be mitigated by proper planning techniques, proper land use, and proper construction practices. The mitigation of disasters is not in itself a new concept. Anyone who has examined the interesting timber chattel house in Barbados and in other parts of the Commonwealth Caribbean, would recognise immediately the response to hurricane forces in the steep pitched roofs, tight framing, timber shutters, no roof overhangs. The devastating hurricane of 1840 which destroyed many buildings in Barbados led to the simple building improvements in small houses; while in large structures such as the military barracks, the legacy of heavy timber shutters, well designed roof structures is still apparent.

However, the pressure of population on available land, and the introduction of the "new aesthetic" have caused a departure from the planning and construction techniques made necessary as responses to natural disasters. The destruction of forests to provide wood for coal fires and for building, has had serious environmental consequences - land slides, polluted rivers, floods and droughts. The sudden recognition of the leisure attribute of beaches has led to an alarming increase of building on the shore line, with the consequential hazards of storm surge, and
pollution of beaches.

It is considered therefore, that while the work of preparedness is vitally necessary in terms of ensuring a planned response to a disastrous occurrence and in terms of providing help and relief when and where necessary, the program of prevention focuses on the root causes of the disasters and attempts to encourage the Governments, insurers and private citizens to develop safe building practices which will prevent disasters.
7. CONCLUSIONS AND LESSONS TO BE LEARNT

7.1 The lessons to be learnt from the impact of hurricane "David" are:

(i) Public Education
There must be a public awareness of the extent to which bad building practices increase losses caused by hurricanes. The program of information and education of the public must be a continuous one. All groups of building officials - the architects, engineers, foremen, master carpenters and master masons and owners - must be taught that it is possible to provide aesthetically acceptable buildings constructed in such a way that damage by hurricanes would be minimized.

(ii) Government Involvement
(a) Building regulations based on building codes such as the Caribbean Uniform Building Code (CUBIC) now being drafted should be enacted. The Regulations should include provisions for ensuring compliance with simple measures needed to mitigate hazards from natural disasters. The Regulations should be enforced.
(b) Building Inspectorates must be established and adequately staffed. The inspectorates must establish simple rules for design and construction of buildings and must have the authority to issue stop orders for any construction not complying with the rules.
(c) The Inspectorates should be mandated to pursue a continuous program of on-the-job education for small builders in the proper techniques of building hurricane-resistant homes. The Inspectorates would therefore have a positive role in the building process and not merely a negative one.
(d) Governments must set the example in their own building programmes by producing hurricane resistant designs.

(e) There should be a careful review of building programs which are sited on land with problems of foundations, or on land which is really a flood plain and subject to flooding by heavier than normal rainfall.

(iii) Construction

For lightweight construction, there is a need to:

(a) Make roof pitches steeper -- 25° to 30°.
(b) Build hip instead of gable roofs.
(c) Cut out overhangs completely, and build canopies and sun shades over doors and windows instead.
(d) Use heavier gauge sheeting (22 ga rather than 26 ga) and check that contractors are supplying what is specified.
(e) Provide more frequent fixings in areas known to have higher wind suction, especially ridges, eave purlins and gable ends.
(f) Where appropriate, consider the inclusion of ridge ventilators to adjust internal pressures. A simple ridge ventilator can be constructed for low income housing.
(g) Pay careful attention to securing roofs to walls, walls to floors, stanchions to their bases.
(h) Reinforce all concrete block walls and construct reinforced concrete ring beams on top of walls.

(iv) Public Utilities

(a) There should be a conscious attempt to design transmission and distribution systems for swift reinstatement after a hurricane. Important utility buildings such as power plants and telephone exchanges must be carefully designed
so as to be free from hazards. Other important Government centres and hospitals should, as far as possible, be connected to the main power plants and switching stations by underground services.

(b) There should be standby electric plants at each of the important Government buildings and hospitals. Water pumping stations should also be equipped with standby power plants.

(c) There should be Disaster Units within each utility properly manned and equipped with adequate tools and basic spares.

(v) Maintenance

There must be a priority effort by all building owners to maintain buildings to the highest possible standards. Unfortunately in our warm and balmy environment, the very air that gives us so much pleasure, is laden with enough salt and moisture to corrode metal fixings, and structural members made of steel. Constant vigilance and a preventative maintenance regimen are very necessary if the buildings are to carry their design loads. Aid agencies should take an active interest in the conditions of structures financed by agencies so as to ensure that the buildings can meet the performance standards as designed. Insurance Companies should also take an active interest in maintenance of buildings by using their influence and encouraging house owners to maintain the value of their assets.

7.2 In the Foreward to the 1984 report "Prevention Better than Cure" by the Swedish Red Cross, the Secretary General of the Swedish Red Cross remarks, "We are convinced that it is possible and indeed necessary to prevent many disasters in the Third World. In our opinion it is urgent". The programs of training and the efforts at improvement of building procedures are our responses to this urgency.
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* * * * *
WHEN YOU BUILD A HOUSE

A Manual of construction details for Caribbean houses
with emphasis on protection from strong winds

Developed by E.H. Robinson for owners: builders of
houses in the Glebe Community, St. Vincent

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when you build a house

a manual of construction details for caribbean houses with emphasis on protection from strong winds.

developed by e.h. robinson for owners, builders of houses in the glebe community, st. vincent.
this manual was designed during the course of a two year involvement in administration and implementation of an aided, self-help housing program involving residents of a rural village in St. Vincent, West Indies. As an architect working with Peace Corps, I was providing technical assistance to the sponsoring organizations* with respect to program development, housing construction and housing education for owner-builders and skilled tradesmen in the village.

This information was distributed to project participants in conjunction with group discussion sessions in which all construction details and methods were fully explained, demonstrated and in some instances, revised as a result of participant response.

The details presented reflect a synthesis of research into existing information concerning construction/design details for hurricane/earthquake prone environments; local construction methods; appropriate design elements relative to the Caribbean climate and low-cost considerations.

*CADEC [Christian Action for Development in the Caribbean] and the St. Vincent Christian Council

ed. Robinson

preface
120 families; the majority living in 2 room dwellings constructed of bamboo and timber, situated on steep mountain terrain. Residents have settled the land, which belongs to a local church, on an informal basis for many years.

Many residents farm small mountain plots earning some seasonal income, others find occasional employment on nearby agricultural estates. Unemployment and overcrowding are serious factors influencing the overall development of the Glebe community.
Keep wood posts and floor at least 2 feet above ground.

termite protection

Termites can destroy a timber house unless the wood, and the ground are treated. Keep all wood out of contact with the ground and use naturally resistive hardwoods.
Footings

Build footings at least 6 feet away from the edge of a slope and at least 3 feet below the ground to keep the house from sliding. Footings should be 2 feet wide.
Wood post construction

cut a notch in the end of the post before pouring concrete piers. Use cross bracing between all posts to protect against high winds.
If your house is going to stand up against high winds, the walls must be securely tied to the foundations.

2x4 wall nailed to 2x6 bridging

2x6 bridging

2x4 plate

1/2" steel bent over (2x4 plate)

Board walls/foundations

2x4 chain plate
Concrete construction

Use steel reinforcement in all floor or ring beams; floors built above the ground; columns and footings.
Use 2x4 bracing in all corners to protect the walls from the force of high winds.
probably the most important construction details to resist high winds are the roofing connections. Wall-to-rafter and rafter-to-purlin connectors should be used.
purlins can be secured to rafters by bending lacing wire over purlin and through a hole drilled in rafter. The rafter can be tied to the wall using 1" wide strips cut from galvanised sheet metal.
nail roofing to purlins through the top of the corrugations using 3/4" washers. roofing should be nailed at every corrugation on eave and ridge purlins as well as all end sheets.
roof overhangs to help prevent damage to your roof during high winds. Limit overhangs as shown so that the wind can't lift off the roof.
If you are building a gable roof, the roof pitch should be steep. Between 6:12 and 12:12 slopes will be effective against high winds. Hip roofs work best to resist high winds.
gable end
roof vent

warm air escapes through vent in eave.

ridge vent

roof ventilation

vents make your house cooler by allowing the hot air escape. Vents such as these also help relieve the buildup of air pressure during high winds.

see photo plate
Before using bamboo for building, soak in seawater for a few days and dry. When building a wattle wall that is going to be plastered, nail chicken wire to bamboo. This stops cracking.
awnings
above doors and windows
Keep the house cool and protect the windows and doors from direct exposure to rain and sun.
HOW TO MAKE A SAFE WOODEN HOUSE

Adapted by Construction Resource and Development Centre
from a Manual prepared by Juliana Marek
INTERTECT, Dallas, USA

Adaptations were made for the Pan Caribbean Disaster-Preparedness and Prevention Project in July 1985 under agreement with the UNDP and the ODP

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HOW TO MAKE A SAFE WOODEN HOUSE
THE MAJOR CAUSES OF FAILURE IN HURRICANES

POORLY BRACED AND JOINTED HOUSES BREAK UP!

HOUSES GET BLOWN OFF THEIR FOUNDATIONS!

ROOF SHEETING GETS RIPPED OFF BY THE WIND!
JOINTS MUST BE RIGID AND STRONG.

These wood joints are weak! Nails are unable to get a good anchorage!

They will separate in a hurricane.

Make them stronger with gussets and hurricane straps!
PURLINS, BATTENS OR LATHS WILL LIFT OFF IF THEY ARE SIMPLY NAILED DOWN WITHplain nails.

Do not depend on nails alone to hold your roof on! Unless you have special purpose anchor nails.

Use galvanised sheet metal straps like these!

Or, tie the roof down with wire!

Wooden or metal cleats can be used to hold down rafters.
TYING THE HOUSE TO THE GROUND IS VERY IMPORTANT. THE BEST WAY TO BUILD A FOUNDATION IS LIKE THIS. BOLT THE WALLS DIRECTLY TO THE FOUNDATION SO THEY CAN'T BLOW OFF IN A HURRICANE!
USE STRONG GABLES.

A GOOD DESIGN TO USE FOR THE GABLES IS LIKE THIS: USE GUSSETS TO HELP HOLD THE WOOD TOGETHER!
ARE THESE NAILS O.K.?

ORDINARY NAILS WILL PULL OUT IN A HURRICANE! USE WOOD BLOCKS TO ENSURE FIRM CONNECTION.

USE NAILS LIKE THIS...

OR USE GALVANISED STEEL WASHERS LIKE THIS.
LOCATION FOR THE HOUSE

BEGIN WITH A GOOD LOCATION. THE HOUSE SHOULD BE PUT ON A FLAT, FIRM SITE!

IF ON A STEEP SLOPE CUT INTO THE EARTH LIKE THIS!
Supports in steep locations.

A house just propped up on a steep slope can be blown off its supports. Build a platform, or brace the supports like this.
ANCHOR • FOUNDATIONS OR SUPPORTS.

A house should be fastened to the posts.

If not, it can blow off in a hurricane.

Fasten it to the posts like this, or to a concrete foundation.
Flat roofs suffer more in hurricanes.

Wind tends to lift flat roofs more easily than pitched roofs... and will blow them off in a hurricane!

The best roof is a four-sided hip roof. If you use a gable roof, be sure to strengthen the gable!
Each wall should have braces in the corners.

The amount of wood used in the frame is important. Be sure to use enough wood, posts, and beams to make small panels.

Good carpentry makes a strong house. Select the right nail for the right job. Do not split the wood! If the wood is very hard, pre-drill the hole.
AND, PUT A BRACE IN EACH CORNER LIKE THIS! UNLESS THE ROOF HAS GOOD TIMBER SARKING.
Unprotected glass windows may break and let wind inside during a hurricane.

Wind, rain, and other things can be blown into the house.

Protect glass windows with storm shutters or nail zinc sheets over glass windows before hurricane arrives.
LONG OVERHANGS MAY ENDANGER THE ROOF.

IF THE ROOF STANDS OUT FROM THE WALLS TOO FAR, THE WIND CAN LIFT THE ROOF OFF!

THIS IS DANGEROUS IN A HURRICANE!

KEEP OVERHANGS AS SHORT AS POSSIBLE, TRY NOT TO EXCEED 18 INCHES.
A strong house must have good strong joints! This is a weak joint!

It will separate in a hurricane.

This is a good, strong joint!
FASTEN EACH GABLER TIGHTLY TO THE TOP OF THE WALL FRAME. USE HURRICANE STRAPS OR FASTENERS.

IN A HURRICANE THEY WILL NOT HOLD!

NAIL THEM SO THAT THE PULL IS SIDEWAYS ON THE NAILS IN A HURRICANE.

DO NOT NAIL THEM LIKE THIS?
WILL YOUR HOUSE STAND UP?

WITH JACK HAMMER
AND STONEY JONES
You know, every time a hurricane comes by, I wonder if my house will blow over.

Could be. Let's check the house and see.

How will we do that?

We'll use this checklist!

Each part of the house will be graded. For good parts we add points. For bad ones, we subtract points!
AT THE END OF THE LIST, ADD UP THE POINTS TO SEE HOW STRONG THE HOUSE IS.

YOU CAN USE THIS LIST, TOO. PUT THE NUMBER OF POINTS ON THE BOTTOM OF EACH PAGE.
THE SITE OR LOT IS VERY IMPORTANT. GIVE YOURSELF 3 POINTS IF IT IS ON FLAT GROUND.

GIVE YOURSELF 3 POINTS IF IT IS ON A SITE LIKE THIS.

YOU GET 0 POINTS FOR A SITE LIKE THIS.

YOU GET 1 POINT FOR A SITE LIKE THIS.

TOTAL POINTS ______
0 POINTS

Give yourself the correct number of points if your house is on posts like these.

1 POINT

2 POINTS

Add the correct number of points if the space between the posts is sealed up!

3 POINTS

Total Points ______
The shape of your house is very important. Choose your house shape and give yourself the correct number of points.

Total Points ___
IF THE WALLS OF YOUR HOUSE SIT ON A FOUNDATION BUILT LIKE ONE OF THESE, GIVE YOURSELF 3 POINTS.
IT IS IMPORTANT TO **REINFORCE** YOUR WALLS. IF YOUR WALLS ARE REINFORCED LIKE THESE, GIVE YOURSELF 3 POINTS.

**TOTAL POINTS**
Some verandas are not very safe. If your porch roof is like one of these, subtract points indicated.

If your veranda has angle irons like these, add 2 points.

Total points —
THE LOCATION OF DOORS AND WINDOWS IS VERY IMPORTANT. IF A WINDOW IS LESS THAN 18" FROM THE CORNER, SUBTRACT 1 POINT.

IF ALL YOUR WINDOWS ARE AT LEAST 36" FROM THE NEAREST CORNER, GIVE YOURSELF 3 POINTS.

TOTAL POINTS
THE PITCH OF THE ROOF IS VERY IMPORTANT. CHOOSE THE SHAPE LIKE YOURS AND GIVE YOURSELF THE CORRECT NUMBER OF POINTS.
IF THE ROOF STANDS OUT FROM THE WALLS TOO FAR, THE WIND CAN Pry the Roof OFF!

YOUR ROOF. IF IT IS LESS THAN 18", GIVE YOURSELF 3 POINTS. IF IT IS 18" TO 24", YOU GET 2 POINTS. 25" TO 30", YOU GET 1 POINT. IF IT IS MORE THAN 30", SUBTRACT 1.

TOTAL POINTS
Check to see how the roof trusses are fastened to the wall. If it is like one of these, you get 1 point.

If you have hurricane straps or fasteners like these, give yourself 3 points.
Here is an open space between the roof and walls.

In a hurricane, wind will go in there and blow off the roof.

If your roof is sealed up like one of these, give yourself 3 points.

Total Points: ___
Some windows will let wind inside during a hurricane.

They can be dangerous.

If you have storm shutters, give yourself 2 points.

Total points
Now, add up your points. If you have less than 10 points, you should leave your house in a hurricane!

If you have 11-20 points, you need to fix up your house to make it stronger!

If you have 20-25 points, you only need to make small changes to make your house safe!

If you have more than 25 points, your house is fairly safe!
COMO HACER UNA CASE MAS SEGURA

Las técnicas recomendadas en el libro son resultado de trabajos realizados por la Cooperativas 'Kato-Ki Quetzal' en Guatemala, con la asesoría de la compañía 'INTERTECT', USA.

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