Zeitschrift: IABSE congress report = Rapport du congrès AIPC = IVBH Kongressbericht

Band: 14 (1992)

Artikel: Cyclone resistance of residential buildings in the Caribbean

Autor: Osborne, Robin W.A. / Prevatt, David O. / Imbert, Ignatius D.C.

DOI: https://doi.org/10.5169/seals-13789

Cyclone Resistance of Residential Buildings in the Caribbean

Résistance des immeubles résidentiels aux cyclones des Caraïbes

Auslegung von Wohnhäusern in der Karibik gegen Wirbelstürme

Robin W.A OSBORNE
Lecturer in Constr. Eng.
Univ. West Indies, St. Augustine,
Trinidad and Tobago

Ignatius D.C. IMBERT
Prof. of Constr. Eng.
Univ. West Indies, St. Augustine,
Trinidad and Tobago

Anil K. SHARMA
Senior Lecturer in Civil Eng.
Univ. West Indies, St. Augustine,
Trinidad and Tobago

David O. PREVATT
Research Assistant,
Univ. West Indies, St. Augustine,
Trinidad and Tobago

Cuthbert P. DRAKES
Research Assistant,
Univ. West Indies, St. Augustine,
Trinidad and Tobago

SUMMARY
The islands of the Caribbean are in a cyclone-prone area and annually suffer damage through the effects of high winds and rainfalls. This paper identifies some problems associated with residential buildings construction practice in the region which contribute to the extent of damage sustained by them. It also discusses the preliminary findings of a research project presently being conducted. This work includes regional housing surveys, wind tunnel model testing, structural tests and the development of a Cyclone Profile of the region. Items of future research activity are also identified.

RESUMÉ
Situées dans une zone à caractère cyclonal, les îles des Caraïbes sont chaque année l'objet de dégâts importants sous l'effet de vents soufflant en tempête et de trombes d'eau. Cet article souligne quelques problèmes liés à la pratique régionale de construction des bâtiment résidentiels, qui contribue à l'ampleur des dommages occasionnés. Il énumère par ailleurs les premiers résultats obtenus par un projet de recherche actuellement en cours. Cette étude comporte un relevé des immeubles d'habitation, des tests sur modèle réduit en tunnel, des essais structuraux et la mise au point d'un plan de découpage régional définissant le degré d'influence des cyclones. Ce project délimite ainsi un certain nombre de points de la recherche future.

ZUSAMMENFASSUNG
Die Inseln der Karibik werden alljährlich von Wirbelstürmen heimgesucht, die Schäden durch hohe Windgeschwindigkeit und Platzregen verursachen. Der Aufsatz zeigt einige Probleme in der regionalen Bauweise, die für die Schäden an Wohnhäusern mitverantwortlich sind, und erörtert erste Ergebnisse eines laufenden Forschungsprojekts. Es umfasst eine Bestandserhebung der Wohnbauten, Windtunneltests, Tragwerksversuche und die Ausarbeitung einer Zonierungskarte für die Wirbelsturmgefährdung.

1. INTRODUCTION

The Caribbean Sea, in common with many other tropical areas worldwide, is subject to the seasonal passage of cyclones (hurricanes) which often attain highly destructive intensities. The area is also within a seismically active zone, and has been the scene of earthquakes and volcanic activity of severe intensity within recorded history. It has been hit by over 2000 cyclones[1] over the past 100 years of which 889 have developed to tropical storm or greater intensity. (See Table I). Reliable estimates of cumulative damage due to recent hurricanes are impossible to obtain, but they are thought to exceed US$5 billion; the recorded loss of life this century is known to exceed 18,000 persons. It is reasonable to expect that had there been proper structural inputs into housing these figures would have been greatly reduced.

Recent hurricane occurrences have identified the particular but not exclusive vulnerability of a specific constituent of the built infrastructure: residential buildings, particularly those of the lower-income groups. The social disruption consequent on the passage of a severe Caribbean windstorm can be enormous, with large sections of the population left either homeless or roofless.

The resistance of dwellings (in particular) to such damage, and the possibilities for improving such resistance, are the focus of a current research project, which is at the preliminary stage of defining the major factors which are at work.

2. THE EFFECTS OF THE TROPICAL CYCLONE

The principal effects of tropical cyclones which affect economic activity, endanger the lives of populations in the region, and disrupt communication and transportation are: high winds, storm surges, super-elevated tides, and excessive rainfall. The islands suffer mainly from the high winds and accompanying rainfall and flooding. A hurricane event does not have to make landfall to cause significant damage since the bands of rain-bearing clouds can affect areas far removed from the centre of the event.

Table I Summary of Caribbean Tropical Storms and Hurricanes (1886-1990)

Type	Wind Velocity (km/h)	Total Number 1886 - 1990	Example	Date of Event	Island Affected
TS	63 - 118	368	Alma	Aug. 1974	Trinidad
HC 1	119 - 153	151	Katrina	Nov. 1981	Cuba
HC 2	154 - 177	174	Edith	Sep. 1963	St. Lucia
HC 3	178 - 209	108	Eloise	Sep. 1975	Hispaniola
HC 4	210 - 249	64	Flora	Sep. 1963	Tobago
HC 5	>249	24	Gilbert	Sep. 1988	Jamaica
Note:	TS = Tropical Storm		HC = Hurricane Category		

Typical damage occurs to the infrastructure such as roads, to communication lines as well as electricity and water utilities and to both engineered and non-engineered construction. Lower-income housing falls into the latter category; because of socio-economic conditions, construction tends to be done using the self-help method with its attendant lack of quality control.

3. POST-DISASTER STUDIES OF CYCLONE DAMAGE

Post-disaster reports have indicated that construction practice may contribute to the severity of damage from cyclones. Through regional post-disaster surveys after Gilbert and Hugo in 1988 and 1989 respectively, the evidence of poor connectors and inadequate structural-member sizes was found in many houses in Jamaica (1988) and Montserrat (1989). The loss to the economy of Jamaica, both insured and uninsured was in the order of J$7000 million (US$ 713 million at current exchange rate). Estimated damage[2] to Montserrat was put at US $170 million. In Montserrat, insurance companies were called upon to settle 40 % of the insured value of buildings and 80 % of the contents.

In Jamaica after Hurricane Gilbert, roofing losses were estimated at 244,080 housing units, 30,235 homes being totally destroyed. The total value of these building losses was more than twice the total value of the entire construction expenditure for buildings that were constructed in Jamaica in 1987[3].

4. THE CARIBBEAN REGION

The Caribbean Sea is an over-deepened, sub-oceanic basin including all the water north of South America and east of the Central American isthmus, south of the Greater Antilles and west of the Lesser Antilles of the West Indies. Its north-south width ranges from 610 km to 1125 km and its maximum length is more than 2400 km. The Caribbean Sea washes the shores of 19 independencies and many small islands. The islands of the West Indies have a total population of approximately 29.8 million people (1983) occupying a land area of 237,800 square kilometers. The average number of persons per household in the region is 3.4 giving a rough estimate of 8.76 million homes at risk of cyclone damage. This is the context for the Cyclone-Resistant Housing (Caribbean) Project, which is briefly described below.

5. THE CYCLONE-RESISTANT HOUSING (CARIBBEAN) PROJECT

The project is a joint research effort between the University of the West Indies (UWI), Trinidad, and the University of Waterloo (UW), Canada, funded by the International Development Research Centre (IDRC), Ottawa, Canada. The objective of the project is to improve through research, information dissemination, training and the construction of demonstration buildings, cyclone-resistant construction techniques and practice in the lower-income housing sector in the Caribbean region.

Major foci of the project to date have been (i) the collection and analysis of housing data, (ii) the preparation of a tropical cyclone profile based on the cyclone data collated over the past 105 years and (iii) wind tunnel and structural testing at the universities. The main activities and findings of the project to date are summarized in the following sections.

6. COLLECTION OF HOUSING DATA

6.1 Preliminary Survey of selected islands

The project has undertaken some preliminary surveys of the islands' housing with two goals in mind; (i) to determine the shapes and sizes of houses to be tested at the University of Waterloo and (ii) to gain an understanding of the methods by which normal house construction proceeds, with special emphasis on current fastener and connector details.

Four Caribbean roof shapes have been identified and are shown in Figure 1: the gable, the double lean-to, the hip and the monopitched. Eaves are common in all four house shapes with their lengths varying from 0.3 m to 1.2 m. Reports on Jamaican lower-income housing areas have shown the most common roof types are the monopitched (40.4%), followed by the gable roof (28.4%) and the hip roof (21.6%). The double lean-to roof type was combined with all other types for a total percentage of (9.6%). It has been found to be common practice to include inset porches and verandahs of various sizes into these basic shapes.

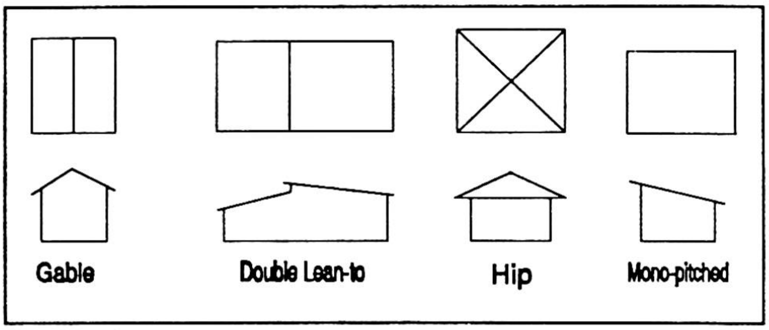

Figure 1 The most common housing shapes found in the West Indies

The most common form of roofing on houses in the region is corrugated galvanized iron sheeting fixed (using nails) to 25-mm x 100-mm timber purlins ("laths" - laid flat), which in turn are typically connected by one or two 75-mm nails to 50-mm x 100-mm timber rafters used on edge. The purlin and rafter spacing ranges from 750 mm to 1200 mm. The typical connection (rafter to wall plate, and rafter to ridge beam) in the above cases uses skewed or toe-nailed common iron nails, typically 75mm to 100mm long.

The lack of proper connections between wallplates and block masonry walls has been identified as the cause of many complete roof removals. In some instances, the wallplate merely rests on the wall embedded in a mortar layer. A major factor in the damage to housing subjected to extreme winds appears to be the loss of roof cladding which leads to significant loss of strength, and increased wind forces, which in many structures can lead to their structural collapse[4].

6.2 Housing Assessment System

A methodology is being developed for the assessment of the cyclone-risk of typical single-family dwelling units. In determining this method, reference was made to international "deemed-to comply building standards"[5] to compare the prescribed construction methods with those used throughout the region.

6.2.1 Wood-frame Construction

The construction techniques used in the Caribbean have developed more from traditional/cultural habits rather than through the application of sound engineering principles. For example, wood-frame buildings are clad with shiplapped or flat boards 19 mm thick. There is insufficient data available on the behaviour of this wall system under racking loads.

6.2.2 Masonry Construction

With regard to block masonry construction the practice in Trinidad and Tobago is the 100-mm thick unreinforced hollow clay block. In Jamaica 150-mm thick reinforced concrete block masonry is the tradition, and in Barbados 200-mm thick unreinforced concrete blocks are replacing the traditional 300 mm thick limestone blocks.

6.2.3 Foundations

The foundations of many older houses built on rented sites in the eastern Caribbean (eg. Antigua, Dominica) are neither fixed to the ground nor the house so as to facilitate the easy relocation of the house when the rental period expires. The supports used in such cases are usually of concrete block, timber poles or boulders. Such practices as outlined above require careful analysis before prescribed construction methods can be applied in the region.

7. TESTING

7.1 Boundary Layer Wind Tunnel Tests

Based on counterpart work being done at the University of Waterloo within the project, pressure coefficients are being obtained for the roof, the external walls and the underside of eaves of the various scale model houses, from which the equivalent wind forces can be calculated on the actual structures. Of particular concern is the effect of verandahs (cut-outs) on wind forces, and the very low-pitched roof slopes often used (to save material) which increase roof-suction forces.

The wind code used by engineers in the region does not take into account house shapes such as those shown in Figure 1. The same can be said about other published wind codes or standards. It is therefore left to the engineer to determine the forces on the structure by other methods.
Results of the wind tunnel tests will be used at the University of the West Indies for setting up tests of various connections found from the field survey, and possibly recommending alternate connector details depending on availability, ease of installation, economy, and durability.

7.2 Static and Dynamic Testing of Structural Components

The interaction of the wind with buildings is usually of a dynamic nature. Since wind forces are generated in a randomly fluctuating manner this introduces the effects of fatigue to the various components and their connections. Therefore, the testing programmes at the UWI Structures Laboratory comprise both static and dynamic testing.

Tests currently being conducted are:-
- Static Withdrawal Tests of Sheeting Fasteners.
- Simulated Wind Loading on Corrugated Roof Sheeting and Fastener Assemblies (static; preliminary to dynamic testing).

8. THE CARIBBEAN CYCLONE PROFILE CHART

Using data on cyclone incidence, intensity and frequency for the period 1886-1990, a Cyclone Profile of the region is being developed. This follows similar work done in the United States and in Mexico for their respective areas. These profiles provide very useful information for policy-makers, engineers and the insurance industry. Figure 2 shows the geographical distribution of tropical cyclones represented by a series

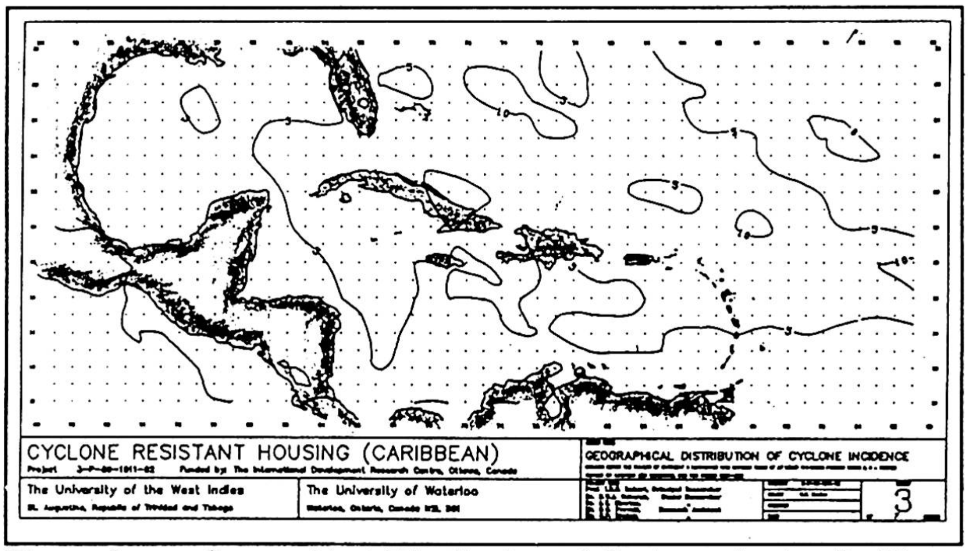

Figure 2 Geographical Distribution of Cyclones in the Caribbean (Hurricane Category 4).

of isolines drawn for Category 4 hurricanes. The isolines depict the number of tropical cyclone occurrences within a four-degree square of latitude and longitude. Similar charts have been developed for all tropical cyclones, and hurricanes of categories 1 to 5. The charts show the likelihood of landfall based on a statistical treatment of historical records.

The profile, together with topographic information of various islands, can be used to estimate: (i) the likelihood of cyclonic influence of a given intensity, and (ii) the likely aggravation of wind force by localized topography. This could be a useful input to the cost-effective structural design of residential units for particular locations within the Caribbean, having regard to stochastic as well as locational considerations.

9. SUMMARY OF FINDINGS

The structural engineering input to housing in the Caribbean has been very low for many reasons, (one of the main reasons has been the lack of enforcement of building codes). In cyclone-prone areas such as the Caribbean enormous losses can be sustained when a cyclone hits an area of poorly built houses. It is essential that we learn from past experiences and attempt to mitigate future residential damage and its consequent risk to human life.

1. Field studies have shown that many poor construction practices (especially inadequate connections) exist in the Caribbean, which increase the damage sustained during a cyclone event.
2. Wind Tunnel tests are necessary in order to develop design guidelines for the use of practising engineers in the design of Caribbean houses.
3. The Cyclone Profile is a useful tool for macro-economic planning and risk assessment related to housing settlements.
4. Adequate building code provisions and housing recommendations suitable for the Caribbean need to be available in a form usable by builders and self-help persons with minimum training and experience.
5. Funds for new housing are extremely scarce, moreso among the poorer classes. It is therefore essential to find means of retrofitting existing houses to improve their resistance to cyclones.

10. REFERENCES

1. NEUMANN, C.J., JARVINEN, B.,. PIKE, A.(National Hurricane Center, U.S.A.), ELMS J.D.(National Climatic Data Center, U.S.A.), Tropical Cyclones of the North Atlantic Ocean, 1871-1986 (3rd. revision), U.S. Dept. of Commerce - NOAA., Dec. 1990

2. GIBBS, T., BROWNE, H.(Consulting Engineers' Partnership), Hurricane Hugo in Montserrat. Reconnaissance Report on the Structural Damage, UNDP, Barbados, Nov. 1989

3. CLEMENT, D.B., Analysis of Disaster - Life after Gilbert, Institute of Social and Economic Research, The University of the West Indies, Jamaica, 1990.

4. WALKER, GEORGE R.(James Cook Univ. of North Queensland), Report on Cyclone Tracy - Effect on Buildings, Volume 1. Department of Housing and Construction, Queensland Australia, March 1975.

5. SOUTHERN BUILDING CODE CONGRESS INTERNATIONAL. Deemed to Comply Standard for Single and Multifamily Dwellings in High Wind Regions SSTD 10-90. Alabama,. U.S.A., Dec. 1990