ANNEX VI

WIND CODE EVALUATION

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Caribbean Islands (CARICOM)
Evaluation Conducted by Winston H.E. Suite

NAME OF DOCUMENT: Caribbean Uniform Building Code (CUBiC)
Part 2 Section 2

YEAR: 1985

GENERAL REMARKS:

Structural Design Requirements. Wind load. Has been adapted from a document prepared for the International Standards Organisation (ISO). Technical Committee 98. Working Group 2 on Wind Loads.

This section of CUBiC consists of a basic document and five technical Appendices.

"The basic document deals with the various actions of wind which should be considered and the general requirements of the standard" [Foreword]. The appendices are listed as follows:

Appendix 1 - Simplified Design Procedure
Appendices - Structural Design Requirement
Appendix 2 - Reference Velocity Pressure, q_{re}
Appendix 3 - Exposure Factor, C_{exp}
Appendix 4 - Aerodynamic Shape Factor,
Appendix 5 - Dynamic Response Factor,

The wind climate has been evaluated from an extensive study of hurricanes in the Caribbean carried out by A.G. Davenport, P.N. Georgiou and D. Surry, *A Hurricane Wind Risk Study For the Eastern Caribbean, Jamaica and Belize with special consideration to the influence of Topography*. Report for the Pan-Caribbean Disaster Prevention and Preparedness Project (PCDPPP), 1985.

SPECIFIC ITEMS:

1. SCOPE [2.201]

1.1 Explicit Concepts and Limitations

"This document describes the action of wind on structures and methods for calculating characteristic values of wind loads for use in designing buildings, towers, chimneys, bridges and other structures as well as their components and appendages. These loads will be suitable for use in conjunction with other ISO Load Standards and with ISO 2394 – General Principles on Reliability for Structures".

"Structures of an unusual nature, size or complexity may require special engineering study".

1.2 Performance Objectives

Knowledge of wind and its effects on structures is needed to ensure safe and, at the same time, economic structures.

No more specific performance objectives are expressly listed but the main objectives are to protect human life and to reduce economic loss caused by wind action (tropical storms and hurricanes). Even structures which are seriously damaged by wind action should not collapse endangering the life of the occupants.

2. WIND HAZARD

2.1 Basic Wind Speed

This equation describes the force on a structure as a result of wind action [2.203.1]. $W = (q_{ref})\,(C_{exp})\,(C_{shp})$

(C_{dyn}) Reference Velocity Pressure:

[2.204]

- q_{ref} = reference velocity pressure
- C_{exp} = exposure factor
- C_{shp} = aerodynamic shape factor
- C_{dyn} = dynamic response factor
- w = wind force per unit area normal to the surface of the Structure

[2.204.1]
Velocity Pressure $q = ½ \rho V^2$

ρ = air density
V = velocity of the wind

C_{exp} – Exposure Factor which accounts for the variability of velocity pressure at the site of the structure due to:

(a) The height above ground level.
(b) The roughness of the terrain and
(c) In undulating terrain, the shape and slope of the ground contours.

The value of the exposure factor may vary with wind direction.

$\sqrt{\gamma_w}$ Where = the normal load factor

V_{ref} γ_w

2.1.1 Height above Ground

[A100] This is listed as less than 15 m above ground see table [A103.1]

2.1.2 Ground Conditions

[A100] Structures should not be situated near a hill crest or head land.

- Deflection under wind loading must always be less than 1/500 of the height of structure.

2.1.3 Averaging Period

[A201] This is based on a 10-minute mean velocity pressure.

2.1.4 Return Period

[A201] This is given as once in 50 years.
Definition of q_{ref} (reference velocity pressure)

2.1.5 Quality of data

The quality of the data is considered very reliable based on an extensive study by A.F. Davenport et al.

2.2 Topography

Exposure Factor C_{exp}

This factor accounts for the variability of velocity pressure at the site of the structure due to the following:

(a) Height above ground level

(b) Roughness of the terrain and

(c) In undulating terrain, the shape and slope of the ground contours.

Recommended values of the exposure factor are given in [Appendix 3]. Table [A301.1].

$$C_{exp}(z) = A\{\ln(z/z_o)\}^2$$

where A is for different roughness length z_0 and terrain is given in Table [A301.1].

$$C_{exp}(z) = B(z/10)^{2\alpha}$$

where α and B depend on ground roughness given in Table [A301.1].

2.2.1 Escarpments

This issue is discussed under sector dealing with Speed up factor. See [A303], [Table A303.1]

2.2.2 Ridges

[see Table A303.1]

2.2.3 Axisymmetric Hills

[see Table A303.1]

2.2.4 Valleys

Not specifically discussed.

2.3 Height above Ground

This is contained in [2.2] above.

2.4 Terrain Roughness

(A301) This is aerodynamically described in terms of a roughness length z_0 which characterises the size and distribution of the obstacles around and over which the wind must blow.

[A400 General] Three Categories of aerodynamic shape factors are discussed.

(i) Aerodynamic shape factor pressure coefficient, acting normal to the surface.

(ii) Aerodynamic factor (force coefficient) acting in the direction of the resulting force.

(iii) Aerodynamic shape factor defining higher order resultant action of the pressure such as movement and torques.

3. WIND DESIGN ACTIONS

The wind actions which shall be considered in the design of structures may produce any of the following effects [2.202]:

(a) Excessive force or instability.
(b) Excessive deflection.
(c) Repeated dynamic forces causing fatigue.
(d) Aeroelastic instability.

3.1 Importance Factors

(i) The wind force per unit area is assumed to act statically in a direction normal to the surface of the structure or element except where others were specified e.g. with tangential frictional forces. [2203.2]

(ii) Both internal and external forces shall be considered [2.203.2] and [table A104.1].

(iii) Resonance may amplify the responses to the forces on certain wind sensitive structures. Such structures are characterised by their lightness, flexibility and low level of structural damping (see app. 5), [2.207.3].

Importance Factors are related to:

Exposure Factor, C_{exp}

Aerodynamic Shape Factor, C_{shp} and

Dynamic Response Factor, C_{dyn}

These are discussed in great detail in Appendices 2, 3, 4 and 5.

3.2 Scale Effects

3.3 Pressure

Velocity Pressure $q = \frac{1}{2} \rho V^2$

ρ = density of air

V = velocity of the wind

The reference velocity pressure is normally the specific value of the velocity pressure for the geographic area in which the structure is located. It refers to standard exposure (roughness, height and topography) see Table A201.1 for reference wind velocity pressures for the different islands in the Caribbean. The aerodynamic shape factor normally refers to the mean value of the pressure.

Enclosed structure will be subjected to internal pressures determined by the size and distribution of openings and by any pressurization. Allowances should be made for these by combining the aerodynamic shape factors for the external pressures with those for the internal pressures (the resultant).

The combined wind loading on external and internal surfaces should be based on the combined factor as follows:

$$(C_{shp}\ C_{dyn})_{combined} = (C_{shp}\ C_{dyn})_{external} - (C_{shp}\ C_{dyn})_{internal}$$

3.4 Dynamic Response Factor, Cdyn

2.207.1 Dynamic response factor accounts for fluctuating pressures.

Resonance may amplify the responses to these forces in certain wind Sensitive structures.

For aeroelastic instability performance may be acceptable for wind speed

$$= \sqrt{\gamma_w}\ V_{ref}$$

where

γ_w = normal load factor and V_{ref} = reference design wind speeds corresponding to q_{ref} [2.204].

3.5 Directionality Effects

"The shape factor C_{shp} is a dimensionless aerodynamic coefficient which expresses the aerodynamic pressure induced on the structure and its elements as a ratio to the velocity pressure (normally $q_{ref}\ C_{exp}$) in the incoming flow. Normally the slope factor refers to mean pressures but in some special application – for pressures transferred to the flow.

4. METHOD OF ANALYSIS

4.1 Simplified Procedure

[Appendix 1]

Wind Force per unit area = $(q_{ref})(C_{exp})(C_{shp})(C_{dyn})$

[A100. Criteria]

This method can be used for the design of the main structural system if

(a) the structure is less than 15 m in height above ground
(b) the structure is not usually exposed for any wind direction, that is, it is not situated near a hill crest or head land
(c) the structure is relatively rigid. Deflection under wind loading less than 1/500.H where H = height of structure.

4.1.1 Scope

The simplified method (procedure) is intended for the design of cladding of most normal structures.

4.1.2 Limitation

See (a), (b), (c) above, for conditions of applicability.

4.1.3 Design Procedures

$$W = (q_{ref})(C_{exp})\,[(C_{shp})\,(C_{dyn})]$$

$(q = \frac{1}{2}\rho V^2)$ reference velocity pressure [Table 103.1] [Table 104.1]

4.2 Analytical Procedure (Detailed Method) [209.3]

4.2.1 Scope

[Appendices 3, 4, 5]

4.2.2 Limitation

This method is principally of assistance in assessing the dynamic response of the structure, the influence of unusual exposure and the characteristics of more complex aerodynamic shapes [2.209.3].

Structures sensitive to wind include those that are particularly flexible, slender, lightweight or tall.

4.2.3 Design Procedure

This is discussed in some detail and there is variation in reference velocity pressure with [A300] height, terrain, roughness and topography.

$$C_{expA}(z) = \left\{ \ln \left(\frac{z}{z_o} \right) \right\}^2 \text{ etc.}$$

[Table A301.1]

4.3 Experimental Procedure

Wind tunnel testing is used principally in order to develop dynamic factors, C_{dyn}.

This is recommended when assessing the influence of unusual exposure and the characteristics of more complex aerodynamic shapes as well as structures sensitive to wind including those that are particularly flexible, slender, lightweight or tall and structures of unusual geometry, which give rise to unexpectedly large responses to wind. It may be necessary to conduct supplementary studies by experts in the field. These tests may include wind tunnel tests. Testing procedures are given in [Appendix 4].

5. INDUCED EFFECTS

5.1 Impact of Flying Object

Not considered. Specific treatment is needed.

5.2 Wind Driven Rain

Not considered. Specific treatment is needed.

6. SAFETY VERIFICATION

Alternative methods of analysis to those recommended in this standard may be permitted provided it can be demonstrated that the level of safety achieved is generally equivalent to that achieved in this standard. Safety considerations are included in Appendix 6.

6.1 Structure

No specific guidance is provided.

It is recommended in the estimation of wind loading the specified load will be multiplied by a load factor. This corresponding load factor to a given risk level can be estimated using reliability theory if statistical properties of the variables are known.

The aim is to ensure that the structure does not become unstable at a wind speed marginally higher than the design wind speed.

6.2 Cladding and Non-Structural Elements

[A500] General Remarks on C_{dyn}

Discussing dynamic action notes, "these forces act on the external surfaces of the structure as a whole or on cladding components ..."

The Code does not deal in any great detail with this issue. This is an area where the Code needs to treat in more detail particularly because of the hurricane occurrence in the region.

7. SMALL RESIDENTIAL BUILDINGS

The Code does not treat with the issue specifically and intended that this would be dealt with in a subsequent exercise.

[Refer to Trinidad and Tobago Small Building Code http://www.boett.org/sbc Board of Engineering of Trinidad and Tobago].

RECOMMENDATION FOR CODE IMPROVEMENT

This Code was developed in 1985 and needs updating. This exercise must be carried out, particularly in the light of the experience of hurricanes and tropical storms in 1988 (Gilbert), 1989 (Hugo), and1992 (Andrew) in the Caribbean region.

Appendix 1

EXPOSURE FACTOR, C_{exp}
(Simplified Method)

Ranges of applicability: Structural design: 0 – 15m Cladding design:0 – 100m

Height Range m	C_{exp}
less than 5	0.9
5 – 10	1.0
10 – 15	1.1
15 – 20	1.2
20 – 25	1.3
25 – 35	1.4
35 – 45	1.5
45 – 55	1.6
55 – 65	1.7
65 – 80	1.8
80 – 100	1.9

Appendix 2

REFERENCE WIND VELOCITY PRESSURES FOR CARIBBEAN

Location	Wind Pressure kPa			Wind Speed m/sec
	q_{ref} *	q_{10}	q_{100}	V_{ref} †
Guyana	0.20	0.05	0.35	18.0
Trinidad-South	0.25	0.05	0.40	20.0
-North	0.40	0.10	0.60	25.5
Tobago	0.47	0.15	0.65	28.0
Grenada	0.60	0.25	0.80	31.5
Barbados	0.70	0.30	0.90	34.2
St. Vincent	0.73	0.35	0.93	35.0
St. Lucia	0.76	0.36	0.95	35.5
Dominica	0.85	0.42	1.06	37.5
Montserrat	0.83	0.40	1.07	37.2
Antigua	0.82	0.39	1.05	37.0
St.Kitts-Nevis	0.83	0.38	1.07	37.2
Jamaica	0.80	0.40	1.00	36.5
Belize-North	0.78	0.38	1.00	36.00
-South	0.55	0.26	0.70	30.5

* It is recommended that 0.25 kPa be taken as a minimum value.

† Calculated from $V_{ref} = \sqrt{(2q_{ref}/0.0012)}$

Appendix 3

Relationship Between Reference Velocity Pressure q_{ref} And peak Windspeeds over Short Time Intervals In open Terrain

(Intermediate values may be interpolated)

q_{ref}	Vpeak(metres/sec) – 10 metres			
	Averaging Time			
10 min.	10min.	1 hr.	1min (or "Fastest mile)	3sec
0.30	22.4	21	27	33
0.40	25.8	25	31	39
0.50	28.9	27	35	43
0.60	31.6	30	38	47
0.70	34.2	32	41	51
0.80	36.5	35	44	55
0.90	38.7	37	47	58
1.00	40.8	39	50	61
1.10	42.8	41	52	64
1.20	44.7	43	54	67
1.30	46.5	44	56	70
1.40	48.3	46	58	73
1.50	50.0	48	61	75

*Assuming air density $\rho_{air} = 1.20 kg/m^3$

Appendix 4
REPRESENTATIVE TERRAINS AND THEIR VELOCITY PROFILE PARAMETERS
(Profiles matched at 30m)

Terrain Description	Logarithmic		Power Law	
	Roughness Length m	Scale Factor	Index	Scale Factor
	z	$A(z_0)$	α	$B(z_0$
1. Rough open sea	0.003	0.021	0.11	1.4
2. Open sea	0.03	0.030	0.14	1.0
3. Suburban, woodland	0.3	0.041	0.22	0.5
4. City centre	3.0	0.058	0.31	0.16

* Recommended values for normal usage

Appendix 5

PARAMETERS FOR MAXIMUM SPEED-UP OVER LOW HILLS

Hill Shape	ΔS_{max}†	a	k	
			x < 0	x > 0
2-dimensional ridges (or valleys with H – minus)	2 H/L	3	1.5	1.5
2-dimensional escarpment	0.8 H/L	2.5	1.5	4
3-dimensional axisymetrical hills	1.6H/L	4	1.5	1.5

Note: † for H/L > 0.5, assume H/L =0.5 in formulae