Loads and Seismic Design

2005 National Building Code
Wind and Snow
Importance Factors

Russ Riffell, P.Eng.
Chair, Standing Committee on Structural Design
Part 4 of the National Building Code of Canada

National Building Code of Canada

- What Is It?
  - Model Code that is essentially a set of provisions for the safety of the public in buildings
    - Safety
    - Health
    - Accessibility
    - Fire and Structural Protection of Buildings
  - Intended for use throughout Canada
    - Consistent set of rules

National Building Code of Canada

- Where Does It Come From?
  - National Research Council publishes the NBC
  - All Canadians have input to it:
    - Provincial/Territorial Policy Advisory Committee on Codes (PTPACC)
    - Public Review
    - Membership in Committees

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National Building Code of Canada

- Under the Constitution Act, provincial and territorial governments regulate building
- PTPACC
  - Established by provincial and territorial code authorities to provide policy guidance to the NBC
  - Liaison with provinces/territories and the NBC
  - Intended to ensure relevance of the NBC
- NBC not law unless officially adopted by a territory or province or Vancouver or Montreal

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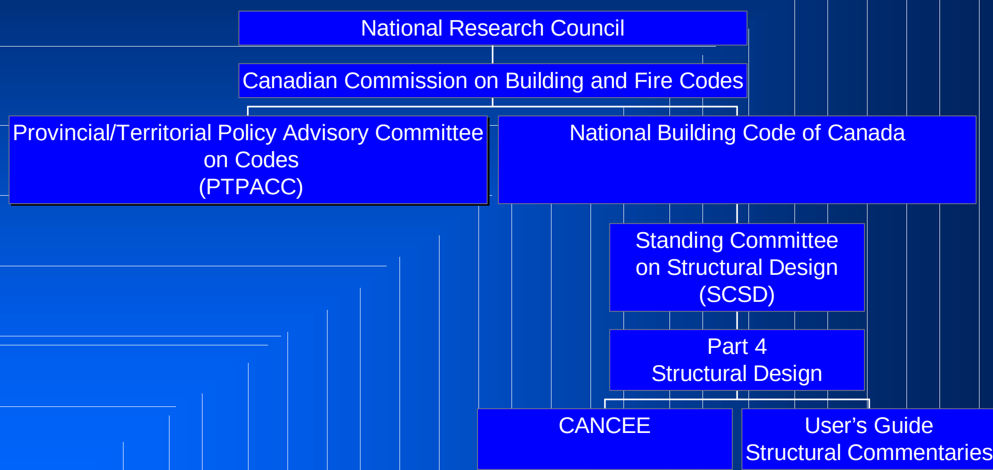
National Building Code of Canada



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NBC - 2005

- Objective-based Code
  - CCBFC declared a partial moratorium on code changes to allow standing committees to concentrate on conversion to objective-based format.
  - Part 4 not affected
  - Created delay in publishing of NBC
- Code objectives clearly defined
- Promote innovation
- Revisions easier to implement

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2005 Code Format

- Two Divisions, A and B
- Division A
  - Compliance
  - Objectives
  - Functional Requirements
- Division B
  - Acceptable Solutions
    - Part 4
    - Other solutions with safety >= Part 4

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Harmonizing Loads

- Wind (1995)
  - Annual probability of being exceeded
    - 1/100 for strength of post-disaster buildings
    - 1/30 for primary structural action
    - 1/10 for cladding and deflection or vibration
- Earthquake (1995)
  - Probability of exceedance of 10% in 50 years
  - Annual probability of being exceeded
    - 1/475

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Harmonizing Loads

- **Earthquake (cont'd)**
  - Specified load includes a Seismic Importance Factor, I
    - I = 1.5 for post-disaster buildings
    - I = 1.3 for schools
    - I = 1.0 for all other buildings
- Snow (1995) 30 year return period, i.e.1/30

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Harmonizing Loads

- SCSD established a task group to study this issue of different methods of accounting for loads
  - Earthquake includes a seismic importance factor
  - Wind varies the return period which is another method of implementing an importance factor
  - Account for buildings used for shelter in time of disaster
  - Review of loads, load factors and load combinations

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Loads

- Dead Load, D
  - permanent load due to weight of building components (and vertical loads due to earth)
- Live Load, L
  - variable load due to intended use and occupancy, including loads due to cranes and pressure of liquids in containers
- H
  - permanent load due to lateral earth pressure, including groundwater

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Loads

- Snow Load, S
  - variable load due to snow + ice + included rain, or rain
- Wind Load, W
  - variable load
- Earthquake Load, E
  - rare load
- P and T
  - permanent load due to prestress
  - temperature, shrinkage, moisture , creep, settlement

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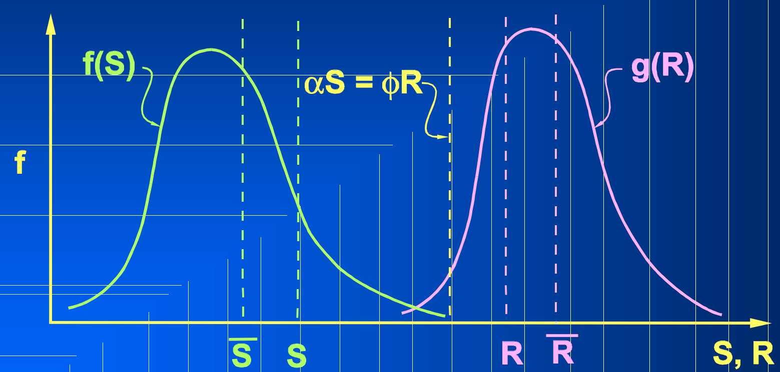
Limit States Design

- Ultimate Limit States



Limit state just satisfied

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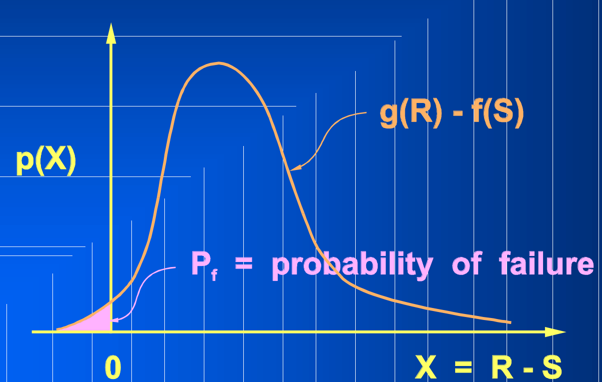
Limit States Design

- **Statistical Analysis of Safety**



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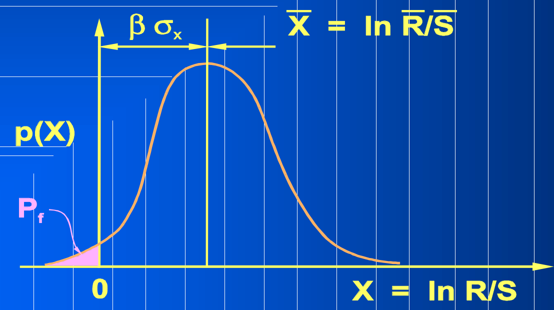
Limit States Design

- **Statistical analysis of safety**

  Let $X = \ln R/S$ $\quad\sigma_x$ = standard deviation of X
  Set distance from 0 to the mean value as β times σ_x.
  Thus, β is the reliability index.



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Reliability Index

- 1995 Code examined to calibrate new loads (return periods) and load factors.
  - Live load that includes both use and occupancy and snow load is conservative
  - Reliability indices for the combination of dead load and snow load are smaller than other load combinations. OK for concrete but not for steel or timber.
  - Combination of dead, wind and snow for steel: reliability index > 3, except where snow load dominates

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Reliability Index & Load Factors

- 2005
  - Combinations of dead and live (use & occupancy) and dead and wind loads from the 1995 NBCC have 50-year reliability indices of 3.0 or larger.
  - Return period of 50 years
  - Target Reliability Index of 3.0

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Wind Load Calibration

- Canadian Meteorological Society has 223 sites with records for at least 10 years.
- Data analyzed by fitting a Gumbel distribution to wind velocities.
- 50 and 500 year return period values calculated from this distribution.
- Importance values calculated from distribution.
  - Mean value for 100 year return period is 1.21.

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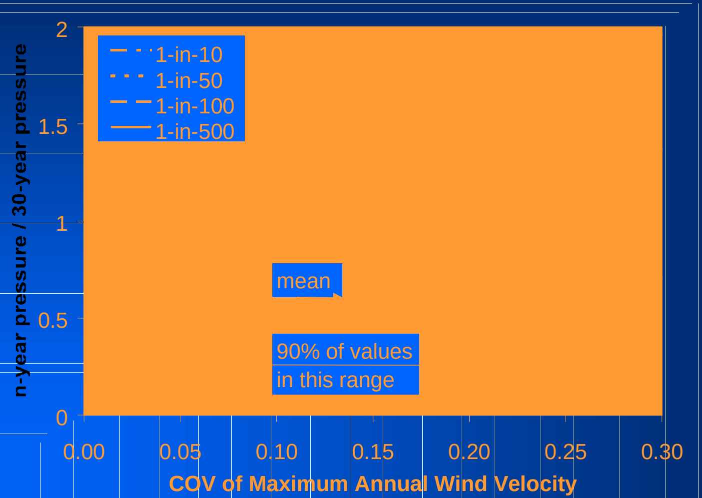
Wind Load Calibration



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Wind Loads

- Exposure factor, Ce
  - Two conditions:
    - Open Terrain - level with scattered buildings, trees or other obstructions, shoreline, open water. (Same as 1995.)
    - Rough Terrain - suburban, urban or wooded for at least 1 km or 10 x the building height.
- Gust Effect Factor for Internal Pressures, Cgi
  - Was 1.0 to 2.0. Now 2.0 unless a detailed calculation yields a lower value.

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Wind Reference Pressure

Location	Reference Velocity Pressure (kPa) 1-in-10	1-in-30	1-in-50	1-in-100	1-in-500
Victoria (Gonzales)	0.49	0.58	0.62	0.69	0.84
Winnipeg	0.32	0.40	0.44	0.51	0.64
Mississauga	0.37	0.45	0.49	0.55	0.68
Halifax	0.40	0.52	0.58	0.67	0.89

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Wind Reference Pressure

Design Wind Velocity Pressures, q_{30} and q_{50}

City	$q_{30}(q_{50})$, kPa
Victoria	0.58(0.63)
Vancouver	0.44(0.48)
Chilliwack	0.63(0.72)
Kamloops	0.37(0.40)
Kelowna	0.43(0.47)
Revelstoke	0.29(0.32)
Calgary	0.46(0.50)
Edmonton	0.40(0.45)

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Internal Pressures

- Category 1 (small, uniformly distributed openings)
  - 1995 Cpi = 0.0 to -0.3; Cg = 1.0
  - 2005 Cpi = 0.0 to -0.15; Cgi = 2.0 or calculated
- Category 2 (significant openings will be closed)
  - 1995 Cpi = 0.7 to -0.7; Cg = 1.0
  - 2005 Cpi = 0.3 to -0.45; Cgi = 2.0 or calculated
- Category 3 (gusts transmitted to interior)
  - 1995 Cpi = 0.7 to -0.7; Cg = 2.0
  - 2005 Cpi = 0.7 to -0.7; Cgi = 2.0 or calculated

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Wind Loads

- Cgi Detailed Calculation
  - $Cgi = 1 + 1/(1 + \tau/10)^{1/2}$
  - $\tau = Vo/(695 \times A) \times (1 + 142000 * As/Vo * \delta)$
    - Vo = internal volume (m^3)
    - A = total area of all openings in the envelope (m^2)
    - As = total exterior surface area (m^2)
    - δ = the average flexibility of walls and roof, and is equal to the interior volume change in m^3 per kPa of pressure change divided by the total surface area in m^2 of slabs and walls excluding slabs on grade

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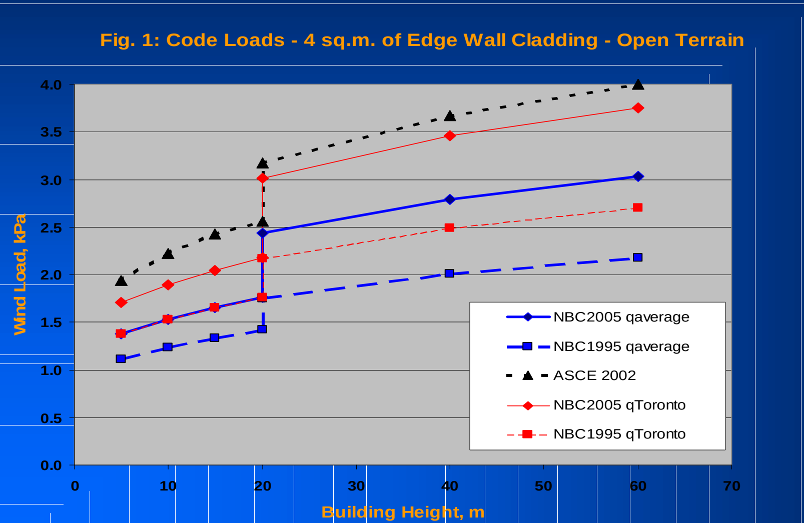
Wind Load Comparison



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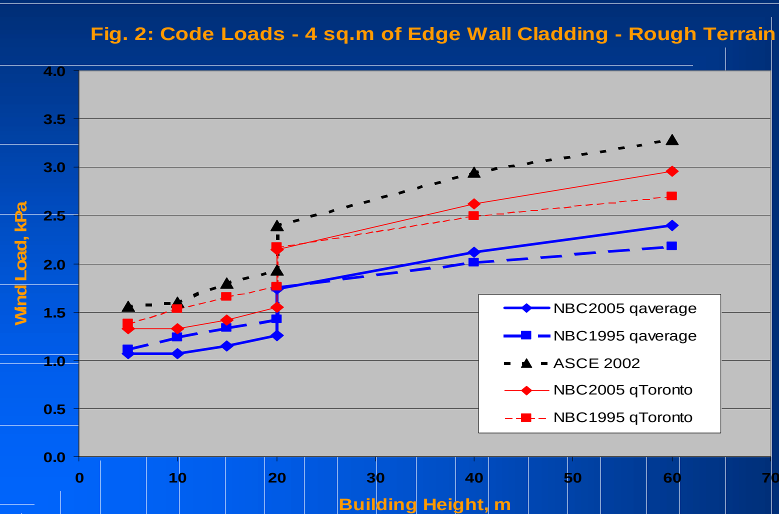
Wind Load Comparison



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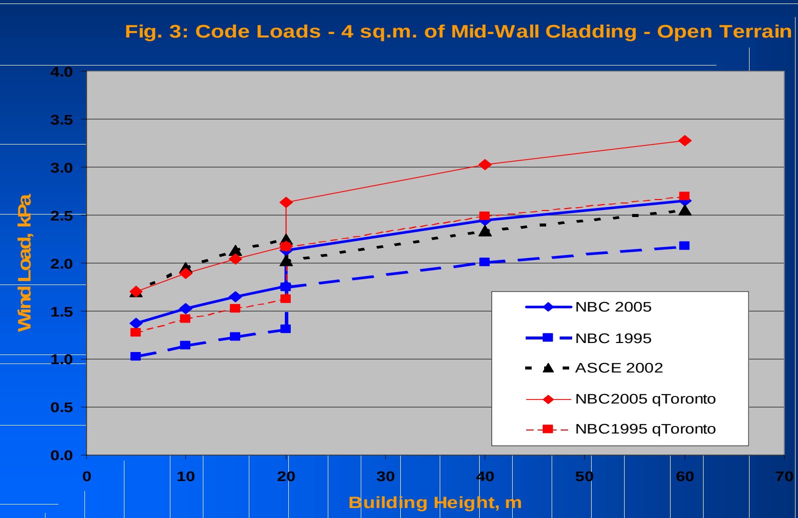
Wind Load Comparison



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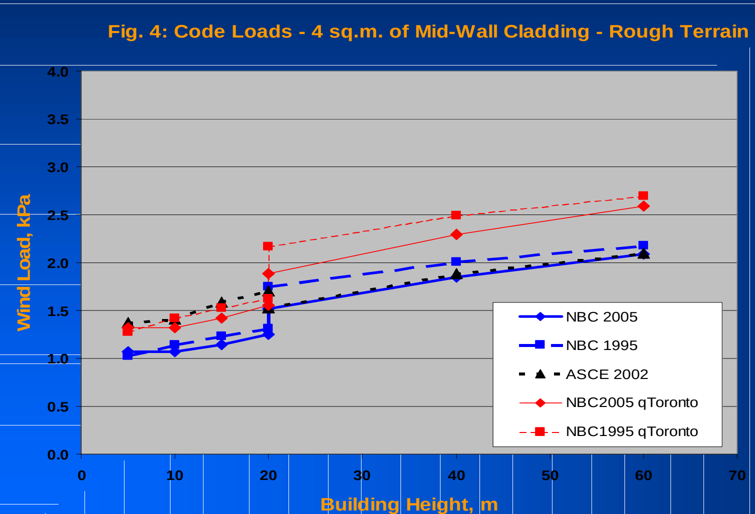
Wind Load Comparison



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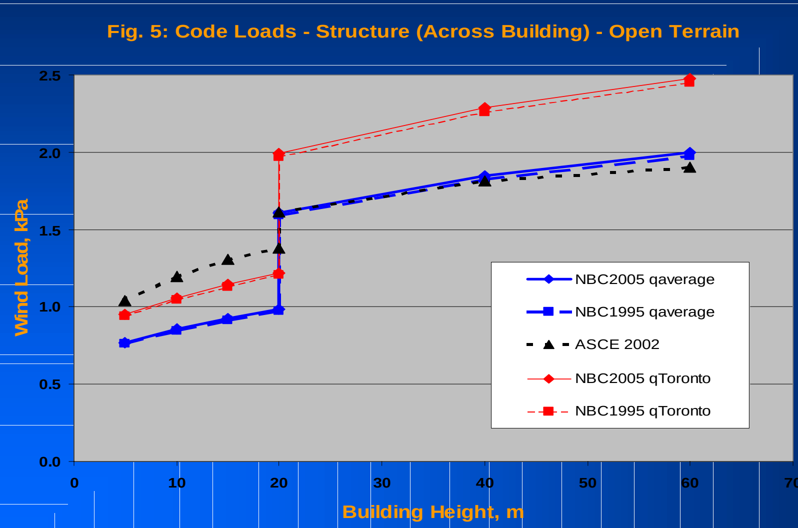
Wind Load Comparison



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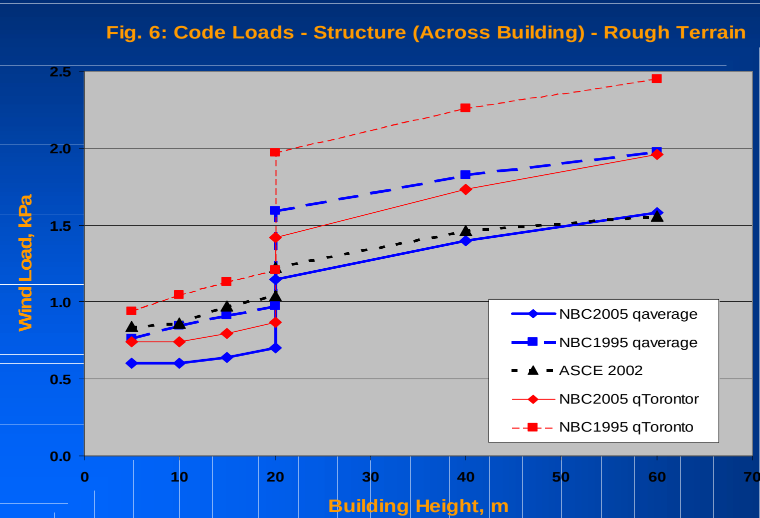
Wind Load Comparison



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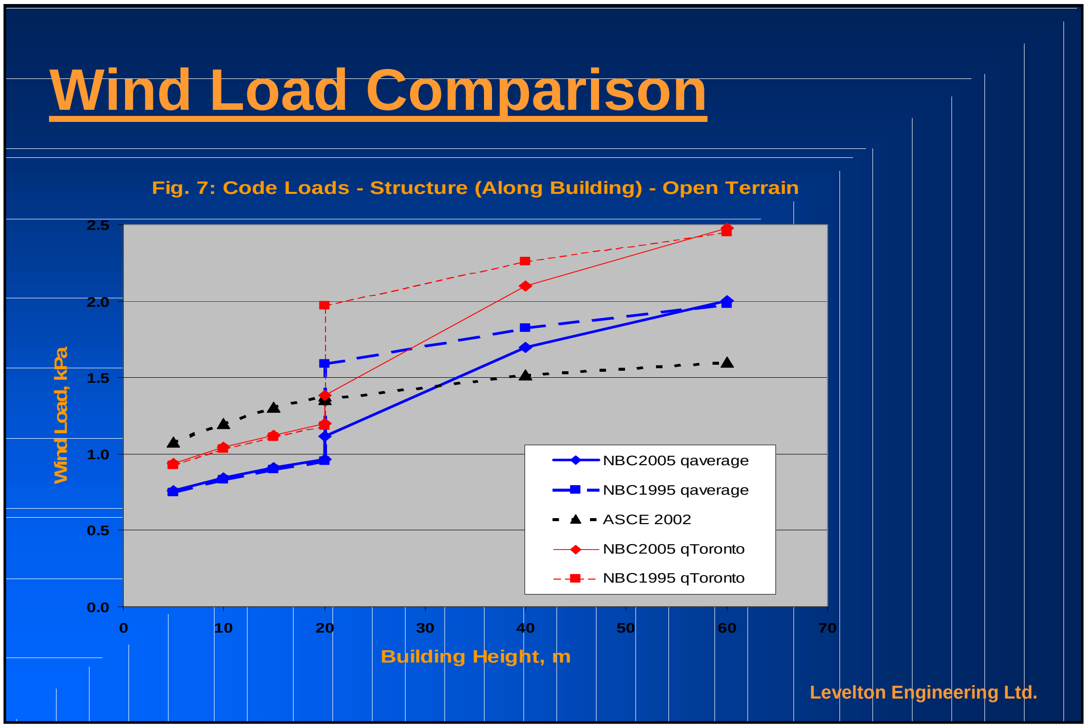
Wind Load Comparison
Fig. 7: Code Loads - Structure (Along Building) - Open Terrain
Wind Load, kPa
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
Building Height, m
NBC2005 qaverage
NBC1995 qaverage
ASCE 2002
NBC2005 qToronto
NBC1995 qToronto
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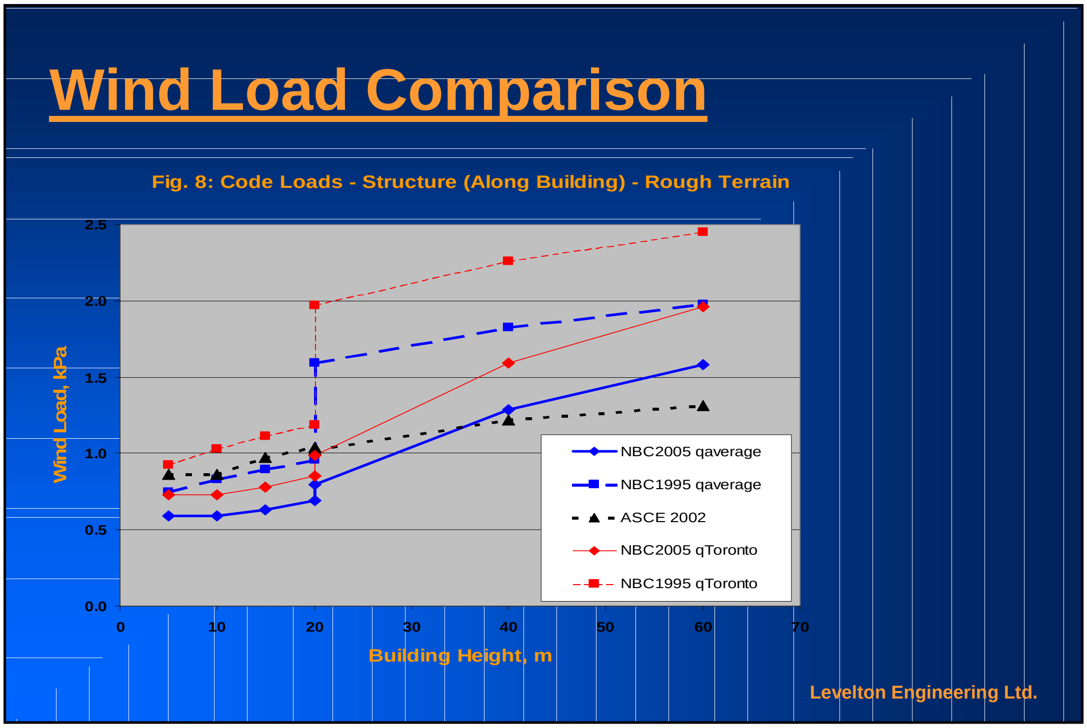
Wind Load Comparison
Fig. 8: Code Loads - Structure (Along Building) - Rough Terrain
Wind Load, kPa
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
Building Height, m
NBC2005 qaverage
NBC1995 qaverage
ASCE 2002
NBC2005 qToronto
NBC1995 qToronto
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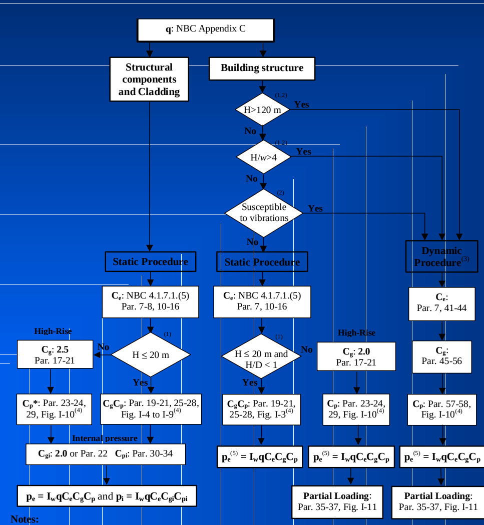
Wind Design Flow Chart



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Reliability Index & Load Factors

- Snow
  - Large variability in load
  - New calibration gave load factor = 1.7
    - Factored snow load would increase by 25%
  - Decided to remain with LF = 1.5
    - Factored snow load now ~ 10% larger than 1995

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Reliability Index

- 1995 Code
  - Reliability indices for the combination of dead load and snow load are smaller than other load combinations. OK for concrete but not for steel or timber.
  - Combination of dead, wind and snow for steel: reliability index > 3, except where snow load dominates

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Snow

- Reduction of wind exposure factor, Cw, tightened. Cannot reduce from 1.0 for Importance categories High and Post-Disaster.
- Drift criteria for curved roofs

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Importance Factors

- Apply an importance factor to all variable loads, based on use and occupancy

- Use and Occupancy
  - **Low Hazard**
  - **All Others**
  - **Emergency Shelter**
  - **Post-Disaster**
- **Importance Category**
  - **Low**
  - **Normal**
  - **High**
  - **Post-Disaster**

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Importance Factor - Wind

Importance Category	**I_W**	
	ULS	**SLS**
Low	**0.8**	**0.75**
Normal	**1.0**	**0.75**
High	**1.15**	**0.75**
Post Disaster	**1.25**	**0.75**

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Importance Factor - Snow

Importance Category	I_s	
	ULS	SLS
Low	0.8	0.9
Normal	1.0	0.9
High	1.15	0.9
Post Disaster	1.25	0.9

Major Changes to Part 4

- Harmonization of Return Periods and Importance Factors
  - Review of reliability index for factored loads and resistances
- Companion Action Load Combinations
  - Re-definition of loads, factors & combinations
- 50 year return periods for Wind and Snow
- Revised Seismic Design Requirements

Other Changes

- WSD gone
  - Masonry standard now only LSD, no WSD
  - Factored resistance of soil for design of foundations - no more allowable bearing pressures
- Steel building systems added to 4.3

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Factored Loads 2005 vs. 1995

- Dead + Live combination is unchanged.
- Dead + Wind combination 1% less than 1995.
- Dead + Snow combination 10% greater than 1995.
- Dead + Live + Snow combination less than 1995.
- Dead+ Live + Wind greater than 1995.
- Dead + Wind + Snow greater than 1995.

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Questions

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