Loads and Load Combinations for NBCC

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CSCE Workshop – NBCC Loads and Seismic Design
2004 June 10, Calgary AB

Outline

- **Companion Action Principle**
- **Review of NBCC 1995**
  - **Snow Load Factor**
  - **Return Period on Environmental Loads**
- **NBCC 2004 Provisions**
  - **Dead Loads & Load Effects**
  - **Load Combinations**
  - **Impact on Design Load Effects**
- **Summary**

NBCC 1995 Format

$\phi R > \alpha_D D + \psi \gamma \{\alpha_L L + \alpha_Q Q + \alpha_T T\}$
where ψ = load combination factor
γ = importance factor

- NBCC 1995 Load Combinations:
  - 1.25 D + 1.5 L
  - 1.25 D + 1.5 Q (wind)
  - 1.25 D + 0.7 {1.5 L + 1.5 Q (wind)}
    = 1.25 D + 1.05 L + 1.05 Q (wind)

note that snow is (was!) included with live

Reminder

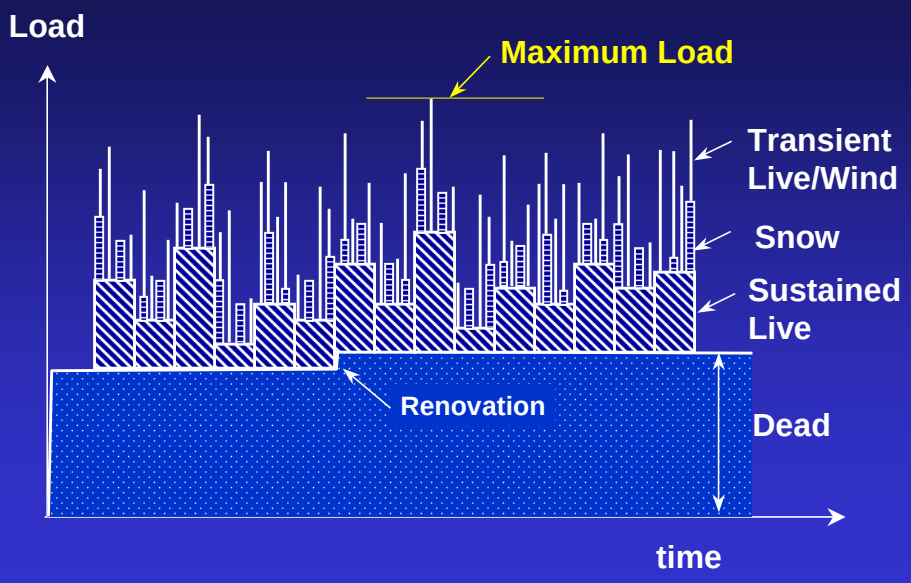
- **These are combinations of *EFFECTS***
  - *ie Axial force in a column, moment in part of a frame, etc*

A – we can apply to the structure the combined factored load and find the resulting effect

OR

B- we can apply unfactored loads of each type, and then calculate the combined factored effect. This is easier to automate, but only valid for linear structures.

Time History of Loading



Turkstra's Rule (early '80s)

Worst case of combined transient loads occurs when:

- **one load, the principal action, is its extreme value**
- **other loads, the companion actions, are the largest that would be expected while the principal action has its extreme value**

Companion Action Format

$\phi R > \alpha_D D + \alpha_i S_i + \Sigma \alpha_{ik} S_k$, $i \neq k$

where S_i = principal action
S_k = companion actions

Typical Load Combinations:

1.25 D + 1.5 L + 0.4 W (wind)

1.25 D + 1.4 W (wind) + 0.5 L

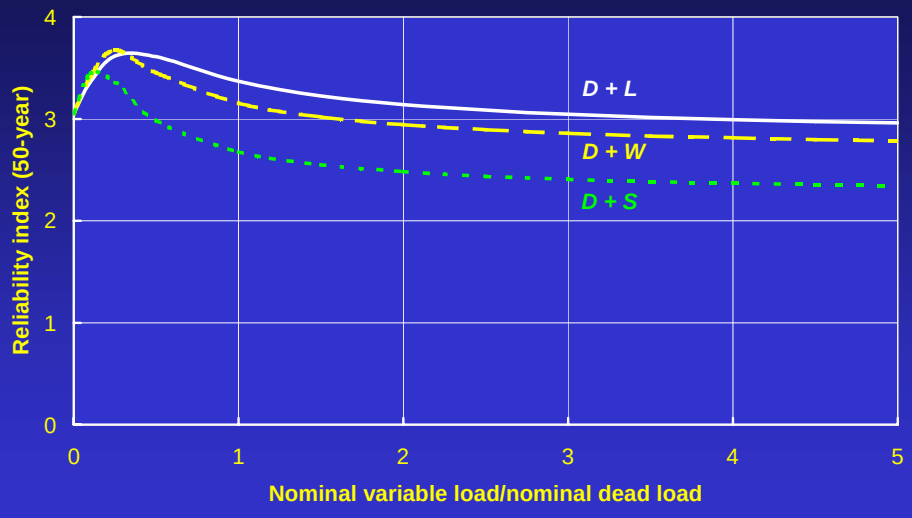
Companion Action Format

- Better represents the situation of one extreme event with the other loads that may be acting
- Permits logical extensions for special cases

Designer can Envisage Hazards

- Correlation of transient loads explicitly considered
- Can you imagine a structure where simultaneous maximum values of transient loads are:
  - unlikely?
  - expected?

1995 NBCC Reliability Indices



- *reliability for snow load deficient?*

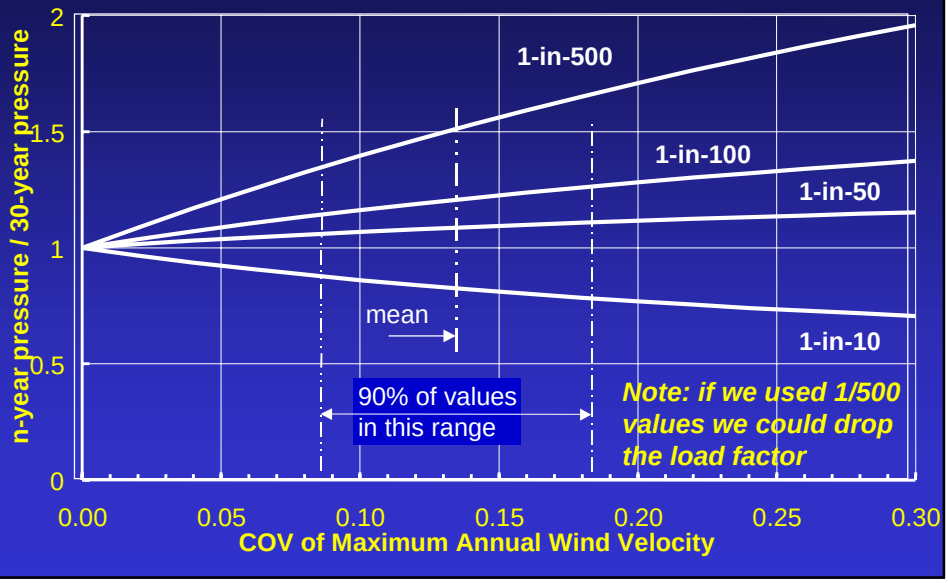
2000/2001 Failures: Sarnia Mall

Source: *Globe and Mail* 2000 December 09

Return Period for Environmental Loads

- NBCC 1995 specifies:
  - 30 years for specified Snow, Wind
  - 10 years for Wind for Deflections
  - 100 years for wind on Important Structures
- Use 50 year or 500 year return periods (only) for 2004 NBCC?
- Ratio n-yr/30-yr depends coefficient of variation of annual maximum load

Specified Load Return Period



NBCC 2004 Calibration Process

1. **Reliability indices for 1995 NBCC**
2. **Preliminary load combinations for 50-yr, 500-yr loads by Bartlett, Hong & Zhou**
   - **review by Part 4 Task Group on Snow & Wind Loads**
   - **review by Part 4 Standing Committee**
3. **Revised load combinations, 50-yr loads**
   - **review by Task Group and Part 4 committee**
   - **public review**

Proposed 1.2 D Criticized

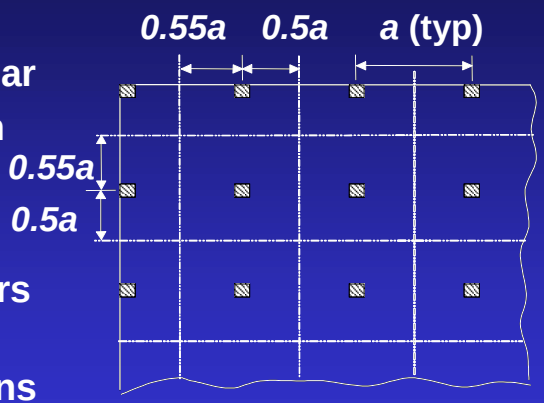
- History: 1.3 proposed for 1975 NBCC reduced to 1.25 to maintain same ratio of dead/live load factor as in ACI 318-71
- Specific concerns:
  - floor thickness variability
  - dead load of soil & landscaping
  - tributary area computation

2000 Survey: Concrete Floor Thickness

- Marked variability for
  - Cast-in-place toppings on precast
  - Cover slabs in unshored composite construction (no specified tolerances?)
- "Uncertain D" with load factor of 1.5 considered but not adopted
- Make allowances for extra dead load
- Consider deflections of supporting members

Tributary Areas in NBCC

Commentary G:
lines of zero shear
halfway between
column lines



- Safe for corners
- Unsafe for 1st interior columns

Note: problem with low D factor when "approximations" are used

2004 NBCC Combinations

1.4 D
1.25 D + 1.5 L + (0.4 W *or* 0.5 S)
1.25 D + 1.4 W + (0.5 L *or* 0.5 S)
1.25 D + 1.5 S + (0.5 L *or* 0.4 W)
0.9 D + (1.5 L *or* 1.4 W *or* 1.5 S)

Add to all combinations:
P = prestress
H = horizontal earth pressures
T = restrained deformations (safety)

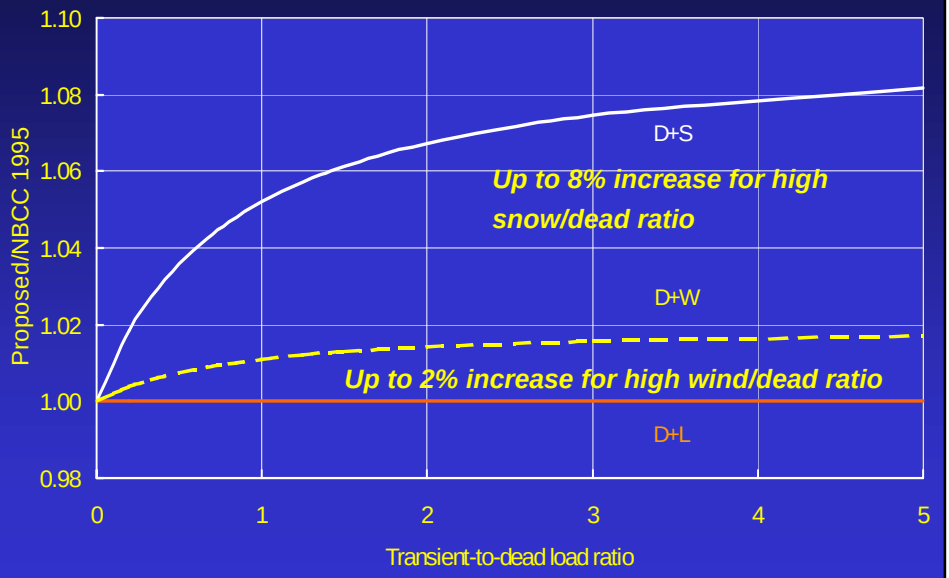
50-yr Wind & Snow Specified

- typically ~10% greater than 30-yr values
- snow load factor initially 1.7, implies a 25% increase in factored load, deemed too big.
- modify for importance categories based on use & occupancy
- reduce for SLS checks

Importance Factors for S, W

Importance Category	Ultimate (Snow or Wind)	Serviceability Snow	Serviceability Wind
Low	0.8	0.9	0.75
Normal	1.0		
High	1.15		
Post Disaster	1.25	0.9	0.75

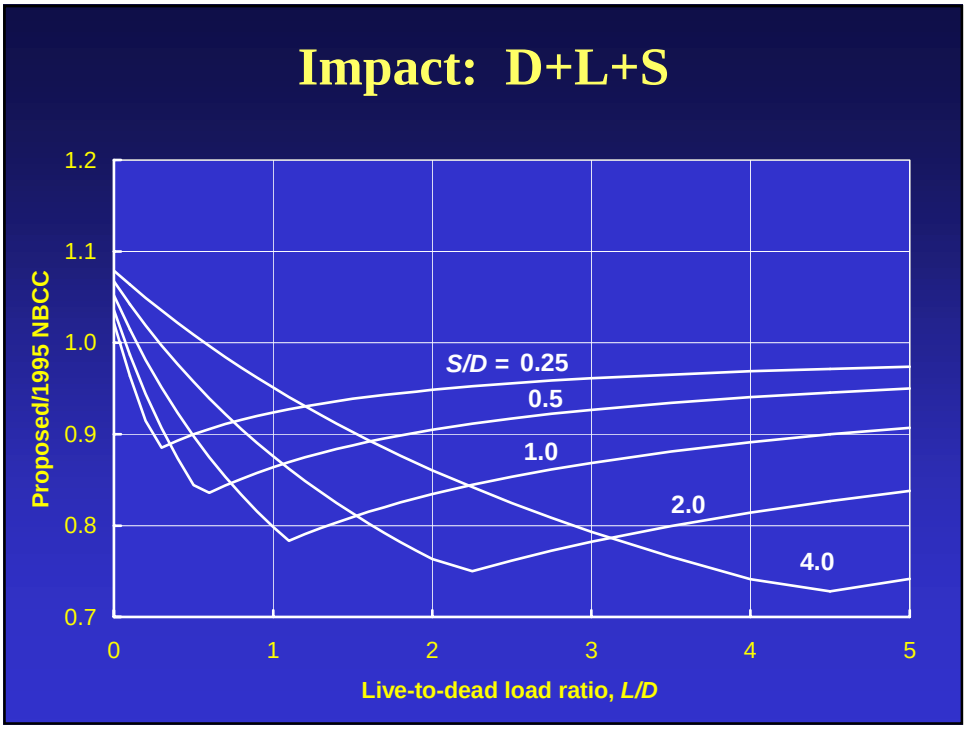
Impact: Single Transient Load



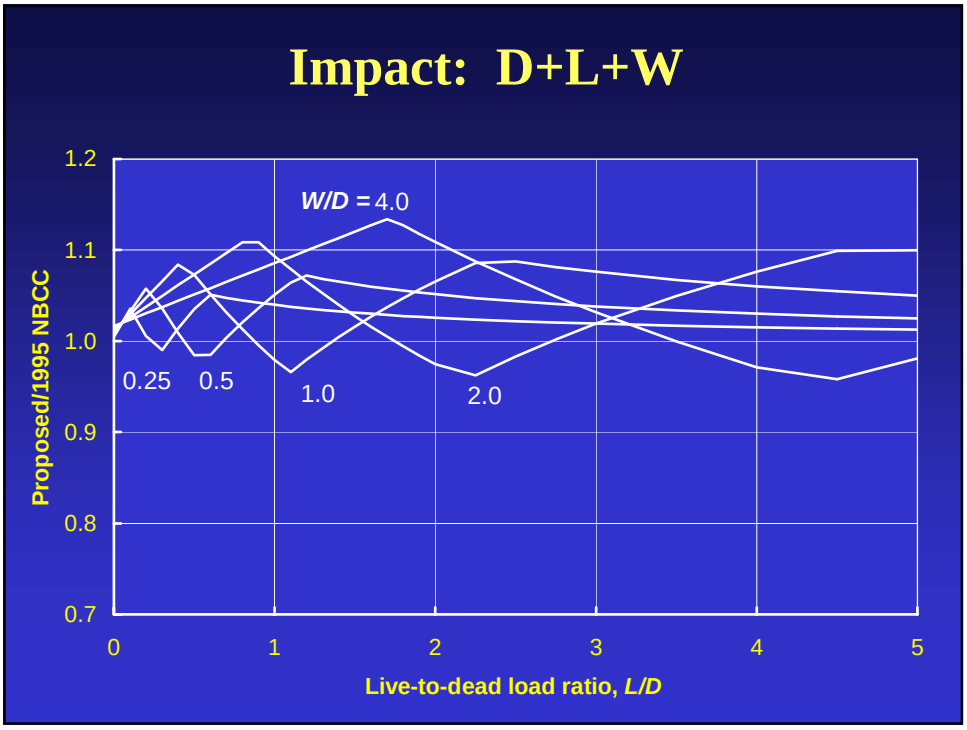
Uncoupling Snow & Live

- **Members resisting low D, high L (use + occupancy), high S require less resistance.**
- **Logical consequence of considering Live and Snow as independent**
- **Similar format adopted in ASCE-7 based on load combinations derived in 1980**

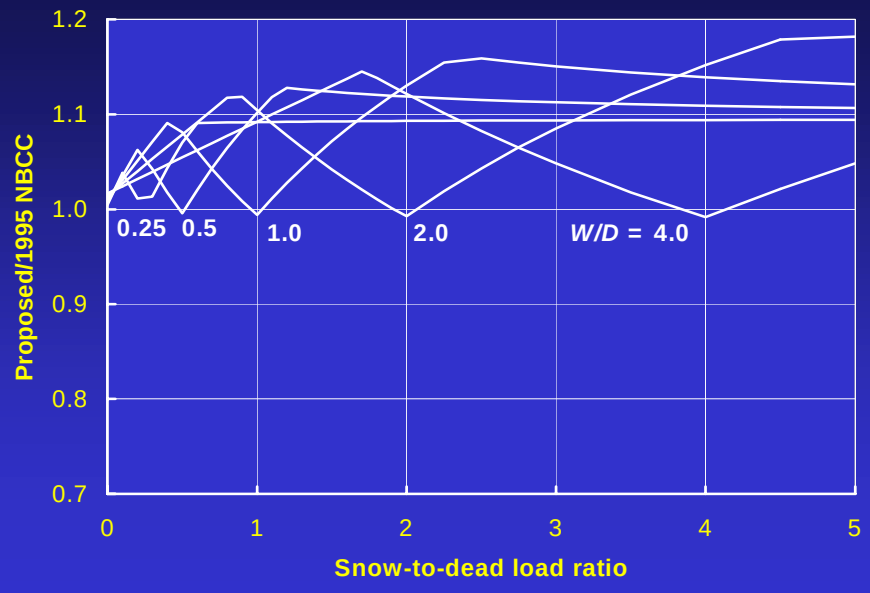
Impact: D+L+S



Impact: D+L+W



Impact: D+W+S



Summary

1. **Companion action load combination format proposed for NBCC 2004:**
   - **more realistic representation**
   - **permits logical decisions for unusual cases**
   - **little difference for many members**
   - **consistent with other international standards (ACI 318, AISC LRFD, etc.)**

2. **Dead loads:**
   - make allowance for extra thickness of thin toppings
   - tributary areas for first interior columns

3. **Snow loads are no longer classified with live loads due to use and occupancy.**
   - less resistance needed for members carrying snow and live loads

4. **Only 50 year environmental loads specified:**
   - increases specified loads by ~ 10%
   - additional increases for important and post-disaster buildings
   - load factors less than 1.0 reduce specified loads for serviceability checks.

5. **New load combinations give similar demands to NBCC 1995:**
   - less demand due to snow & live loads
   - more demand due to snow only

6. **New load combinations have been reviewed by various committees**

- **Additional references: papers by Bartlett, Hong & Zhou in *Canadian Journal of Civil Engineering***

Acknowledgements

- **National Research Council of Canada**
- **Natural Sciences & Engineering Research Council of Canada**
- **NBC Part 4 Task Group on Snow and Wind Loads (D. E. Allen, Chair)**
- **Canadian Meteorological Centre**
- **Steel Structures Education Foundation**
- **J. G. MacGregor**
- **Michael Bartlett (who prepared this presentation and permitted its use for this CSCE short course)**