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Proposed Change 1980

Code Reference(s):	**NBC20 Div.B 4.1.3.2. (first printing)** **NBC20 Div.B 4.1.6.2. (first printing)** **NBC20 Div.B 4.1.6.5. (first printing)** **NBC20 Div.B 4.1.6.7. (first printing)** **NBC20 Div.B 4.1.6.9. (first printing)** **NBC20 Div.B 4.1.6.10. (first printing)** **NBC20 Div.B 4.1.7.3. (first printing)** **NBC20 Div.B 4.1.8.2. (first printing)**
Subject:	Climatic Loads
Title:	Specified Wind and Snow Loads in Part 4
Description:	This proposed change revises provisions for wind and snow loading to account for potential loading changes resulting from climate change.
Related Code Change Request(s):	CCR 1639, CCR 1638, CCR 1626, CCR 1625, CCR 1624, CCR 1623, CCR 1622, CCR 1621, CCR 1620, CCR 1619, CCR 1618, CCR 1617
Related Proposed Change(s):	PCF 1979, PCF 2018, PCF 2048

This change could potentially affect the following topic areas:

- ☐ Division A
- ☐ Division C
- ☐ Building operations
- ☑ Small Buildings
- ☐ Fire Protection
- ☐ Accessibility
- ☐ Building Envelope
- ☐ Heating, Ventilating and Air Conditioning
- ☐ Construction and Demolition Sites
- ☑ Division B
- ☐ Design and Construction
- ☑ Housing
- ☑ Large Buildings
- ☐ Occupant safety in use
- ☑ Structural Requirements
- ☐ Energy Efficiency
- ☐ Plumbing

Problem

Climate change effects not yet addressed in the NBC

In the 2020 and previous editions of NBC Part 4, it was assumed that climatic data statistics used in structural design are time-independent (or “stationary”). Although not specifically stated in the NBC, the service life of buildings has implicitly been taken as 50 years. Accordingly, the climatic design data in the NBC have been updated for each code cycle using past weather observations collected and analyzed by Environment and Climate Change Canada (ECCC), under the assumption that past statistics will continue to be applicable to the future. In the face of extensive evidence that the climate is changing across Canada, this practice raises real safety concerns for the design of the main structural systems and envelope of buildings to withstand climatic loads such as those due to snow and wind.

In addition, in the current edition of the NBC, wind data are based mainly on synoptic wind observations and do not account for the different existing climatic influences in Canada, where some regions are more prone to local convective thunderstorms. This phenomenon is expected to be exacerbated in the future with climate warming.

Uniform hazard approach in load calculations yields non-uniform probability of failure

An additional problem identified in reliability studies is that the current methodology for the structural design of buildings in the NBC uses what has been termed a “uniform hazard” approach. In this approach, reference design wind and snow loads at various locations across Canada are specified at an annual probability of exceedance of 1/50, corresponding to a 50-year return period in a stationary climate. The minimum safety criterion adopted in the NBC, expressed as a reliability index of 3.0, corresponds to a probability of failure (i.e., probability that the effects of loads are higher than the resistance of a structural member in a building) of 0.001 during the 50-year assumed service life of a building in the Normal Importance Category. To provide an acceptable probability of failure, the "specified design loads" or so-called "service loads" have been multiplied by load factors—1.5 for snow and 1.4 for wind—to obtain the "ultimate loads" applied in design calculations, where the load factor is function of the target reliability index and the variability of the load. These factors have been taken as constant across all regions of Canada. However, reliability studies [1] have shown that, due to the different behaviour of wind and snow events in Canada's various regions and the uncertainties in wind and snow loads identified by their coefficients of variation, this approach leads to a non-uniform probability of failure across the country. The probability of failure can differ by as much as a factor of 10, depending on where the project is located, and this variability could be further exacerbated by climate change.

Roof snow load adjustments needed for scouring effects and increase in roof insulation

There are some additional issues with the factors or coefficients that convert reference ground snow loads to snow loads on roofs of various configurations. These coefficients, which are intended to reflect the effects of scouring of snow off roofs by the wind and the accumulation of snow in drifts, have also been assumed to be essentially the same in all regions of Canada. Recent research [1] (also supported by past anecdotal evidence) has shown that the ability of wind to scour snow or form drifts depends on the combination of ambient temperatures and wind speeds during the winter months, and this combination varies significantly depending on geographic location. For example, in the milder winter climate of Vancouver, where snow tends not to persist for long before melting, the wind does not typically scour snow off roofs or form drifts to the same extent as at a location such as Winnipeg with its more prolonged intervals of cold temperatures combined with strong winds. Studies [1] have identified how the ground-to-roof conversion factors can more rationally account for regional climatic differences both in the present and in the future as the climate changes.

Snow loads on roofs are also affected by the combination of internal temperature inside the building, external temperature, and degree of roof insulation, a phenomenon left unaccounted for in the current edition of the NBC, while other codes and standards use a temperature factor to account for this effect. In a changing climate and with the trend towards better-insulated roofs for more energy-efficient buildings, the argument is made for introducing a thermal factor, C_T, in the assessment of snow loads on roofs in NBC Part 4.

Justification

Updating climatic data for climate change

Extensive research has been conducted by ECCC [2] into how the climate statistics are likely to change in various regions of Canada between now and 2100 under various greenhouse gas (GHG) emissions scenarios, namely representative concentration pathways RCP2.6, RCP4.5, RCP6 and RCP8.5.

This research provides a rational basis for future projections of climatic loads, such as those due to wind and snow, during the service life of buildings in different locations, and for inclusion of these expected future climatic load effects in the NBC. For the NBC 2025, the approach that is proposed to account for climate change effects in climatic data used for building design is based on RCP 8.5 (8.5 W/m^2), corresponding to a 2.5°C global warming scenario in a 50-year horizon. Refer to PCF 1979 for the updated climatic data.

RCP8.5 was selected by consensus among climate scientists and code experts, including regulators, across the country, considering that the differences between the different climate scenarios in the ECCC study were small and within the uncertainties inherent to the model predictions over the 50-year design life of a building.

In general terms, temperature and precipitation are expected to increase in all regions of the country between now and 2100, wind loads are expected to increase in most regions of the country, and ground snow loads are expected to decrease in all regions, except the Far North where some increases are expected [2].

For wind data, synoptic wind storms and design wind speeds for thunderstorms (convective wind storms) have been studied separately and the worst effects included in Table C-2 in accordance with the Minimax approach (see PCF1979). This is an important new aspect to consider since thunderstorms and synoptic storms may change differently in the future climate.

Adjusting loads to account for non-stationarity in a future changing climate

Results obtained using RCP8.5, corresponding to 2.5°C global warming, were adopted to establish future climatic loads for structural design. Comparisons were made on the basis of a building constructed in 2025 having a service life of 50 years, and the differences between the four RCP scenarios included in the ECCC study [2] remained within a narrow range. The decision to adopt RCP8.5 reflects a prudent approach, as there is uncertainty on the evolution of climate variables over the next 50 years. Recent studies [1] revealed the statistical significance of the non-stationarity of extreme wind speeds and ground snow loads based on the future projections provided by ECCC [2] for many regions across Canada.

Therefore, a non-stationary extreme-value analysis approach, known as the "Minimax Method," is proposed to design for the worst-case year of the building's service life, which ensures that the annual probability of failure remains acceptably low during its entire service life. For instance, for wind loads, future projections mostly show increases in reference pressure, making the last year of service life the worst case; for ground snow loads, future projections mostly show decreases, making the first year of service life the worst case.

Using ECCC's climate projections [2], regional climate change factors have been developed that can be applied to the wind and snow reference values in different regions across the country. These factors were used to determine the reference values tabulated in NBC Table C-2, Climatic Design Data for Selected Locations in Canada.

Introducing the uniform risk approach in ultimate limit state (ULS) design

To address the shortcomings related to the variability of the probability of failure across the country, a so-called "uniform risk" approach is proposed in which "ultimate loads" are specified directly for each location with load factors of 1.0, similar to the approach used for earthquake design in the NBC and other approaches adopted internationally. Notably, ASCE/SEI 7, "Minimum Design Loads for Buildings and Other Structures," converted to uniform risk for wind loads in the 2010 edition [3] (and more recently for snow loads in the 2022 edition) and was preceded in this step by the Australian Building Code many years before [4].

Climate change factors were calculated as ratios of the future design-level values determined using the Minimax approach to the design-level values calculated in a stationary historical period using the conventional approach. For reference design wind pressures, most areas in Canada have a climate change factor of 1.05, while locations in Ontario, the Atlantic provinces, and west of 120°W in British Columbia have a climate change factor of 1.1. For ground snow loads, excepting the northern territories where a climate change factor of 1.05 applies, most regions have a climate change factor of 1.0, as the governing scenario is based on the present climate (see [5] and PCF1979).

In deriving climate change factors for the "uniform risk" approach, target annual probabilities of exceedance of 1/500 for wind and 1/1000 for snow were selected for Normal Importance Category buildings, and the worst-case reference value during the future service life was compared with the present value used in NBC 2020 (with an annual probability of exceedance of 1/50 for both wind and snow). With the proposed uniform risk approach, the reference wind pressures and ground snow loads are specified at much lower annual probabilities of exceedance, while eliminating the need for load factors (i.e., setting them to 1.0) for both wind and snow. The 1/500 and 1/1000 annual probabilities of exceedance were selected to maintain the average risk of failure across the country, without any consideration of climate change. As a result, the same target probability of failure of approximately 1/1000 is set, but with less variation from location to location.

Revising the roof snow load formula for scouring and heat loss effects

When considering snow accumulation on a roof, it is important to understand the relationship between the amount of snow on a roof and the amount of snow on the ground. In the NBC, this relationship is characterized through the combination of the basic roof snow load factor, C_b, and the wind exposure factor, C_w. An examination of the current NBC 2020 provisions reveals that the combination C_bC_w varies between 0.4 and 1.0, depending on the roof size and exposure to wind. However, the wind exposure factor currently does not account for variations in wind speed and temperature across the country, which can have a significant effect on the resulting roof snow distributions.

The effects of the winter wind speed and temperature were parametrically assessed for the representative range of stations used to observe the variations in ground snow load. The simulated ground snow loads were compared to the accumulations determined for a range of roof sizes. In general, buildings in cold regions, where snow builds up on a roof throughout the winter months with relatively high wind speeds, will experience significantly more scouring of snow off the roof compared to buildings in warmer regions with lower wind speeds. The wind exposure factor, C_w, currently used in the snow load formula in the NBC does not account for variations in the amount of snow that is scoured by the wind as a result of local climate conditions. Differences in the local winter temperatures and wind speeds result in variations in the scouring of snow off a roof surface. The current provisions acknowledge this in the form of reductions in snow load due to additional scouring for roofs that are exposed. However, they do not account for the potential for reduced scouring in warmer climates or in areas with low wind speeds. A change to the definition of C_w is proposed to account for these variations. In addition, a reduction in snow drift depth in sheltered areas, such as roof steps, occurs in regions with milder winters, and this variation can be accounted for with a revision to the snow accumulation factor, C_a.

Another aspect to consider is that the current edition of the NBC does not directly address the amount of melting due to heat loss through the roof; historic snow roof observations used in calibration have been collected for a variety of locations and roof geometries without differentiating for roof insulation levels. This shortcoming can become particularly problematic for new buildings designed to achieve the improved energy performance required in the NBC 2020 and the NECB 2020. The increase in the amount of insulation required in roofing results in reduced snow melting due to heat loss and, therefore, potentially increased snow depth. The proposed introduction of a new thermal factor, C_T, in the NBC snow load formula addresses this problem. The thermal factor was derived to include a reduction in roof snow loading due to heat loss; accordingly, where no heat loss is assumed, the factor is 1.0, as should be the case for most new buildings. If the internal temperature in the area directly underneath the roof surface or if the roof insulation properties are not known or highly uncertain, the thermal factor should be taken as 1.0. Whenever conditions for snow melting prevail, the C_T factor should not be less than 0.7.

Calibration studies and benefits of uniform risk approach

From the wind load perspective, regional variations in probability of failure can be significantly reduced by adopting ultimate return periods (1/500 annual probability of exceedance) for reference wind pressure, in accordance with the uniform risk approach. A load calibration procedure has been undertaken [1] that demonstrates that the variability range of the probability of failure and reliability index substantially decreases with the uniform risk approach. To illustrate the benefits of the new approach, the following two cases were considered:

- a uniform hazard case with a return period of 50 years and wind load factor of 1.4, which matches that currently used in the NBC 2020, and
- a uniform risk case with a return period of 500 years and a wind load factor of 1.0.

Buildings in the Low, Normal, High and Post-disaster Importance Categories were investigated. For the uniform hazard case, the range of reliability index, β, is 1.6 for coefficients of variation (COVs) ranging from 0.05 to 0.3. For the uniform risk case, the β range narrows significantly to 0.7 for the same range of COVs. Most sites have a COV in the range of 0.1 to 0.2; for these sites, the uniform hazard approach shows a β range of 0.7, whereas for the uniform risk approach, the β range narrows to 0.25.

New load combinations based on uniform risk

In moving to the uniform risk approach for wind and snow loads, new load calibrations have been carried out to update the various design load combinations needed for both the ultimate limit states (ULS) and the serviceability limit states (SLS). NBC Tables 4.1.3.2.-A and 4.1.3.2.-B for ULS have been updated, including the NBC 2020 load combination that relates to seismic loads. The roof snow load combination, E + 0.25S, has been reassessed and updated to E + 0.15S, where S is now based on the 1/1000 annual probability of exceedance rather than 1/50 for Normal Importance Category buildings. The 0.15 coefficient was selected to keep the total value equivalent to the current value prescribed in the NBC 2020 for most locations. NBC Table 4.1.3.4. for SLS required no changes, because revised importance factors for SLS in NBC Table 4.1.6.2. for snow and NBC Table 4.1.7.3. for wind essentially keep the snow and wind serviceability loads close to what they were before.

References

[1] RWDI Report No. 1702484 (2020). Development of Climate Change Provisions for Structural Design of Buildings and Implementation Plan in the National Building Code.

[2] Cannon, A.J., Jeong, D.I., Zhang, X., Zwiers, F.W. (2020). Climate-Resilient Buildings and Core Public Infrastructure: An Assessment of the Impact of Climate Change on Climatic Design Data in Canada. Government of Canada, Ottawa, ON. 106 p. (https://climate-scenarios.canada.ca/?page=buildings-report-overview).

[3] American Society of Civil Engineers/Structural Engineering Institute (ASCE/SEI) 7-22 (2022). Minimum Design Loads for Buildings and Other Structures.

[4] Australian/New Zealand Standard (AS/NZS) 1170.2:2002 (2002). Structural design actions, Part 2: Wind actions.

[5] Li, S.H., Irwin, P., Lounis, Z., Attar, A., Dale, J., Gibbons, M., Beaulieu, S. (2022). Effects of Nonstationarity of Extreme Wind Speeds and Ground Snow Loads in a Future Canadian Changing Climate. Natural Hazards Review, 23(4), 04022022.

PROPOSED CHANGE

[4.1.3.2.] 4.1.3.2. Strength and Stability

[1] **1)** A *building* and its structural components shall be designed to have sufficient strength and stability so that the factored resistance, φR, is greater than or equal to the effect of factored loads, which shall be determined in accordance with Sentence (2).

[2] **2)** Except as provided in Sentence (3), the effect of factored loads for a *building* or structural component shall be determined in accordance with the requirements of this Article and the following load combination cases, the applicable combination being that which results in the most critical effect:

[a] a) for load cases without crane loads, the load combinations listed in Table 4.1.3.2.-A, and
[b] b) for load cases with crane loads, the load combinations listed in Table 4.1.3.2.-B.

(See Note A-4.1.3.2.(2).)

[3] **3)** Other load combinations that must also be considered are the principal loads acting with the companion loads taken as zero.

[4] **4)** Where the effects due to lateral earth pressure, H, restraint effects from pre-stress, P, and imposed deformation, T, affect the structural safety, they shall be taken into account in the calculations, with load factors of 1.5, 1.0 and 1.25 assigned to H, P and T respectively. (See Note A-4.1.3.2.(4).)

[5] **5)** Except as provided in Sentence 4.1.8.16.(2), the counteracting factored *dead load*—0.9D in load combination cases 2, 3 and 4 and 1.0D in load combination case 5 in Table 4.1.3.2.-A, and 0.9D in load combination cases 1 to 5 and 1.0D in load combination case 6 in Table 4.1.3.2.-B—shall be used when the *dead load* acts to resist overturning, uplift, sliding, failure due to stress reversal, and to determine anchorage requirements and the factored resistance of members. (See Note A-4.1.3.2.(5).)

[6] **6)** The principal-load factor 1.5 for *live loads* L in Table 4.1.3.2.-A and L_{XC} in Table 4.1.3.2.-B may be reduced to 1.25 for liquids in tanks.

[7] **7)** The companion-load factor for *live loads* L in Table 4.1.3.2.-A and L_{XC} in Table 4.1.3.2.-B shall be increased by 0.5 for storage areas, and equipment areas and *service rooms* referred to in Table 4.1.5.3.

Table [4.1.3.2.-A] 4.1.3.2.-A
Load Combinations Without Crane Loads for Ultimate Limit States
Forming Part of Sentences [4.1.3.2.] 4.1.3.2.([2] 2) and ([5] 5) to ([10] 10), and 4.2.4.1.(3)

Case	**Load Combination (1)**	
	Principal Loads	**Companion Loads**
1	1.4D (2)	—
2	(1.25D (3) or 0.9D (4)) + 1.5L (5)	0.7~~1.0~~S (6) or 0.3~~0.4~~W
3	(1.25D (3) or 0.9D (4)) + 1.0~~1.5~~S	1.0L (6) (7) or 0.3~~0.4~~W
4	(1.25D (3) or 0.9D (4)) + 1.0~~1.4~~W	0.5L (7) or 0.35~~0.5~~S
5	1.0D (4) + 1.0E (8)	0.5L (6) (7) + 0.15~~0.25~~S (6)

Notes to Table [4.1.3.2.-A] 4.1.3.2.-A:

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(1) See Sentences 4.1.3.2.(2) to (4).

(2) See Sentence 4.1.3.2.(9).

(3) See Sentence 4.1.3.2.(8).

(4) See Sentence 4.1.3.2.(5).

(5) See Sentence 4.1.3.2.(6).

(6) See Article 4.1.5.5.

(7) See Sentence 4.1.3.2.(7).

(8) See Sentence 4.1.3.2.(10).

Table [4.1.3.2.-B] 4.1.3.2.-B
Load Combinations With Crane Loads for Ultimate Limit States
Forming Part of Sentences [4.1.3.2.] 4.1.3.2.([2] 2), ([5] 5) to ([8] 8), and ([10] 10)

Case	Load Combination (1)	
	Principal Loads	**Companion Loads**
1	(1.25D (2) or 0.9D (3)) + (1.5C + 1.0L_{XC})	0.7~~1.0~~S (4) or 0.3~~0.4~~W
2	(1.25D (2) or 0.9D (3)) + (1.5L_{XC} (5) + 1.0C)	0.7~~1.0~~S (4) or 0.3~~0.4~~W
3	(1.25D (2) or 0.9D (3)) + 1.0~~1.5~~S	1.0C + 1.0L_{XC} (4) (6)
4	(1.25D (2) or 0.9D (3)) + 1.0~~1.4~~W	1.0C (7) + 0.5L_{XC} (4) (6)
5	(1.25D (2) or 0.9D (3)) + C_7	—
6	1.0D (3) + 1.0E (8)	1.0C_d + 0.5L_{XC} (4) (6) + 0.15~~0.25~~S (4)

Notes to Table [4.1.3.2.-B] 4.1.3.2.-B:

(1) See Sentences 4.1.3.2.(2) to (4).

(2) See Sentence 4.1.3.2.(8).

(3) See Sentence 4.1.3.2.(5).

(4) See Article 4.1.5.5.

(5) See Sentence 4.1.3.2.(6).

(6) See Sentence 4.1.3.2.(7).

(7) Side thrust due to cranes need not be combined with full wind load.

(8) See Sentence 4.1.3.2.(10).

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[8] 8) Except as provided in Sentence (9), the load factor 1.25 for *dead load*, D, for *soil*, superimposed earth, plants and trees given in Tables 4.1.3.2.-A and 4.1.3.2.-B shall be increased to 1.5, except that when the *soil* depth exceeds 1.2 m, the factor may be reduced to 1 + 0.6/h_s but not less than 1.25, where h_s is the depth of *soil*, in m, supported by the structure.

[9] 9) A principal-load factor of 1.5 shall be applied to the weight of saturated *soil* used in load combination case 1 of Table 4.1.3.2.-A.

[10] 10) Earthquake load, E, in load combination cases 5 of Table 4.1.3.2.-A and 6 of Table 4.1.3.2.-B includes horizontal earth pressure due to earthquake determined in accordance with Sentence 4.1.8.16.(7).

[11] 11) Provision shall be made to ensure adequate stability of the structure as a whole and adequate lateral, torsional and local stability of all structural parts.

[12] 12) Sway effects produced by vertical loads acting on the structure in its displaced configuration shall be taken into account in the design of *buildings* and their structural members.

[4.1.6.2.] 4.1.6.2. Specified Snow Load

(See Note A-4.1.6.2.)

[1] 1) The specified load, S, due to snow and associated rain accumulation on a roof or any other *building* surface subject to snow accumulation shall be calculated using the formula

$$\boxed{S = I_s\left[S_s\left(C_bC_wC_sC_a\right) + S_r\right]}$$

$$S = I_s\left[S_s\left(C_bC_wC_sC_aC_T\right) + S_r\right]$$

where

I_s = importance factor for snow load, as provided in Table 4.1.6.2.-A,
S_s = 1-in-1 000~~50-year~~ annual probability ground snow load, in kPa, determined in accordance with Subsection 1.1.3.,
C_b = basic roof snow load factor in Sentence (2),
C_w = wind exposure factor in Sentences (3) and (4),
C_s = slope factor in Sentences (5) to (7),
C_a = accumulation factor in Sentence (8), and
C_T = thermal factor in Sentences (10) and (11), and
S_r = 1-in-1 000~~50-year~~ annual probability associated rain load, in kPa, determined in accordance with Subsection 1.1.3., but not greater than $S_s(C_bC_wC_sC_aC_T)$~~$S_s(C_bC_wC_sC_a)$~~.

Table [4.1.6.2.-A] 4.1.6.2.-A
Importance Factor for Snow Load, I_S
Forming Part of Sentence [4.1.6.2.] 4.1.6.2.([1] 1)

Importance Category	Importance Factor, I_s	
	ULS	SLS
Low	0.8	0.6~~0.9~~
Normal	1	0.6~~0.9~~
High	1.15	0.6~~0.9~~
Post-disaster	1.25	0.6~~0.9~~

[2] 2) The basic roof snow load factor, C_b, shall

[a] a) be determined as follows:

[i] i) $C_b = 0.8$ for $l_c \le 70$, and

$$\boxed{C_b = 0.8 \text{ for } l_c \leq \left(\frac{70}{C_w^2}\right), \text{ and}}$$

[ii] ii)

$$C_b = 1 - (0.2)\exp\left(-\frac{l_c - 70}{100}\right) \text{ for } l_c > 70$$

$$\boxed{C_b = \frac{1}{C_w}\left[1 - \left(1 - 0.8C_w\right)\exp\left(-\frac{l_c C_w^2 - 70}{100}\right)\right] \text{ for } l_c > \left(\frac{70}{C_w^2}\right)}$$

where

l_c = characteristic length of the upper or lower roof, defined as $2w - w^2/l$, in m,

w = smaller plan dimension of the roof, in m, and

l = larger plan dimension of the roof, in m, or

[b] b) ~~conform to Table 4.1.6.2.-B, using linear interpolation for intermediate values of~~ $\boxed{l_c C_w^2}$~~, or~~

[c] c) be taken as equal to 1 for any roof structure with a mean height of less than $1 + S_s/\gamma$, in m, above *grade*, where γ is the specific weight of snow determined in accordance with Article 4.1.6.13.

(See Note A-4.1.6.2.(2).)

[3] 3) Except as provided ~~for~~ in Sentence (4), the wind exposure factor, C_w, shall be ~~1.0.~~determined as follows:

$$C_w = 1.25 + \left[-0.00075\left(-T_{ws}\right)^{0.75}\left(V_{ws}^3\right)\right], \text{ but } C_w \geq 0.5$$

where

T_{ws} = winter average temperature, in °C, determined in accordance with Subsection 1.1.3., and

V_{ws} = winter average wind speed, in m/s, determined in accordance with Subsection 1.1.3.

[4] 4) The wind exposure factor, C_w, shall be greater than or equal to 1.0 where~~For *buildings* in the Low and Normal Importance Categories as set out in Table 4.1.2.1., the wind exposure factor, C_w, given in Sentence (3) may be reduced to 0.75 for rural areas only, or to 0.5 for exposed areas north of the treeline, where~~

[a] a) ~~the *building* is exposed on all sides to wind over open terrain as defined in Clause 4.1.7.3.(5)(a), and is expected to remain so during its life,~~

[b] b) the area of roof under consideration is sheltered by~~exposed to the wind on all sides with no~~ significant obstructions on the roof, such as parapet walls, within a distance of at least 10 times the difference between the height of the obstruction and $C_bC_wS_s/\gamma$, in m, where γ is the specific weight of snow on roofs as specified in Article 4.1.6.13., ~~and~~

[c] c) the loading ~~does not~~ involves the accumulation of snow due to drifting from adjacent surfaces~~.~~, or

[d] --) the building is in the High or Post-disaster Importance Category as set out in Table 4.1.2.1.

[5] 5) Except as provided for in Sentences (6) and (7), the slope factor, C_s, shall be

[a] a) 1.0 where the roof slope, α, is equal to or less than 30°,

[b] b) (70° − α)/40° where α is greater than 30° but not greater than 70°, and

[c] c) 0 where α exceeds 70°.

~~Table [4.1.6.2.-B] 4.1.6.2.-B~~

~~Basic Roof Snow Load Factor for~~ $\boxed{I_c > \left(70 / C_w^2\right)}$

~~Forming Part of Sentence [4.1.6.2.] 4.1.6.2.([2] 2)~~

~~Value of~~ $\boxed{I_c C_w^2}$	~~Value of C_w~~		
	~~1.0~~	~~0.75~~	~~0.5~~
	~~Value of C_b~~		
~~70~~	~~0.80~~	~~0.80~~	~~0.80~~
~~80~~	~~0.82~~	~~0.85~~	~~0.91~~
~~100~~	~~0.85~~	~~0.94~~	~~1.11~~
~~120~~	~~0.88~~	~~1.01~~	~~1.27~~
~~140~~	~~0.90~~	~~1.07~~	~~1.40~~
~~160~~	~~0.92~~	~~1.12~~	~~1.51~~
~~180~~	~~0.93~~	~~1.16~~	~~1.60~~
~~200~~	~~0.95~~	~~1.19~~	~~1.67~~
~~220~~	~~0.96~~	~~1.21~~	~~1.73~~
~~240~~	~~0.96~~	~~1.24~~	~~1.78~~
~~260~~	~~0.97~~	~~1.25~~	~~1.82~~
~~280~~	~~0.98~~	~~1.27~~	~~1.85~~
~~300~~	~~0.98~~	~~1.28~~	~~1.88~~
~~320~~	~~0.98~~	~~1.29~~	~~1.90~~
~~340~~	~~0.99~~	~~1.30~~	~~1.92~~
~~360~~	~~0.99~~	~~1.30~~	~~1.93~~
~~380~~	~~0.99~~	~~1.31~~	~~1.95~~
~~400~~	~~0.99~~	~~1.31~~	~~1.96~~
~~420~~	~~0.99~~	~~1.32~~	~~1.96~~
~~440~~	~~1.00~~	~~1.32~~	~~1.97~~
~~460~~	~~1.00~~	~~1.32~~	~~1.98~~
~~480~~	~~1.00~~	~~1.32~~	~~1.98~~
~~500~~	~~1.00~~	~~1.33~~	~~1.98~~
~~520~~	~~1.00~~	~~1.33~~	~~1.99~~
~~540~~	~~1.00~~	~~1.33~~	~~1.99~~
~~560~~	~~1.00~~	~~1.33~~	~~1.99~~
~~580~~	~~1.00~~	~~1.33~~	~~1.99~~
~~600~~	~~1.00~~	~~1.33~~	~~1.99~~
~~620~~	~~1.00~~	~~1.33~~	~~2.00~~

[6] **6)** The slope factor, C_s, for unobstructed slippery roofs where snow and ice can slide completely off the roof shall be

[a] a) 1.0 where the roof slope, α, is equal to or less than 15°,

[b] b) (60° − α)/45° where α is greater than 15° but not greater than 60°, and

[c] c) 0 where α exceeds 60°.

[7] **7)** Unless otherwise stated in this Subsection, the slope factor, C_s, shall be 1.0 when used in conjunction with accumulation factors for increased snow loads.

[8] **8)** The accumulation factor, C_a, shall be 1.0, which corresponds to the uniform snow load case, except that where appropriate for the shape of the roof, it shall be assigned other values that account for

[a] a) increased non-uniform snow loads due to snow drifting onto a roof that is at a level lower than other parts of the same *building* or at a level lower than another *building* within 5 m of it horizontally, as prescribed in Articles 4.1.6.5., 4.1.6.6. and 4.1.6.8.,

[b] b) increased non-uniform snow loads on areas adjacent to roof projections, such as penthouses, large *chimneys* and equipment, as prescribed in Articles 4.1.6.7. and 4.1.6.8.,

[c] c) non-uniform snow loads on gable, arch or curved roofs and domes, as prescribed in Articles 4.1.6.9. and 4.1.6.10.,

[d] d) increased snow or ice loads due to snow sliding as prescribed in Article 4.1.6.11.,

[e] e) increased snow loads in roof valleys, as prescribed in Article 4.1.6.12., and

[f] f) increased snow or ice loads due to meltwater draining from adjacent *building* elements and roof projections.

[9] **9)** For shapes not addressed in Sentence (8), C_a corresponding to the non-uniform snow load case shall be established based on applicable field observations, special analyses including local climatic effects, appropriate model tests, or a combination of these methods.

[10] --) Except as provided in Sentence (11), the thermal factor, C_T, shall be taken as the greater of 0.7 and $C_T = -0.01\left(T_{\text{in}}U_{\text{roof}}\right)\sqrt{S_s} + 1.0$, but not greater than 1.0, where

T_{in} = expected average indoor operating temperature of the *building*, in °C, and
U_{roof} = overall thermal transmittance of the roof, in W/(m^2×K).

[11] --) Where T_{in} or U_{roof} is not known, the thermal factor, C_T, shall be taken as 1.0.

[4.1.6.5.] 4.1.6.5. Multi-level Roofs

[1] **1)** The drifting load of snow on a roof adjacent to a higher roof shall be taken as trapezoidal, as shown in Figure 4.1.6.5.-A, and the accumulation factor, C_a, shall be determined as follows:

$$C_a = C_{a0} - \left(C_{a0} - 1\right)\left(\frac{x}{x_d}\right) \text{ for } 0 \le x \le x_d,$$

or

$$C_a = 1.0 \text{ for } x > x_d$$

where

C_{a0} = peak value of C_a at x = 0 determined in accordance with Sentences (3) to (5) and as shown in Figure 4.1.6.5.-B,
x = distance from roof step as shown in Figure 4.1.6.5.-A, and
x_d = length of drift determined in accordance with Sentence (2) and as shown in Figure 4.1.6.5.-A.

[2] **2)** The length of the drift, x_d, shall be calculated as follows:

$$x_d = 5\frac{C_b C_w S_s}{\gamma}\left(C_{a0} - 1\right)$$

$$\boxed{x_d = 5\frac{C_b S_s}{\gamma}\left(C_{a0} - 1\right)}$$

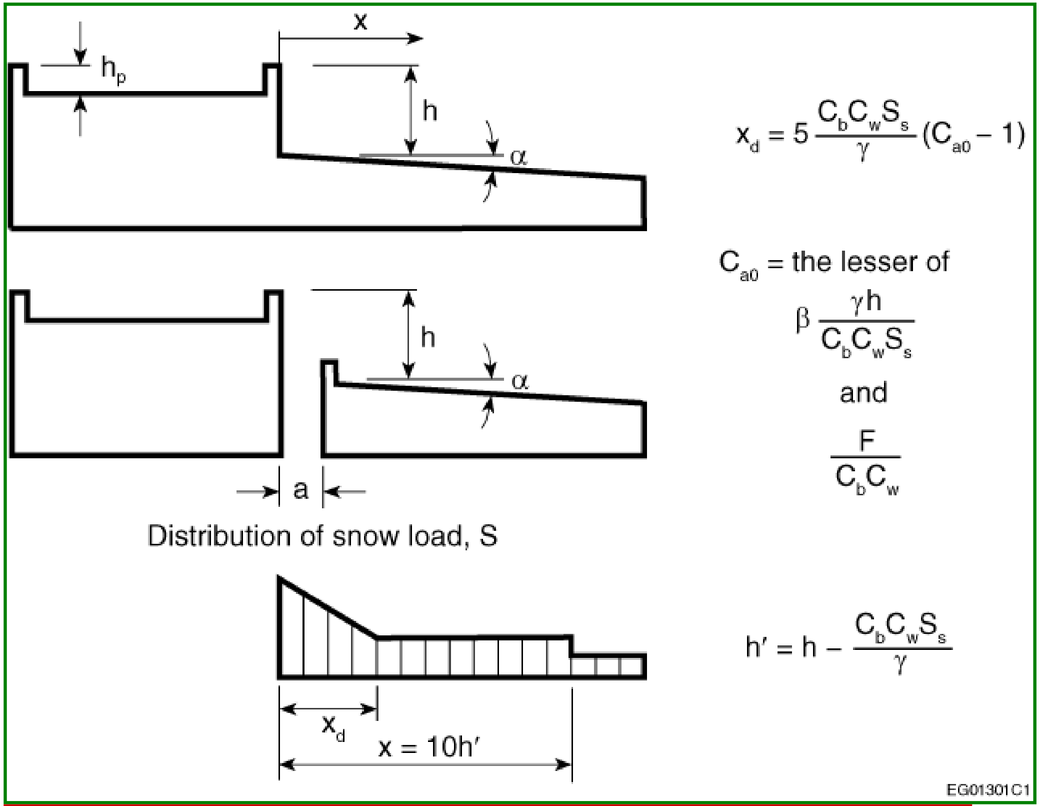
where

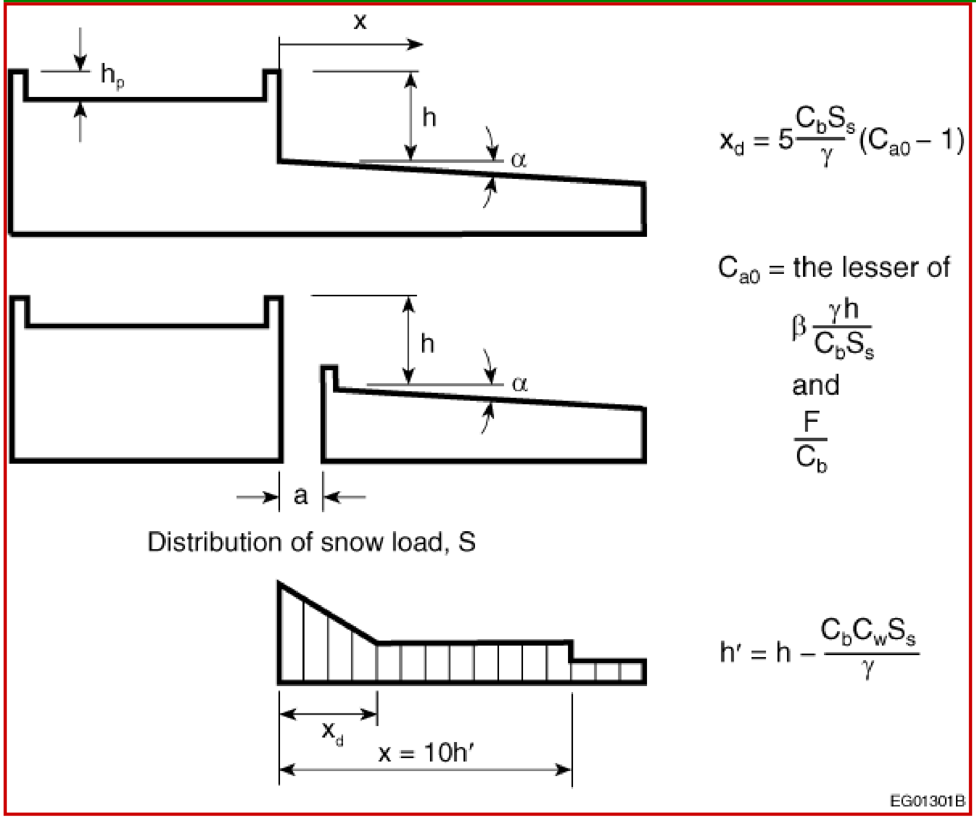
γ = specific weight of snow as specified in Article 4.1.6.13.

Figure [4.1.6.5.-A] 4.1.6.5.-A

Snow load factors for lower level roofs

Forming Part of Sentences 4.1.6.5.(1) and (3), Table 4.1.6.5.-A and Sentence 4.1.6.6.(1)





Notes to Figure 4.1.6.5.-A:

(1) If a > 5 m or $h \le 0.8S_s/\gamma$, drifting from the higher roof need not be considered.

(2) If h ≥ 5 m, the value of C_{a0} for Case I is permitted to be determined in accordance with Sentence 4.1.6.5.(4).

Table [4.1.6.5.-A] 4.1.6.5.-A
~~Wind Exposure,~~ Slope and Accumulation Factors in Figure 4.1.6.5.-A

Distance from Roof Step, x	Factors		
	~~C_w~~	C_s (1)	C_a
0	~~1.0~~	f(α)	C_{a0}
$0 < x \le x_d$	~~1.0~~	f(α)	$C_{a0} - (C_{a0} - 1)(x/x_d)$
$x_d < x \le 10h'$	~~1.0~~	f(α)	1.0
$x > 10h'$	~~1.0 for unexposed roof areas~~	f(α)	1.0
	~~0.75 for exposed roof areas~~		
	~~0.5 for exposed roof areas north of tree line~~		

Note to Table [4.1.6.5.-A] 4.1.6.5.-A:

(1) For lower roofs with parapets, C_s = 1.0; otherwise, C_s varies as a function of slope, α, as defined in Sentences 4.1.6.2.(5) and (6).

[3] **3)** Except as provided in Sentence (4), the value of C_{a0} for each of Cases I, II and III shall be the lesser of

$$C_{a0} = \beta \frac{\gamma h}{C_b C_w S_s}$$

and

$$C_{a0} = \frac{F}{C_b C_w}$$

$$\boxed{\begin{gathered} C_{a0} = \beta \frac{\gamma h}{C_b S_s} \\ \text{and} \\ C_{a0} = \frac{F}{C_b} \end{gathered}}$$

where

β = 1.0 for Case I, and 0.67 for Cases II and III,
h = difference in elevation between the lower roof surface and the top of the parapet on the upper roof as shown in Figure 4.1.6.5.-A, and

$$F = 0.43\,\beta\,F_{ws}\sqrt{\frac{\gamma\left(l_{cs} - 5h'_p\right)}{S_s}} + C_b C_w\text{, but } F \le 5 \text{ for } C_{ws} \ge 1.0$$

$$\boxed{F = 0.35\,\beta\sqrt{\frac{\gamma\left(l_{cs} - 5h'_p\right)}{S_s}} + C_b\text{, but } F \le 5 \text{ for } C_{ws} = 1.0}$$

where

F_{ws} = $0.019(-T_{ws})^{0.45}(V_{ws})^{1.6} + 0.45$, where T_{ws} and V_{ws} are as defined in Sentence 4.1.6.2.(3),
C_{ws} = value of C_w applicable to the source of drifting,
l_{cs} = characteristic length of the source area for drifting, defined as

$l_{cs} = 2w_s - \left(w_s^2 / l_s\right)$, where w_s and l_s are respectively the shorter and longer dimensions of the relevant source areas for snow drifting shown in Figure 4.1.6.5.-B for Cases I, II and III, and

$$h_p' = h_p - \left(\frac{0.8S_s}{\gamma}\right), \text{ but } 0 \le h_p' \le \left(\frac{l_{cs}}{5}\right)$$

where

h_p = height of the roof perimeter parapet of the source area, to be taken as zero unless all the roof edges of the source area have parapets.

[4] **4)** Where $h \ge 5$ m, the value of C_{a0} for Case I is permitted to be taken as

$$C_{a0}\left(\frac{25-h}{20}\right)\left(\frac{F}{C_bC_w} - 1\right) + 1 \text{ for } 5\ m \le h \le 25\ m\text{, and}$$

$$C_{a0} = 1 \text{ for } h > 25\ m$$

$$\boxed{\begin{gathered} C_{a0} = \left(\frac{25-h}{20}\right)\left(\frac{F}{C_b} - 1\right) + 1 \text{ for } 5\ m \le h \le 25\ m\text{, and} \\ C_{a0} = 1 \text{ for } h > 25\ m \end{gathered}}$$

[5] **5)** The value of C_{a0} shall be the highest of Cases I, II and III, considering the different roof source areas for drifting snow, as specified in Sentences (3) and (4) and Figure 4.1.6.5.-B.

Figure [4.1.6.5.-B] 4.1.6.5.-B
Snow load cases I, II and III for lower level roofs
Forming Part of Sentences 4.1.6.5.(1), (3) and (5), and Table 4.1.6.5.-B

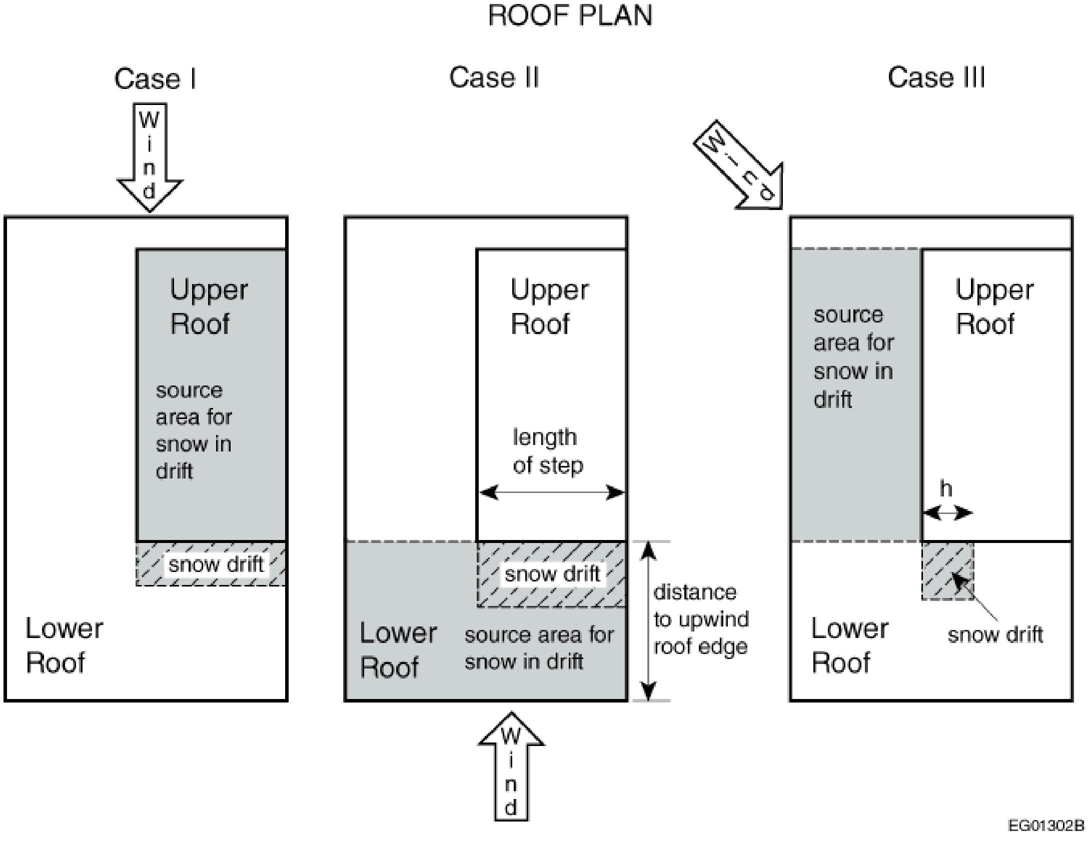


Table [4.1.6.5.-B] 4.1.6.5.-B
Parameters for Snow Load Cases in Figure 4.1.6.5.-B

Parameter	Case I	Case II	Case III
β	1.0	0.67	0.67
h_p	parapet height of upper-roof source area	parapet height of lower-roof source area	parapet height of lower-roof source area
$l_{cs} = 2w_s - \frac{w_s^2}{l_s}$	with w_s and l_s being the shorter and longer dimensions of the upper roof	with w_s and l_s being the shorter and longer dimensions of the source area on the lower roof for upwind-facing step	with w_s and l_s being the shorter and longer dimensions of the source area on the lower roof for downwind-facing step

---

[4.1.6.7.] 4.1.6.7. Areas Adjacent to Roof Projections

[1] **1)** Except as provided in Sentences (2) and (3), the accumulation factor, C_a, for areas adjacent to roof-mounted vertical projections shall be calculated in accordance with Sentence 4.1.6.5.(1) using the following values for the peak accumulation factor, C_{a0}, and the drift length, x_d:

[a] a) C_{a0} shall be taken as the lesser of

$$0.67\frac{\gamma h}{C_b C_w S_s} \text{ and } F_{ws}\left(\frac{\gamma l_0}{7.5 C_b C_w S_s}\right) + 1, \text{ and}$$

$$\boxed{0.67\frac{\gamma h}{C_b S_s} \text{and} \frac{\gamma l_0}{7.5 C_b S_s} + 1, \text{ and}}$$

[b] b) x_d shall be taken as the lesser of 3.35h and (2/3)l_0, where

F_{ws} = as defined in Sentence 4.1.6.5.(3),
h = height of the projection, and
l_0 = longest horizontal dimension of the projection.

(See Note A-4.1.6.7.(1).)

[2] **2)** C_a is permitted to be calculated in accordance with Article 4.1.6.5. for larger projections. (See Note A-4.1.6.7.(2).)

[3] **3)** Where the longest horizontal dimension of the roof projection, l_0, is less than 3 m, the drift surcharge adjacent to the projection need not be considered.

[4.1.6.9.] 4.1.6.9. Gable Roofs

(See Note A-4.1.6.9.)

[1] **1)** For all gable roofs, the full and partial load cases defined in Article 4.1.6.3. shall be considered.

[2] **2)** For gable roofs with a slope $\alpha > 15°$, the unbalanced load case shall also be considered by setting the values of the accumulation factor, C_a, as follows:

[a] a) on the upwind side of the roof peak, C_a shall be taken as 0, and

[b] b) on the downwind side of the roof peak, C_a shall be taken as

[i] i) $F_{ws}(0.25 + \alpha/20)$~~, where~~ for $15° \le \alpha \le 20°$, and

[ii] ii) 1.25F_{ws}~~, where~~ for $20° < \alpha \le 90°$~~.~~, where F_{ws} is as defined in Sentence 4.1.6.5.(3).

[3] **3)** For all gable roofs, the slope factor, C_s, shall be as prescribed in Sentences 4.1.6.2.(5) and (6).

[4] **4)** For all gable roofs, the wind exposure factor, C_w, shall be

[a] a) as prescribed in Sentences 4.1.6.2.(3) and (4) for the full and partial load cases, and

[b] b) 1.0 or the value prescribed in Sentence 4.1.6.2.(3)~~1.0~~, whichever is greater, for the unbalanced load case referred to in Sentence (2).

[4.1.6.10.] 4.1.6.10. Arch Roofs, Curved Roofs and Domes

[1] **1)** For all arch roofs, curved roofs and domes, the full and partial load cases defined in Article 4.1.6.3. shall be considered.

[2] **2)** For arch roofs, curved roofs and domes with a rise-to-span ratio h/b > 0.05 (see Figure 4.1.6.10.-A), the load cases provided in Sentences (3) to (7) shall also be considered.

[3] **3)** For arch roofs with a slope at the edge $\alpha_e \le 30°$ (see Figure 4.1.6.10.-A and Table 4.1.6.10.), C_a shall be

[a] a) taken as 0 on the upwind side of the peak, and

[b] b) on the downwind side of the peak, taken as

$$C_a = F_{\text{ws}}\left(\frac{\text{xh}}{0.03C_bC_wb^2}\right) \text{ for } 0.05 < \frac{h}{b} \le 0.12\text{, and}$$

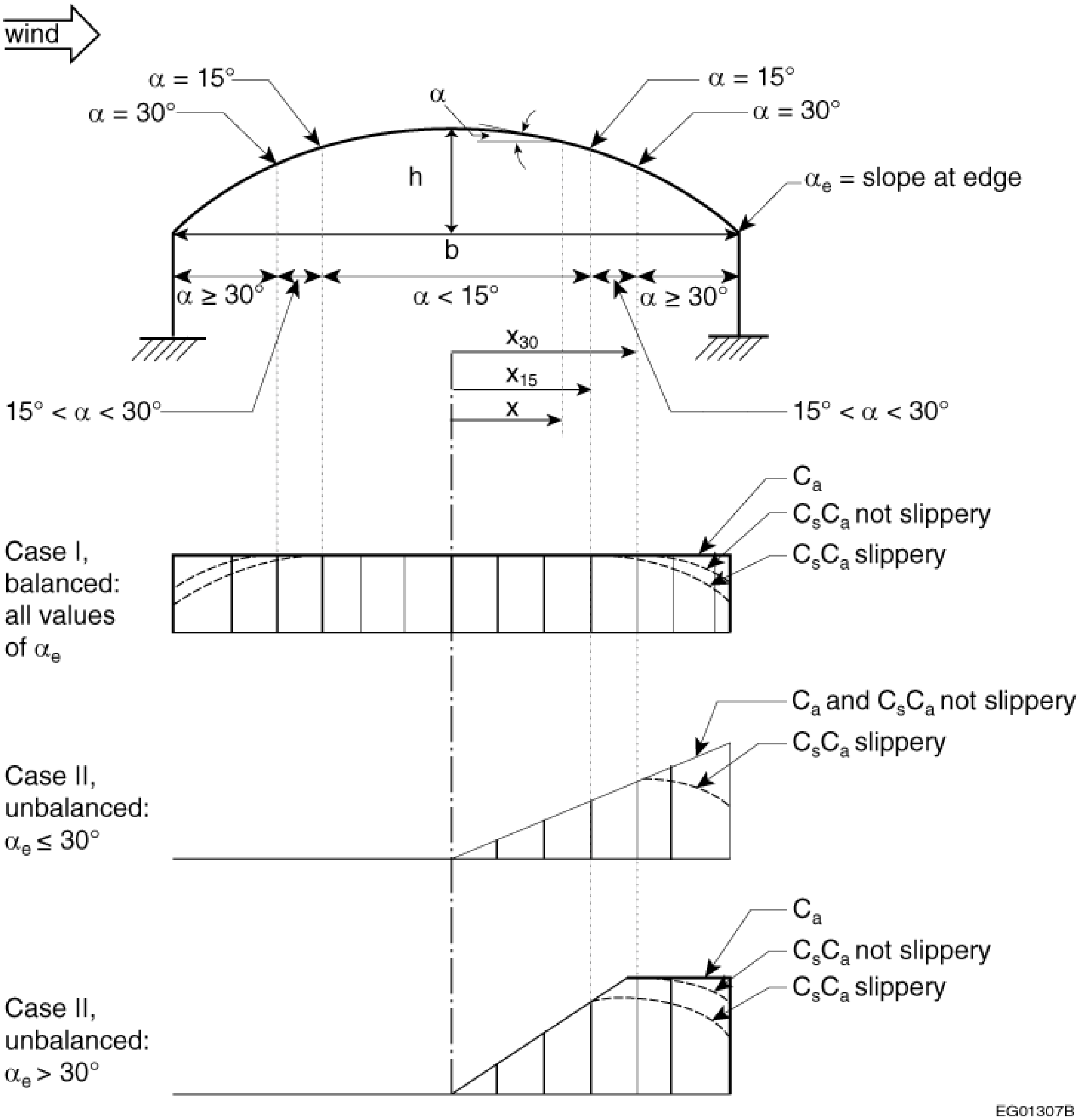
$$C_a = F_{\text{ws}}\left(\frac{4x}{C_bC_wb}\right) \text{ for } \frac{h}{b} > 0.12$$

$$\boxed{\begin{gathered} C_a = \frac{\text{xh}}{0.03C_bb^2} \text{ for } 0.05 < \frac{h}{b} \le 0.12 \text{ and} \\ C_a = \frac{4x}{C_bb} \text{ for } \frac{h}{b} > 0.12 \end{gathered}}$$

where

F_{ws} = as defined in Sentence 4.1.6.5.(3),
x = horizontal distance from the roof peak,
h = height of arch, and
b = width of arch.

Figure [4.1.6.10.-A] 4.1.6.10.-A
Accumulation factors for arch roofs and curved roofs
Forming Part of Sentences 4.1.6.10.(2) to (4)



Note to Figure 4.1.6.10.-A:

(1) Refer to Table 4.1.6.10. for applicable values of C_w and Sentences 4.1.6.2.(5) and (6) for applicable values of C_s.

[4] **4)** For arch roofs with a slope at the edge $\alpha_e > 30°$ (see Figure 4.1.6.10.-A and Table 4.1.6.10.), C_a shall be

[a] a) taken as 0 on the upwind side of the peak, and

[b] b) on the downwind side of the peak,

[i] i) for the part of the roof between the peak and point where the slope $\alpha = 30°$, taken as

$$C_a = F_{ws}\left(\frac{xh}{0.06 C_b C_w x_{30} b}\right) \text{ for } 0.05 < \frac{h}{b} \leq 0.12, \text{ and}$$

$$C_a = F_{ws}\left(\frac{2x}{C_b C_w x_{30}}\right) \text{ for } \frac{h}{b} > 0.12$$

$$\boxed{\begin{gathered} C_a = \frac{\mathrm{xh}}{0.06C_b x_{30} b} \text{ for } 0.05 < \frac{h}{b} \le 0.12\text{, and} \\ C_a = \frac{2x}{C_b x_{30}} \text{ for } \frac{h}{b} > 0.12 \end{gathered}}$$

where

F_{ws} = as defined in Sentence 4.1.6.5.(3),
x, h, b = as specified in Sentence (2), and
x_{30} = value of x where the slope α = 30°, and

[ii] ii) for the part of the roof where the slope α > 30°, taken as

$$C_a = F_{ws}\left(\frac{h}{0.06C_bC_wb}\right) \text{ for } 0.05 < \frac{h}{b} \le 0.12\text{, and}$$

$$C_a = F_{ws}\left(\frac{2}{C_bC_w}\right) \text{ for } \frac{h}{b} > 0.12$$

$$\boxed{\begin{gathered} C_a = \frac{h}{0.06C_b b} \text{ for } 0.05 < \frac{h}{b} \le 0.12\text{,and} \\ C_a = \frac{2}{C_b} \text{ for } \frac{h}{b} > 0.12 \end{gathered}}$$

[5] **5)** Except as provided in Sentence (6), C_a for curved roofs shall be determined in accordance with the requirements for arch roofs stated in Sentences (3) and (4).

Table [4.1.6.10.] 4.1.6.10.
Load Cases for Arch Roofs, Curved Roofs and Domes
Forming Part of Sentences [4.1.6.10.] 4.1.6.10.([3] 3), ([4] 4) and ([9] 9)

Load Case	**Range of Application**	**Factors**			
		All Arch or Curved Roofs and Domes	**Arch and Curved Roofs**		**Domes**
		C_w	**C_a Upwind Side**	**C_a Downwind Side**	**C_a Downwind Side**
Case I	All values of h/b	As stated in 4.1.6.2.(3) and (4)	1.0	1.0	1.0
Case II	Slope at edge ≤ 30° h/b > 0.05 all values of x	1.0	0.0	$C_a = F_{ws}\left(\frac{\mathrm{xh}}{0.03C_bC_wb^2}\right) \text{ for } \frac{h}{b} \le 0.12$ $C_a = F_{ws}\left(\frac{4x}{C_bC_wb}\right) \text{ for } \frac{h}{b} > 0.12$ $\boxed{\begin{gathered} C_a = \frac{\mathrm{xh}}{0.03C_bb^2} \text{ for } \frac{h}{b} \le 0.12 \\ C_a = \frac{4x}{C_bb} \text{ for } \frac{h}{b} > 0.12 \end{gathered}}$	$C_a(x,y) = C_a(x,0)\left(1 - \frac{y}{r}\right)$

Load Case	**Range of Application**	**Factors**			
		All Arch or Curved Roofs and Domes	**Arch and Curved Roofs**		**Domes**
		C_w	**C_a Upwind Side**	**C_a Downwind Side**	**C_a Downwind Side**
	Slope at edge > 30° h/b > 0.05 $0 < x < x_{30}$	1.0	0.0	$C_a = F_{\text{ws}}\left(\frac{xh}{0.06C_bC_wx_{30}b}\right)$ for $\frac{h}{b} \le 0.12$ $C_a = F_{\text{ws}}\left(\frac{2x}{C_bC_wx_{30}}\right)$ for $\frac{h}{b} > 0.12$ $\boxed{\begin{array}{c} C_a = \frac{xh}{0.06C_bx_{30}b} \text{ for } \frac{h}{b} \le 0.12 \\ C_a = \frac{2x}{C_bx_{30}} \text{ for } \frac{h}{b} > 0.12 \end{array}}$	
	Slope at edge > 30° h/b > 0.05 $x \ge x_{30}$	1.0	0.0	$C_a = F_{\text{ws}}\left(\frac{h}{0.06C_bC_wb}\right)$ for $\frac{h}{b} \le 0.12$ $C_a = F_{\text{ws}}\left(\frac{2}{C_bC_w}\right)$ for $\frac{h}{b} > 0.12$ $\boxed{\begin{array}{c} C_a = \frac{h}{0.06C_bb} \text{ for } \frac{h}{b} \le 0.12 \\ C_a = \frac{2}{C_b} \text{ for } \frac{h}{b} > 0.12 \end{array}}$	

[6] **6)** Where the slope, α, of a curved roof at its peak is greater than 10°, C_a shall be determined in accordance with the requirements for gable roofs stated in Article 4.1.6.9. using a slope equal to the mean slope of the curved roof.

[7] **7)** For domes of circular plan form (see Figure 4.1.6.10.-B), C_a shall

[a] a) along the central axis parallel to the wind, vary in the same way as for an arch roof with the same rise-to-span ratio, h/b, and

[b] b) off this axis, vary according to

$$C_a(x,y) = C_a(x,0)\left(1 - \frac{y}{r}\right)$$

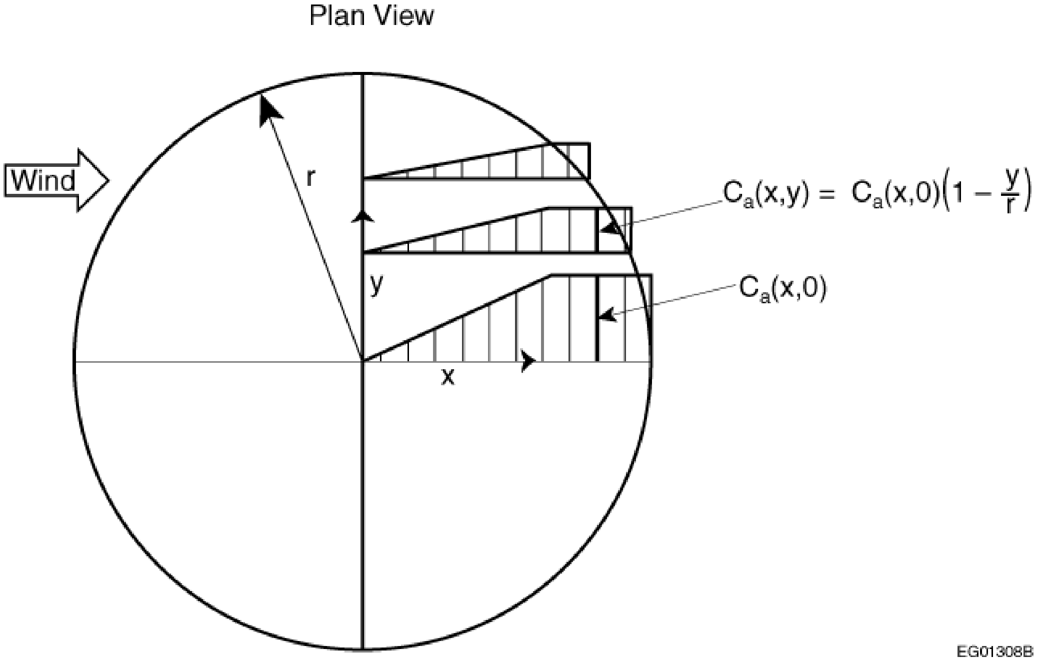
where

$C_a(x,y)$ = value of C_a at location (x,y),
$C_a(x,0)$ = value of C_a on the central axis parallel to the wind,
x = distance along the central axis parallel to the wind,
y = horizontal coordinate normal to the x direction, and
r = radius of dome.

[8] **8)** For all arch roofs, curved roofs and domes, the slope factor, C_s, shall be as prescribed in Sentences 4.1.6.2.(5) and (6).

[9] **9)** For all arch roofs, curved roofs and domes, the wind exposure factor, C_w, shall be as prescribed in Table 4.1.6.10.

Figure [4.1.6.10.-B] 4.1.6.10.-B
Unbalanced snow accumulation factor on a circular dome
Forming Part of Sentence 4.1.6.10.(7)



Notes to Figure 4.1.6.10.-B:

(1) Refer to Table 4.1.6.10. for applicable values of C_w and Sentences 4.1.6.2.(5) and (6) for applicable values of C_s.

(2) Refer to Sentences 4.1.6.10.(3) and (4) for the calculation of $C_a(x,0)$.

[4.1.7.3.] 4.1.7.3. Static Procedure

[1] **1)** The specified external pressure or suction due to wind on part or all of a surface of a *building* shall be calculated as follows:

$$p = I_W q C_e C_t C_g C_p$$

where

p = specified external pressure acting statically and in a direction normal to the surface, considered positive when the pressure acts towards the surface and negative when it acts away from the surface,
I_W = importance factor for wind load, as provided in Table 4.1.7.3.,
q = reference velocity pressure, as provided in Sentence (4),
C_e = exposure factor, as provided in Sentences (5) and (7),
C_t = topographic factor, as provided in Article 4.1.7.4.,
C_g = gust effect factor, as provided in Sentence (8), and
C_p = external pressure coefficient, as provided in Articles 4.1.7.5. and 4.1.7.6.

Table [4.1.7.3.] 4.1.7.3.
Importance Factor for Wind Load, I_W
Forming Part of Sentences [4.1.7.3.] 4.1.7.3.([1] 1) and 4.1.7.8.(4)

Importance Category	Importance Factor, I_W	
	ULS	SLS
Low	0.8	~~0.75~~0.6
Normal	1	~~0.75~~0.6
High	1.15	~~0.75~~0.6
Post-disaster	1.25	~~0.75~~0.6

[2] **2)** The net wind load for the *building* as a whole shall be the algebraic difference of the loads on the windward and leeward surfaces, and in some cases, may be calculated as the sum of the products of the external pressures or suctions and the areas of the surfaces over which they are averaged as provided in Sentence (1).

[3] **3)** The net specified pressure due to wind on part or all of a surface of a *building* shall be the algebraic difference, such as to produce the most critical effect, of the external pressure or suction calculated in accordance with Sentence (1) and the specified internal pressure or suction due to wind calculated as follows:

$$p_i = I_W q C_{ei} C_t C_{gi} C_{pi}$$

where

p_i = specified internal pressure acting statically and in a direction normal to the surface, either as a pressure directed towards the surface or as a suction directed away from the surface,
I_W, q, C_t = as defined in Sentence (1),
C_{ei} = exposure factor for internal pressure, as provided in Sentence (7),
C_{gi} = internal gust effect factor, as provided in Sentence (10), and
C_{pi} = internal pressure coefficient, as provided in Article 4.1.7.7.

[4] **4)** The reference velocity pressure, q, shall be the appropriate value determined in conformance with Subsection 1.1.3., based on a probability of being exceeded in any one year of 1 in 50.

[5] **5)** The exposure factor, C_e, shall be based on the reference height, h, determined in accordance with Sentence (6), for the surface or part of the surface under consideration and shall be

[a] a) $(h/10)^{0.2}$ but not less than 0.9 for open terrain, where open terrain is level terrain with only scattered *buildings*, trees or other obstructions, open water or shorelines thereof,

[b] b) $0.7(h/12)^{0.3}$ but not less than 0.7 for rough terrain, where rough terrain is suburban, urban or wooded terrain extending upwind from the *building* uninterrupted for at least 1 km or 20 times the height of the *building*, whichever is greater, or

[c] c) an intermediate value between the two exposures defined in Clauses (a) and (b) in cases where the site is less than 1 km or 20 times the height of the *building* from a change in terrain conditions, whichever is greater, provided an appropriate interpolation method is used (see Note A-4.1.7.3.(5)(c)).

[6] **6)** The reference height, h, shall be determined as follows:

[a] a) for *buildings* whose height is less than or equal to 20 m and less than the smaller plan dimension, h shall be the mid-height of the roof above *grade*, but not less than 6 m,

[b] b) for other *buildings*, h shall be

  [i] i) the actual height above *grade* of the point on the windward wall for which external pressures are being calculated,

  [ii] ii) the mid-height of the roof for pressures on surfaces parallel to the wind direction, and

[iii] iii) the mid-height of the *building* for pressures on the leeward wall, and

[c] c) for any structural element exposed to wind, h shall be the mid-height of the element above the ground.

[7] **7)** The exposure factor for internal pressures, C_{ei}, shall be determined as follows:

[a] a) for *buildings* whose height is greater than 20 m and that have a dominant opening, C_{ei} shall be equal to the exposure factor for external pressures, C_e, calculated at the mid-height of the dominant opening, and

[b] b) for other *buildings*, C_{ei} shall be the same as the exposure factor for external pressures, C_e, calculated for a reference height, h, equal to the mid-height of the *building* or 6 m, whichever is greater.

[8] **8)** Except as provided in Sentences (9) and 4.1.7.6.(1), the gust effect factor, C_g, shall be one of the following values:

[a] a) 2.0 for the *building* as a whole and main structural members, or

[b] b) 2.5 for external pressures and suctions on secondary structural members, including cladding.

[9] **9)** For cases where C_g and C_p are combined into a single product, C_gC_p, the values of C_g and C_p need not be independently specified. (See Article 4.1.7.6.)

[10] **10)** The internal gust effect factor, C_{gi}, shall be 2.0, except it is permitted to be calculated using the following equation for large structures enclosing a single large unpartitioned volume that does not have numerous overhead doors or openings:

$$C_{gi} = 1 + \frac{1}{\sqrt{1 + \frac{V_0}{6950A}}}$$

where

V_0 = internal volume, in m^3, and
A = total area of all exterior openings of the volume, in m^2.

(See Note A-4.1.7.3.(10).)

[4.1.8.2.] 4.1.8.2. Notation

[1] **1)** In this Subsection

A_r = element or component force amplification factor to account for type of attachment, as defined in Sentence 4.1.8.18.(1),
A_x = height factor at level x to account for variation of response of an element or component with elevation within the *building*, as defined in Sentence 4.1.8.18.(1),
B_x = ratio at level x used to determine torsional sensitivity, as defined in Sentence 4.1.8.11.(10),
B = maximum value of B_x, as defined in Sentence 4.1.8.11.(10),
C_p = seismic coefficient for an element or component, as defined in Sentence 4.1.8.18.(1),
D_{nx} = plan dimension of the *building* at level x perpendicular to the direction of seismic loading being considered,
e_x = distance measured perpendicular to the direction of earthquake loading between centre of mass and centre of rigidity at the level being considered (see Note A-4.1.8.2.(1)),
F_a = acceleration-based site coefficient for application in standards referenced in Subsection 4.1.8., as defined in Sentence 4.1.8.4.(7),
F_s = site coefficient as defined in Sentence 4.1.8.1.(2) for application in Article 4.1.8.1.,
F_t = portion of V to be concentrated at the top of the structure, as defined in Sentence 4.1.8.11.(7),
F_v = velocity-based site coefficient for application in standards referenced in Subsection 4.1.8., as defined in Sentence 4.1.8.4.(7),

F_x = lateral force applied to level x, as defined in Sentence 4.1.8.11.(7),

h_i, h_n, h_x = height, in m, above the base (i = 0) to level i, n, or x respectively, where the base of the structure is the level at which horizontal earthquake motions are considered to be imparted to the structure,

h_s = inter*storey* height ($h_i - h_{i-1}$),

I_E = earthquake importance factor of the structure, as described in Sentence 4.1.8.5.(1),

J = numerical reduction coefficient for base overturning moment, as defined in Sentence 4.1.8.11.(6),

J_x = numerical reduction coefficient for overturning moment at level x, as defined in Sentence 4.1.8.11.(8),

Level i = any level in the *building*, i = 1 for first level above the base,

Level n = level that is uppermost in the main portion of the structure,

Level x = level that is under design consideration,

M_v = factor to account for higher mode effects on base shear, as defined in Sentence 4.1.8.11.(6),

M_x = overturning moment at level x, as defined in Sentence 4.1.8.11.(8),

N = total number of *storeys* above exterior *grade* to level n,

$\overline{N}_{60}$ = average standard penetration resistance, in blows per 0.3 m, in the top 30 m of *soil*, corrected to a rod energy efficiency of 60% of the theoretical maximum,

PGA(X) = peak ground acceleration, expressed as a ratio to gravitational acceleration, for site designation X, as defined in Sentence 4.1.8.4.(1),

PGV(X) = peak ground velocity, in m/s, for site designation X, as defined in Sentence 4.1.8.4.(1),

PI = plasticity index for *soil*,

R_d = ductility-related force modification factor reflecting the capability of a structure to dissipate energy through reversed cyclic inelastic behaviour, as defined in Article 4.1.8.9.,

R_o = overstrength-related force modification factor accounting for the dependable portion of reserve strength in a structure designed according to these provisions, as defined in Article 4.1.8.9.,

R_p = element or component response modification factor, as defined in Sentence 4.1.8.18.(1),

R_s = combined overstrength and ductility-related modification factor, as defined in Sentence 4.1.8.1.(7), for application in Article 4.1.8.1.,

$S_a(T,X)$ = 5%-damped spectral acceleration, expressed as a ratio to gravitational acceleration, at period T for site designation X, as defined in Sentence 4.1.8.4.(1),

SC = Seismic Category assigned to a *building* based on its Importance Category and the design spectral acceleration values at periods of 0.2 s and 1.0 s, as defined in Article 4.1.8.5.,

SFRS = seismic force resisting system, that part of the structural system that has been considered in the design to provide the required resistance to the earthquake forces and effects defined in Subsection 4.1.8.,

S_p = horizontal force factor for part or portion of a *building* and its anchorage, as given in Sentence 4.1.8.18.(1),

S(T) = design spectral acceleration, expressed as a ratio to gravitational acceleration, at period T, as defined in Sentence 4.1.8.4.(6),

$\overline{s}_u$ = average undrained shear strength, in kPa, in the top 30 m of *soil*,

T = period, in s,

T_a = fundamental lateral period of vibration of the *building* or structure, in s, in the direction under consideration, as defined in Sentence 4.1.8.11.(3),

TDD = total design displacement of any point in a seismically isolated structure, within or above the isolation system, obtained by calculating the mean + (I_E × the standard deviation) of the peak horizontal displacements from all sets of ground motion time histories analyzed, but not less than $\sqrt{I_E}$ × the mean, where the peak horizontal displacement is based on the vector sum of the two orthogonal horizontal displacements considered for each time step,

T_s = fundamental lateral period of vibration of the *building* or structure, in s, in the direction under consideration, as defined in Sentence 4.1.8.1.(7),

T_x = floor torque at level x, as defined in Sentence 4.1.8.11.(11),

V = specified lateral earthquake force at the base of the structure, as determined in Article 4.1.8.11.,

V_d = specified lateral earthquake force at the base of the structure, as determined in Article 4.1.8.12.,

V_e = lateral earthquake elastic force at the base of the structure, as determined in Article 4.1.8.12.,

V_{ed} = adjusted lateral earthquake elastic force at the base of the structure, as determined in Article 4.1.8.12.,

V_p = specified lateral earthquake force on an element or component, as determined in Article 4.1.8.18.,

V_s = specified lateral earthquake force at the base of the structure, as determined in Sentence 4.1.8.1.(7), for application in Article 4.1.8.1.,

V_{s30} = average shear wave velocity, in m/s, in the top 30 m of *soil* or *rock,*

W = specified *dead load*, as defined in Article 4.1.4.1., except that the minimum *partition* weight as defined in Sentence 4.1.4.1.(3) need not exceed 0.5 kPa, plus 15%~~25%~~ of the specified snow load as defined in Subsection 4.1.6., plus 60% of the storage load for areas used for storage, except that *storage garages* need not be considered storage areas, and the full contents of any tanks (see Note A-4.1.8.2.(1)),

W_i, W_x = portion of W that is located at or is assigned to level i or x respectively,

W_p = weight of a part or portion of a structure, e.g., cladding, *partitions* and appendages,

X = site designation, either X_V or X_S,

X_S = site designation in terms of Site Class, where S is the Site Class determined in accordance with Sentence 4.1.8.4.(3),

X_V = site designation in terms of V_{s30}, where V is the V_{s30} value calculated from in situ measurements of shear wave velocity,

X_{450} = site designation X_V with V_{s30} = 450 m/s,

δ_{ave} = average displacement of the structure at level x, as defined in Sentence 4.1.8.11.(10), and

δ_{max} = maximum displacement of the structure at level x, as defined in Sentence 4.1.8.11.(10).

Impact analysis

To evaluate the expected cost impacts of the proposed change on both the structural design and the building envelope design, buildings located in 17 major cities selected to represent the variability in climate parameters across Canada were assessed, namely: British Columbia: Vancouver, Victoria; Alberta: Calgary, Edmonton; Saskatchewan: Regina; Manitoba: Winnipeg; Ontario: Ottawa, Toronto, Thunder bay; Quebec: Montréal, Québec City; New Brunswick: Fredericton; Nova Scotia: Halifax; Prince Edward Island: Charlottetown; Newfoundland and Labrador: St John’s; Yukon: Whitehorse; Nunavut: Iqaluit.

Three building archetypes of 2-storey (with steel, concrete or wood primary structure), 10-storey (with steel, concrete or wood primary structure) and 20-storey (with steel or concrete primary structure) were considered for each location, each with a footprint of 800 m^2 (i.e., covered under Part 4 of the NBC; see Figure 1). These building archetypes were intended to represent typical building forms commonly seen for commercial or multi-unit residential buildings across Canada. The full impact analysis is included in [6].

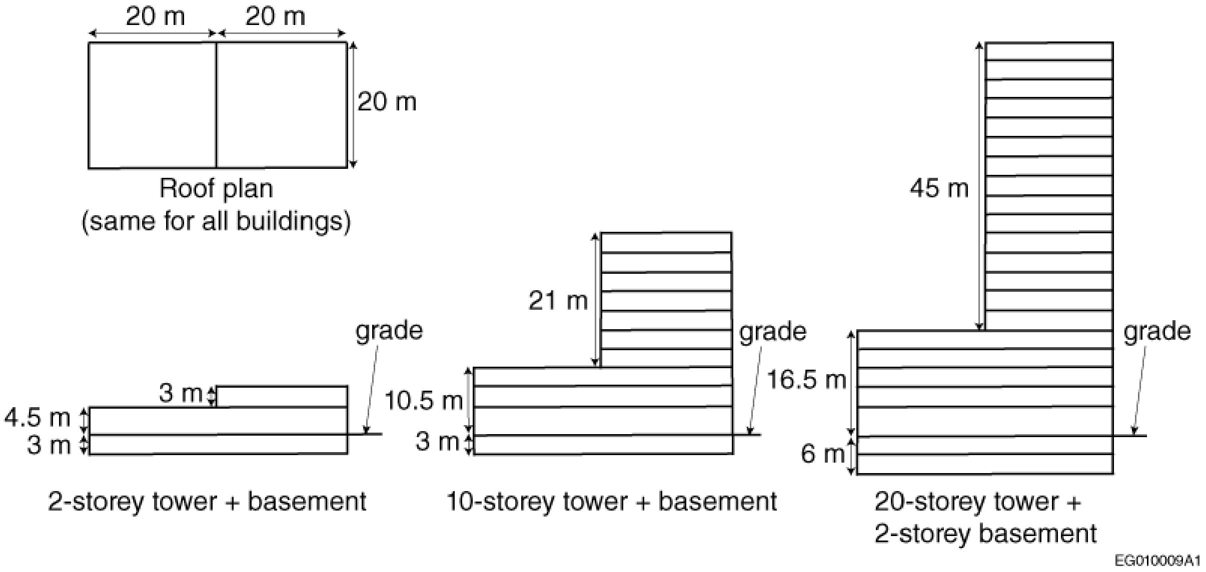


Figure 1. Building archetypes: 2-storey, 10-storey, and 20-storey towers with podium sections.

1. Impact on the structural design

The study included the cost of each structure as a new build under both the existing NBC 2020 provisions and the proposed change.

Three construction materials were considered in this impact assessment: concrete, steel and cross-laminated timber (CLT). The costs of the construction materials per unit were determined based on RMS Online Construction Base for each of the 17 locations, except for Iqaluit where the data was not available and, as such, was determined based on the data for the nearest Canadian city.

The proposed change, including the impact of climate change on building design and material selection, affects structural design wind loads differently for different city locations. The change in the overturning moments are mostly within 10%, except for the locations of Thunder Bay and Vancouver. Although the interstorey drift was found to increase for some locations, the magnitude of the increase was negligible relative to the building design capacity.

For concrete building archetypes, the results of the assessments show that the cost change due to the proposed change, with consideration of the impact of climate change on building design and material selection, was within 0.1% for all locations and building heights examined in this study.

For steel building archetypes, the results of the assessments show that the change in cost due to the proposed change, with consideration of the impact of climate change on building design and material selection, was within 2% for all locations and building heights examined in this study.

For CLT building archetypes, the results of the assessments show that the change in cost due to the proposed change, with consideration of the impact of climate change on building design and material selection, was within 0.5% for all locations and building heights examined in this study.

In general, the proposed change is expected to have negligible to very small economic impact on the cost of a new structure, primarily due to the following:

- In regions where seismic forces govern, changes to the wind or snow load do not result in a significant impact on structural costs.
- Moving to the uniform risk approach for the NBC 2025 results in a decrease to wind and snow loads at the 1/500 or 1/1000 annual probability of exceedance in several cases.
- For the building archetypes assessed, there was little impact on the lateral systems, implying that additional structural reinforcement would not be warranted.

With respect to structural design and material selection for new concrete, structural steel and CLT buildings, the greatest cost impact was a 1.5% increase for a 2-storey steel building located in St. John’s. When the proposed change was considered in the assessment, for the majority of cases, no changes were evident or a decrease to the cost was found. Overall, the costs for reinforcement were negligible relative to the total costs of the buildings. In some regions, seismic loads were found to govern the cost of the building, regardless of the changes to the wind and snow loads.

2. Impact on the building envelope

The impact assessment pertaining to building envelope design was conducted for the 17locations across Canada, as previously identified. Wind loads on wall, roof and fenestration assemblies, and snow loads on roofs were determined for the three building archetypes considered in this study. These configurations included both steel and wood stud wall cladding, as well as different roof assemblies and fenestration systems. The configurations were selected based on conventional design choices for the respective building archetypes.

Economic impacts of the proposed change were determined for wall assemblies, roof assemblies and fenestration systems and are presented in Supplementary Report B in [6]. A summary of the findings is provided below.

2.1 Wall assemblies

It was noted that in cases of increased load demands due to the proposed change, the magnitude of the increase was typically found to be within the range that a designer could accommodate within the existing structural design capacity or through solutions such as minor detailing, connections or spans and that would not affect costs.

For projects where the existing capacity or minor design changes were insufficient, it was determined that decreasing the spacing of secondary supporting structures could provide a solution (e.g., changing the spacing of secondary supporting structures from 16 in. to 12 in.). In cases where a reduced spacing for secondary supporting structures would be required to satisfy the proposed change, it was shown that costs would increase by up to 6.8% for buildings located in the five climate zones investigated. The potential maximum cost increases are summarized in Table 1 below. There was little difference between the maximum and average cost increases for the locations considered (within 0.2% for all cases); as such, only the maximum values are presented in the Table.

Table 1: Maximum Percentage Cost Increase by Wall Assembly Type Based on Decreasing Support Spacing from 16 in. to 12 in.

Wall Assembly(1)	Maximum Cost Increase
W1 - Exterior insulated steel stud wall, fiber cement cladding	6.8%
W2 - Exterior insulated steel stud wall, metal panel cladding	3.2%
W3 - Exterior insulated steel stud wall, brick cladding	0.5%
W4 - Interior insulated wood-framed wall, wood siding	2.0%
W5 - Interior insulated wood-framed wall, brick cladding	0.5%
W6 - Split insulated wood-framed wall, wood siding	1.7%
W7 - Split insulated wood-framed wall, brick cladding	0.5%

Note to Table 1:
(1) Wall types W1, W2 and W3 are applicable to all three building archetypes, while the remaining wall types (W4 to W7) are only applicable to the 2- and 10-storey buildings.

2.2 Roof assemblies

Findings show that for positive pressures that impart a compressive force on roofing materials, the compressive strength of the roofing materials far exceeds any observed increases in positive roof load; therefore, no significant increases in costs are expected.

For negative pressures, the impacts are dependent on the roof assembly construction type, namely, mechanically secured or ballasted. For mechanically secured roofs, the estimated potential maximum cost increase was determined to be 5%. In providing this estimate, it was noted that additional fasteners would only be required in localized areas across the roof. This is taken to mean that, if only 50% of the roof required additional fasteners, the cost impact would be half of 5% (i.e., 2.5%) or less.

For ballasted roofs, the estimated potential maximum cost increase was determined to be 3%, based on increased aggregate costs.

It is important to note that these cost increases are maximum cost increases and do not apply to every building archetype or to every roof zone within a given building archetype and roof construction configuration. Similarly to wall pressures, roof uplift pressure differences from the NBC 2020 to the proposed NBC 2025 provisions range from −2% to +13%, with an average difference of +4% across the 17 cities investigated. Therefore, a pressure difference to cost increase relationship can be determined on a city-by-city basis, based on the maximum change in wind pressure (+13%) and the maximum cost differences (3% and 5%). Where factored wind pressures decreased, the cost increases were set to 0%.

Table 2: Maximum Percentage Cost Increase by City Based on Roof Assembly Construction

City	Increase in Factored Wind Pressure	Maximum Increase in Cost, Mechanically Secured Roofs	Maximum Increase in Cost, Ballasted Roofs
Calgary	−2%	0%	0%
Charlottetown	7%	3%	2%
Edmonton	−2%	0%	0%
Fredericton	5%	2%	1%
Halifax	7%	3%	2%
Iqaluit	2%	1%	0%
Montréal	2%	1%	0%
Ottawa	7%	3%	2%
Québec City	2%	1%	0%
Regina	−1%	0%	0%
St John’s	7%	3%	2%
Thunder Bay	13%	5%	3%
Toronto	7%	3%	2%
Vancouver	10%	4%	2%
Victoria	3%	1%	1%
Whitehorse	7%	3%	2%
Winnipeg	0%	0%	0%

From Table 2, the average maximum cost increase is 1.8% for mechanically secured roofs and 1.1% for ballasted roofs, which assumes a 0% increase in cost in locations where factored pressures decrease.

2.3 Fenestration

While there could be cost implications associated with the proposed change, it may also be possible for designers to avoid these cost implications through value engineering solutions. The situation is similar to that for wall and roof assemblies.

The cost implications of increasing the frame depth for three fenestration systems were considered. The biggest cost increase was seen for aluminum curtain wall systems for which the frame depth increased from 7.5 in. to 10.5 in.; this corresponds to a maximum cost increase of 13.33%.

Table 3: Maximum Percentage Cost Increase by Fenestration Assembly Type Based on Indicated Frame Depth Increase

Fenestration Assembly	Maximum Cost Increase
F1 - Aluminum curtain wall, double glazed, 6 in. to 7.5 in. frame	3.45%
F1 - Aluminum curtain wall, double glazed, 7.5 in. to 10.5 in. frame	13.33%
F1 - Aluminum curtain wall, triple glazed, 6.75 in. to 8.25 in. frame	3.03%

Table 3: Maximum Percentage Cost Increase by Fenestration Assembly Type Based on Indicated Frame Depth Increase (Continued)

Fenestration Assembly	Maximum Cost Increase
F1 - Aluminum curtain wall, triple glazed, 8.25 in. to 11.25 in. frame	11.76%
F2 - Aluminum punched window, double glazed, 4 in. to 5 in. frame	3.57%
F2 - Aluminum punched window, double glazed, 5 in. to 6 in. frame	3.45%
F2 - Aluminum punched window, triple glazed, 4 in. to 5 in. frame	3.13%
F2 - Aluminum punched window, triple glazed, 5 in. to 6 in. frame	3.03%

As above, wall types W1, W2 and W3 are applicable to all three building archetypes, while the remaining wall types (W4 to W7) are only applicable to the 2- and 10-storey buildings.

The percentage of window assemblies that would require changes to their frame depth to accommodate increased loads was not quantified in this study. Mullion stress was found to decrease in 4 out of the 17 locations considered; it can, therefore, be concluded that the proposed change would not result in any cost increases. A further 6 of the 17 locations showed nominal mullion stress increases (5% or less). Similarly to what was observed for the other assemblies, the largest increase in mullion stress, 11%, was found for Thunder Bay.

With respect to vinyl punched windows, which were only considered for the 2-storey building archetype, exceeding the load case requirements in the NBC 2020 and the proposed change indicates that there are no cost implications for this specific type of fenestration system.

In summary, the effects of the slight changes in the specified wind loads and snow loads (in the North only), are not expected to significantly increase the total cost of a new building. While changes in some locations may seem significant, the approach being proposed is reasonably simple and is not disruptive to the current practice.

The main benefit of the proposed change is a lower risk of failure during the building service life as compared to past practice.

In most cases, it is expected that common construction methods, material spacings, and design considerations would prove to be resilient enough that no significant additional measures or costs are needed to satisfy the engineering design resulting from the shift to the proposed uniform risk approach and climate change factors.

References

[6] RWDI Report No. 1702484 (2023). Code Amendments for Climate Change and Economic Impact Assessment.

Enforcement implications

There are no foreseeable enforcement implications.

Who is affected

Designers, architects, building regulators and building owners.

OBJECTIVE-BASED ANALYSIS OF NEW OR CHANGED PROVISIONS

[4.1.3.2.] 4.1.3.2. ([1] 1) [F20-OP2.1] [F22-OP2.4]

[4.1.3.2.] 4.1.3.2. ([1] 1) [F20-OS2.1]

[4.1.3.2.] **4.1.3.2. ([2] 2) [F20-OS2.1] [F22-OS2.4,OS2.5]** Applies to the stabilizing resistance of the *dead load*.

[4.1.3.2.] **4.1.3.2. ([2] 2) [F20-OP2.1] [F22-OP2.4,OP2.5]**

[4.1.3.2.] **4.1.3.2. ([3] 3) [F20-OS2.1] [F22-OS2.4,OS2.5]** Applies to the stabilizing resistance of the *dead load*.

[4.1.3.2.] **4.1.3.2. ([3] 3) [F20-OP2.1] [F22-OP2.4,OP2.5]**

[4.1.3.2.] **4.1.3.2. ([4] 4) [F20-OS2.1]**

[4.1.3.2.] **4.1.3.2. ([4] 4) [F20-OP2.1] [F22-OP2.4]**

[4.1.3.2.] **4.1.3.2. ([5] 5) [F20-OS2.1] [F22-OS2.4,OS2.5]**

[4.1.3.2.] **4.1.3.2. ([5] 5) [F20-OP2.1] [F22-OP2.4,OP2.5]**

[4.1.3.2.] **4.1.3.2. ([6] 6) no attributions**

[4.1.3.2.] **4.1.3.2. ([7] 7) no attributions**

[4.1.3.2.] **4.1.3.2. ([8] 8) [F20-OS2.1]**

[4.1.3.2.] **4.1.3.2. ([8] 8) [F20-OP2.1] [F22-OP2.4]**

[4.1.3.2.] **4.1.3.2. ([9] 9) [F20-OS2.1]**

[4.1.3.2.] **4.1.3.2. ([9] 9) [F20-OP2.1] [F22-OP2.4]**

[4.1.3.2.] **4.1.3.2. ([10] 10) no attributions**

[4.1.3.2.] **4.1.3.2. ([11] 11) [F20-OS2.1] [F22-OS2.4,OS2.5]**

[4.1.3.2.] **4.1.3.2. ([12] 12) [F20-OS2.1]**

[4.1.3.2.] **4.1.3.2. ([12] 12) [F20-OP2.1] [F22-OP2.4]**

[4.1.6.2.] **4.1.6.2. ([1] 1) [F20-OS2.1]**

[4.1.6.2.] **4.1.6.2. ([1] 1) [F20-OP2.1] [F22-OP2.4]**

[4.1.6.2.] **4.1.6.2. ([2] 2) [F20-OS2.1]**

[4.1.6.2.] **4.1.6.2. ([2] 2) [F20-OP2.1] [F22-OP2.4]**

[4.1.6.2.] **4.1.6.2. ([3] 3) [F20-OS2.1]**

[4.1.6.2.] **4.1.6.2. ([3] 3) [F20-OP2.1] [F22-OP2.4]**

[4.1.6.2.] **4.1.6.2. ([4] 4) no attributions**

[4.1.6.2.] **4.1.6.2. ([5] 5) [F20-OS2.1]**

[4.1.6.2.] **4.1.6.2. ([5] 5) [F20-OP2.1] [F22-OP2.4]**

[4.1.6.2.] **4.1.6.2. ([6] 6) [F20-OS2.1]**

[4.1.6.2.] **4.1.6.2. ([6] 6) [F20-OP2.1] [F22-OP2.4]**

[4.1.6.2.] **4.1.6.2. ([7] 7) [F20-OS2.1]**

[4.1.6.2.] **4.1.6.2. ([7] 7) [F20-OP2.1] [F22-OP2.4]**

[4.1.6.2.] **4.1.6.2. ([8] 8) [F20-OS2.1]** Applies to portion of Code text: “The accumulation factor, C_a, shall be 1.0, …”

[4.1.6.2.] **4.1.6.2. ([8] 8) [F20-OP2.1] [F22-OP2.4]** Applies to portion of Code text: “The accumulation factor, C_a, shall be 1.0, …”

[4.1.6.2.] **4.1.6.2. ([8] 8) ([a] a) to ([f] f) [F20-OS2.1]** Applies to roof shapes and configurations that call for a higher accumulation factor.

[4.1.6.2.] **4.1.6.2. ([8] 8) ([a] a) to ([f] f) [F20-OP2.1] [F22-OP2.4]** Applies to roof shapes and configurations that call for a higher accumulation factor.

[4.1.6.2.] 4.1.6.2. ([9] 9) [F20-OS2.1]

[4.1.6.2.] 4.1.6.2. ([9] 9) [F20-OP2.1] [F22-OP2.4]

[4.1.6.2.] -- ([10] --) [F20-OS2.1]

[4.1.6.2.] -- ([10] --) [F20-OP2.1] [F22-OP2.4]

[4.1.6.5.] 4.1.6.5. ([1] 1) [F20-OS2.1]

[4.1.6.5.] 4.1.6.5. ([1] 1) [F20-OP2.1] [F22-OP2.4]

[4.1.6.5.] 4.1.6.5. ([2] 2) [F20-OS2.1]

[4.1.6.5.] 4.1.6.5. ([2] 2) [F20-OP2.1] [F22-OP2.4]

[4.1.6.5.] 4.1.6.5. ([3] 3) [F20-OS2.1]

[4.1.6.5.] 4.1.6.5. ([3] 3) [F20-OP2.1] [F22-OP2.4]

[4.1.6.5.] 4.1.6.5. ([4] 4) [F20-OS2.1]

[4.1.6.5.] 4.1.6.5. ([4] 4) [F20-OP2.1] [F22-OP2.4]

[4.1.6.5.] 4.1.6.5. ([5] 5) [F20-OS2.1]

[4.1.6.5.] 4.1.6.5. ([5] 5) [F20-OP2.1] [F22-OP2.4]

[4.1.6.7.] 4.1.6.7. ([1] 1) [F20-OS2.1]

[4.1.6.7.] 4.1.6.7. ([1] 1) [F20-OP2.1] [F22-OP2.4]

[4.1.6.7.] 4.1.6.7. ([2] 2) no attributions

[4.1.6.7.] 4.1.6.7. ([3] 3) no attributions

[4.1.6.9.] 4.1.6.9. ([1] 1) [F20-OS2.1]

[4.1.6.9.] 4.1.6.9. ([1] 1) [F20-OP2.1] [F22-OP2.4]

[4.1.6.9.] 4.1.6.9. ([2] 2) [F20-OS2.1]

[4.1.6.9.] 4.1.6.9. ([2] 2) [F20-OP2.1] [F22-OP2.4]

[4.1.6.9.] 4.1.6.9. ([3] 3) no attributions

[4.1.6.9.] 4.1.6.9. ([4] 4) [F20-OS2.1]

[4.1.6.9.] 4.1.6.9. ([4] 4) [F20-OP2.1] [F22-OP2.4]

[4.1.6.9.] 4.1.6.9. ([4] 4) no attributions

[4.1.6.10.] 4.1.6.10. ([1] 1) [F20-OS2.1]

[4.1.6.10.] 4.1.6.10. ([1] 1) [F20-OP2.1] [F22-OP2.4]

[4.1.6.10.] 4.1.6.10. ([2] 2) [F20-OS2.1]

[4.1.6.10.] 4.1.6.10. ([2] 2) [F20-OP2.1] [F22-OP2.4]

[4.1.6.10.] 4.1.6.10. ([3] 3) [F20-OS2.1]

[4.1.6.10.] 4.1.6.10. ([3] 3) [F20-OP2.1] [F22-OP2.4]

[4.1.6.10.] 4.1.6.10. ([4] 4) [F20-OS2.1]

[4.1.6.10.] 4.1.6.10. ([4] 4) [F20-OP2.1] [F22-OP2.4]

[4.1.6.10.] 4.1.6.10. ([5] 5) [F20-OS2.1]

[4.1.6.10.] 4.1.6.10. ([5] 5) [F20-OP2.1] [F22-OP2.4]

[4.1.6.10.] 4.1.6.10. ([6] 6) [F20-OS2.1]

[4.1.6.10.] 4.1.6.10. ([6] 6) [F20-OP2.1] [F22-OP2.4]

[4.1.6.10.] 4.1.6.10. ([7] 7) [F20-OS2.1]

[4.1.6.10.] 4.1.6.10. ([7] 7) [F20-OP2.1] [F22-OP2.4]

[4.1.6.10.] 4.1.6.10. ([8] 8) no attributions

[4.1.6.10.] 4.1.6.10. ([9] 9) [F20-OS2.1]

[4.1.6.10.] 4.1.6.10. ([9] 9) [F20-OP2.1] [F22-OP2.4]

[4.1.6.10.] 4.1.6.10. ([9] 9) no attributions

[4.1.7.3.] 4.1.7.3. ([1] 1) [F20-OS2.1]

[4.1.7.3.] 4.1.7.3. ([1] 1) [F20-OP2.1] [F22-OP2.4]

[4.1.7.3.] 4.1.7.3. ([1] 1) [F22-OH4]

[4.1.7.3.] 4.1.7.3. ([2] 2) [F20-OS2.1]

[4.1.7.3.] 4.1.7.3. ([2] 2) [F20-OP2.1] [F22-OP2.4]

[4.1.7.3.] 4.1.7.3. ([2] 2) [F22-OH4]

[4.1.7.3.] 4.1.7.3. ([3] 3) [F20-OS2.1]

[4.1.7.3.] 4.1.7.3. ([3] 3) [F20-OP2.1] [F22-OP2.4]

[4.1.7.3.] 4.1.7.3. ([3] 3) [F22-OH4]

[4.1.7.3.] 4.1.7.3. ([4] 4) [F20-OS2.1]

[4.1.7.3.] 4.1.7.3. ([4] 4) [F20-OP2.1] [F22-OP2.4]

[4.1.7.3.] 4.1.7.3. ([4] 4) [F22-OH4]

[4.1.7.3.] 4.1.7.3. ([5] 5) [F20-OS2.1]

[4.1.7.3.] 4.1.7.3. ([5] 5) [F20-OP2.1] [F22-OP2.4]

[4.1.7.3.] 4.1.7.3. ([5] 5) [F22-OH4]

[4.1.7.3.] 4.1.7.3. ([6] 6) [F20-OS2.1]

[4.1.7.3.] 4.1.7.3. ([6] 6) [F20-OP2.1] [F22-OP2.4]

[4.1.7.3.] 4.1.7.3. ([6] 6) [F22-OH4]

[4.1.7.3.] 4.1.7.3. ([7] 7) [F20-OS2.1]

[4.1.7.3.] 4.1.7.3. ([7] 7) [F20-OP2.1] [F22-OP2.4]

[4.1.7.3.] 4.1.7.3. ([7] 7) [F22-OH4]

[4.1.7.3.] 4.1.7.3. ([8] 8) [F20-OS2.1]

[4.1.7.3.] 4.1.7.3. ([8] 8) [F20-OP2.1] [F22-OP2.4]

[4.1.7.3.] 4.1.7.3. ([8] 8) [F22-OH4]

[4.1.7.3.] 4.1.7.3. ([9] 9) no attributions

[4.1.7.3.] 4.1.7.3. ([10] 10) [F20-OS2.1]

[4.1.7.3.] 4.1.7.3. ([10] 10) [F20-OP2.1] [F22-OP2.4]

[4.1.7.3.] 4.1.7.3. ([10] 10) [F22-OH4]

[4.1.8.2.] 4.1.8.2. ([1] 1) no attributions