Notes to Part 4
Structural Design

A-4.1.1.3.(1) Structural Integrity. The requirements of Part 4, including the CSA design standards, generally provide a satisfactory level of structural integrity. Additional considerations may, however, be required for building systems made of components of different materials, whose interconnection is not covered by existing CSA design standards, buildings outside the scope of existing CSA design standards, and buildings exposed to severe accidental loads such as vehicle impact or explosion. Further guidance can be found in the Commentary entitled Structural Integrity in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.1.3.(2) Serviceability. Information on serviceability can be found in the Commentary entitled Deflection and Vibration Criteria for Serviceability and Fatigue Limit States in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.1.5.(2) Structural Equivalents. Sentence 4.1.1.5.(2) provides for the use of design methods not specified in Part 4, including full-scale testing and model analogues. This provision is usually used to permit the acceptance of new and innovative structures or to permit the acceptance of model tests such as those used to determine structural behaviour, or snow or wind loads. Sentence 4.1.1.5.(2) specifically requires that the level of safety and performance be at least equivalent to that provided by design to Part 4 and requires that loads and designs conform to Section 4.1.

Sentence 4.1.1.5.(2) and the provision for alternative solutions stated in Clause 1.2.1.1.(1)(b) of Division A are not intended to allow structural design using design standards other than those listed in Part 4. The acceptance of structures that have been designed to other design standards would require the designer to prove to the appropriate authority that the structure provides the level of safety and performance required by Clause 1.2.1.1.(1)(b) of Division A. The equivalence of safety and performance can only be established by analyzing the structure for the loads and load factors set out in Section 4.1. and by demonstrating that the structure at least meets the requirements of the design standards listed in Sections 4.3. and 4.4.

A-4.1.2.1. Loads and Effects. Information on the definitions can be found in the Commentary entitled Limit States Design in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.2.1.(1) Temperature Changes. Information on effects due to temperature changes can be found in the Commentary entitled Effects of Deformations in Building Components in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.2.1.(3) Major Occupancies. In a building containing more than one major occupancy and classified in more than one Importance Category, the classification of each independent structural system shall be the same as for any part of the building that is dependent on that structural system and for the highest usage group according to Table 4.1.2.1.

A-Table 4.1.2.1. Importance Categories for Buildings.

Low Importance Category Buildings

Low human-occupancy farm buildings are defined in the National Farm Building Code of Canada 1995 as having an occupant load of 1 person or less per 40 m^2 of floor area. Minor storage buildings include only those storage buildings that represent a low direct or indirect hazard to human life in the event of structural failure, either because people are unlikely to be affected by structural failure, or because structural failure causing damage to materials or equipment does not present a direct threat to human life.

Buildings Containing Hazardous Materials

The following buildings contain sufficient quantities of toxic, explosive or other hazardous substances to be classified in the High Importance Category of use and occupancy:

- petrochemical facilities,
- fuel storage facilities (other than those required for post-disaster use), and
- manufacturing or storage facilities for dangerous goods.

The following types of buildings may be classified in the Normal Importance Category: buildings that are equipped with secondary containment of toxic, explosive or other hazardous substances, including but not limited to, double-wall tanks, dikes of sufficient size to contain a spill, or other means to contain a spill or a blast within the property boundary of the facility and prevent the release of harmful quantities of contaminants to the air, soil, groundwater, surface water or atmosphere, as the case may be.

A-4.1.3. Limit States Design. Information on limit states design can be found in the Commentary entitled Limit States Design in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.3.2.(2) Load Combinations.

Load Combination Equations

The load combinations in Tables 4.1.3.2.-A and 4.1.3.2.-B apply to most situations for loadbearing building structures. Guidance on special situations such as load combinations for fire resistance and building envelopes is given in the Commentary entitled Limit States Design in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

Load Cases and Crane Load Effects

The load combinations in Table 4.1.3.2.-A are to be evaluated for structures with crane load effects for the scenario where the crane loads are zero, and for structures without crane loads. The load combinations in Table 4.1.3.2.-B are to be evaluated for structures with crane loads for the scenario where the crane load effects are other than zero.

Crane Loads

Crane-supporting structures that have cranes in multiple parallel bays should be designed for the maximum vertical crane load with the cranes positioned for the most critical effect in conjunction with a lateral load with each crane in turn positioned for the most critical effect. For load combinations that include crane loads, additional guidance can be found in CISC/ICCA, "Crane-Supporting Steel Structures: Design Guide."

A-4.1.3.2.(4) Effects of Lateral Earth Pressure, H, Pre-stress, P, and Imposed Deformation, T, in Design Calculations.

Effects of Lateral Earth Pressure, H, in Design Calculations

For common building structures below ground level, such as walls, columns and frames, 1.5 H is added to load combinations 2 to 4. For cantilever retaining wall structures, see the Commentary entitled Limit States Design in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

Effects of Pre-stress, P, and Imposed Deformation, T, in Design Calculations

For structures and building envelopes designed in accordance with the requirements specified in the standards listed in Section 4.3., with the exception of Clauses 8 and 18 of CSA A23.3, "Design of Concrete Structures," P and T need not be included in the load combinations of Table 4.1.3.2.-A. For structures not within the scope of the standards listed in Section 4.3., including building envelopes, P and T must be taken into account in the design calculations. For recommended load combinations including T, see the Commentary entitled Limit States Design in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.3.2.(5) Overturning, Uplift or Sliding. Information on overturning, uplift and sliding can be found in the Commentary entitled Limit States Design in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.3.3.(1) Failure due to Fatigue. Failure due to fatigue of building structures referred to in Section 4.3. and designed for serviceability in accordance with Article 4.1.3.6. is, in general, unlikely except for girders supporting heavily used cranes, on which Article 4.1.5.11. provides guidance.

A-4.1.3.3.(2) Vibration Effects. Guidance on vibration effects can be found in the Commentary entitled Deflection and Vibration Criteria for Serviceability and Fatigue Limit States in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.3.4.(1) Loads and Load Combinations for Serviceability. The loads and load combinations for serviceability depend on the serviceability limit states and on the properties of the structural materials. Information on loads and load combinations for the serviceability limit states, other than those controlled by deflection, can be found in the Commentary entitled Deflection and Vibration Criteria for Serviceability and Fatigue Limit States in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.3.5.(1) Deflections. Serviceability criteria for deflections that cause damage to non-structural building components can be found in the standards listed in Section 4.3. Information on deflections can be found in the Commentary entitled Deflection and Vibration Criteria for Serviceability and Fatigue Limit States in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)." Information on loads and load combinations for calculating deflection can be found in the Commentary entitled Limit States Design in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.3.5.(3) Lateral Deflection of Buildings. The limitation of 1/500 drift per storey may be exceeded if it can be established that the drift as calculated will not result in damage to non-structural elements. Information on lateral deflection can be found in the Commentary entitled Wind Load and Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.3.6.(1) Floor Vibration. Information on floor vibration can be found in the Commentary entitled Deflection and Vibration Criteria for Serviceability and Fatigue Limit States in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)." Information on loads and load combinations for the calculation of vibration can be found in the Commentary entitled Limit States Design in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.3.6.(2) Dynamic Analyses of Floor Vibrations. Information on a dynamic analysis of floor vibrations from rhythmic activities can be found in the Commentary entitled Deflection and Vibration Criteria for Serviceability and Fatigue Limit States in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.3.6.(3) Lateral Vibration Under Wind Load. Information on lateral vibrations and accelerations under dynamic wind loads can be found in the Commentary entitled Wind Load and Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.4.1.(6) Counteracting Dead Load Due to Soil. Examples of structures that traditionally employ the dead load of soil to resist loadings are pylon signs, tower structures, retaining walls, and deadmen, which resist wind uplift and overturning in light structures.

A-4.1.5.1.(1) Loads Due to Use of Floors and Roofs. In many areas of buildings, such as equipment areas, service rooms, factories, storage areas, warehouses, museums, and office filing areas, live loads due to their intended use may exceed the minimum specified loads listed in Table 4.1.5.3. In these instances, the probable live load shall be calculated and used as the specified live load for the design of that particular area.

A-Table 4.1.5.3. Considerations for Live Loads.

Arenas, Grandstands and Stadia

The designer should give special consideration to the effects of vibration.

Attics – Limited Accessibility

Attic live loading is not required when the ceiling below the attic consists of removable panels that permit access to the ceiling space without loading the ceiling supporting members. Attic live loading is not required in any area of the attic where the least dimension of the attic space is less than 500 mm.

Corridors, Aisles and Rows of Seats

The spaces between rows of seats are typically designed for the loads of the occupancy they serve. Rows of seats typically discharge into aisles that are designed for the loads used for the rows of seats. Corridors have a minimum width of 1 100 mm and may serve as collectors for aisles; they are therefore part of the exit system and are required to be designed for a minimum live load of 4.8 kPa.

Floor Areas That Could Be Used As Viewing Areas

Some interior balconies, mezzanines, corridors, lobbies and aisles that are not intended to be used by an assembly of people as viewing areas are sometimes used as such; consequently, they are subject to loadings much higher than those for the occupancies they serve. Floor areas that may be subject to such higher loads must, therefore, be designed for a loading of 4.8 kPa.

Lecture Halls and Classrooms

For the purposes of applying the requirements of Table 4.1.5.3., lecture halls with fixed seats are similar to theatres in configuration (the seats may have a writing tablet affixed to one arm). Classrooms are typically furnished with full-sized desks having separate or integrated seats.

Minimum Roof Live Load

Articles 4.1.5.3. and 4.1.5.9. stipulate a minimum uniform roof live load of 1.0 kPa and a minimum concentrated live load of 1.3 kN. These live loads are "use and occupancy loads" intended to provide for maintenance loadings: they are not reduced as a function of area or as a function of the roof slope due to their variability in distribution and location.

Vehicle Loads

A special study should be undertaken to determine the distributed loads to be used for the design of floors and areas used by vehicles exceeding 9 000 kg gross weight and of driveways and sidewalks over areaways and basements. Where appropriate, the designer should refer to CSA S6, "Canadian Highway Bridge Design Code."

A-4.1.5.5. Loads on Exterior Areas. In Article 4.1.5.5., "accessible" refers to the lack of a physical barrier that prevents or restricts access by vehicles or persons to the site in the context of the specific use.

A-4.1.5.8. Tributary Area. Information on tributary area can be found in the Commentary entitled Live Loads in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-Table 4.1.5.9. Loads Due to Concentrations. Special study is required to determine concentrated loads for the design of floors and areas used by vehicles exceeding 9 000 kg gross weight, and of driveways and sidewalks over areaways and basements. Where appropriate the designer should refer to CSA S6, "Canadian Highway Bridge Design Code."

A-4.1.5.11. Crane-Supporting Structures. Guidance on crane-supporting structures can be found in CSA S16, "Design of Steel Structures."

A-4.1.5.14. and 4.1.5.15.(1) Design of Guards. In the design of guards, due consideration should be given to the durability of the members and their connections.

A-4.1.5.17. Loads on Firewalls. Information on loads on firewalls can be found in the Commentary entitled Structural Integrity of Firewalls in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.6.2. Coefficients for Snow Loads on Roofs. Information on coefficients for snow loads on roofs can be found in the Commentary entitled Snow Loads in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.6.2.(2) Basic Roof Snow Load Factor. Figure A-4.1.6.2.(2) shows the basic roof snow load factor, C_b, plotted against $l_c C_w^2$.

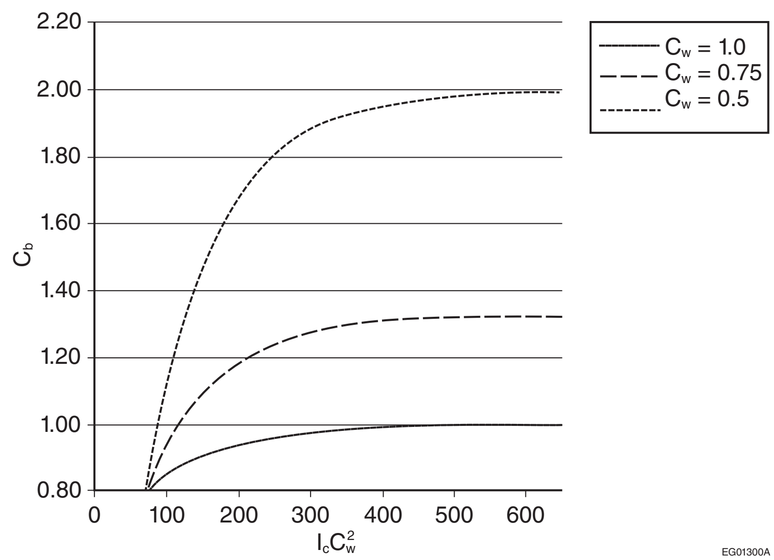


Figure A-4.1.6.2.(2)
Basic roof snow load factor, C_b

A-4.1.6.3.(2) Full and Partial Loading under Snow Loads. Information on full and partial snow loading on roofs can be found in the Commentary entitled Snow Loads in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.6.4.(1) Rain Loads. Information on rain loads can be found in the Commentary entitled Rain Loads in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.6.4.(3) Flow Control Drains. Book II (Plumbing Services) of this By-law contains requirements regarding the use of flow control roof drains. The designer must ensure that the building complies with both Book I and Book II of the Building By-law.

A-4.1.6.7.(1) Roof Projections. Elevator, air-conditioning and fan housings, small penthouses and wide chimneys are examples of roof projections.

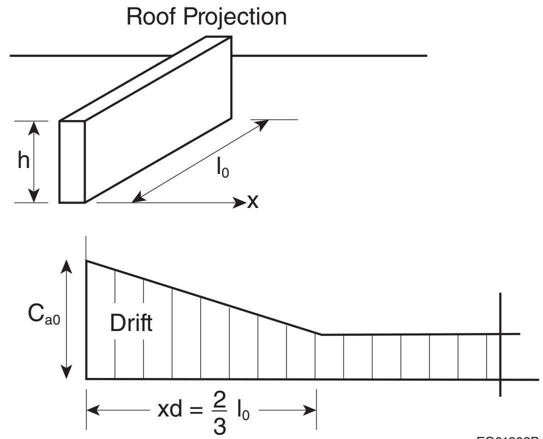
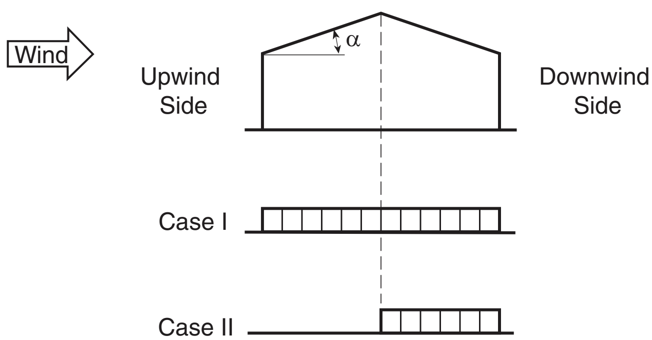


Figure A-4.1.6.7.(1)
Roof projections

A-4.1.6.7.(2) Values of C_a for Small Roof Projections. Calculating C_a in accordance with Article 4.1.6.5. rather than Sentence 4.1.6.7.(1) results in lower values for small projections.

A-4.1.6.9. Snow on Gable Roofs.



Load Case	Roof Slope, α	Factors			
		C_w	C_s	C_a on upwind side	C_a on downwind side
I	0° ≤ α ≤ 90°	(2)	f(α)(3)	1.0	1.0
II(1)	15° < α ≤ 20° 20° < α ≤ 90°	1.0 1.0	f(α)(3)	0.0 0.0	0.25 + α/20 1.25

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Figure A-4.1.6.9.
Load cases for gable roofs

Notes to Figure A-4.1.6.9.:

(1) Case II loading does not apply to gable roofs with slopes of 15° or less, to single-sloped (shed) roofs, or to flat roofs.

(2) The value of C_W for load case I is as prescribed in Sentences 4.1.6.2.(3) and (4).

(3) Varies as a function of slope, α, as defined in Sentences 4.1.6.2.(5) and (6).

A-4.1.7.1.(6) Computational Fluid Dynamics (CFD). It is not currently possible to verify the reliability and accuracy of CFD and no standards address it; as such, this method is not permitted to be used to determine specified wind loads.

A-4.1.7.2.(1) and (2) Natural Frequency. Information on calculating the natural frequency of a building can be found in the Commentary entitled Wind Load and Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.7.3.(5)(c) Procedure for Calculating Intermediate C_e. Information on calculating intermediate values of C_e between two exposures can be found in the Commentary entitled Wind Load and Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.7.3.(10) Internal Gust Effect Factor, C_{gi}. The effect of building envelope flexibility can be included in the calculation of C_{gi}. See the Commentary entitled Wind Load and Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.7.5.(2) and (3) Pressure Coefficients for Main Structural System on Rectangular Buildings.

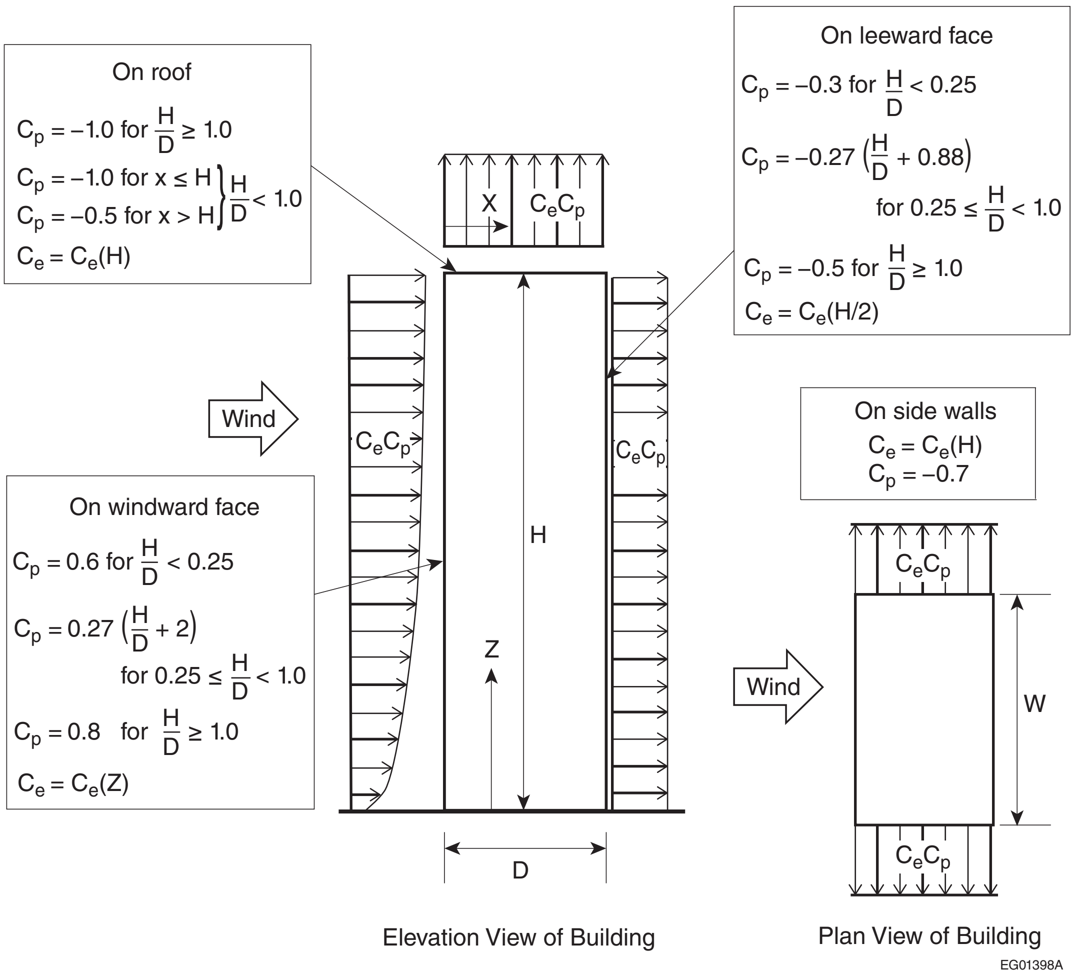

Figure A-4.1.7.5.(2) and (3)
Values of C_p for main structural system on rectangular buildings

A-4.1.7.5.(4) Pressure coefficients for roof and wall claddings and secondary structural supports of cladding on rectangular buildings.

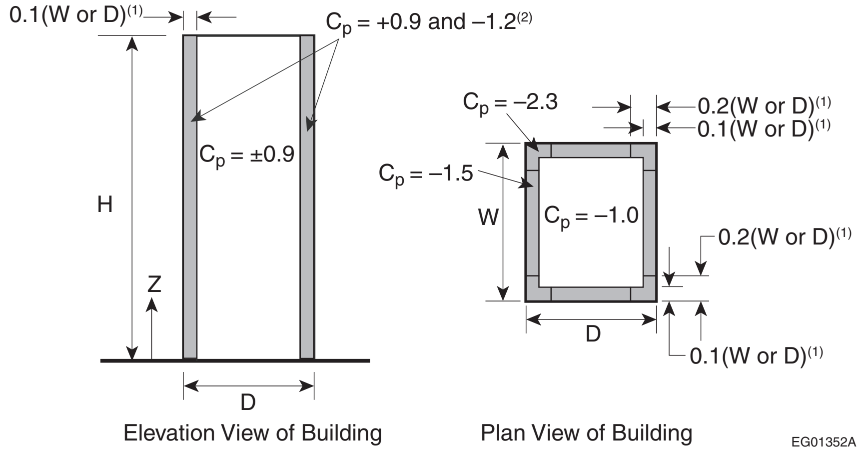

Figure A-4.1.7.5.(4)
Values of C_p for roof and wall claddings and secondary structural supports of cladding on rectangular buildings

Notes to Figure A-4.1.7.5.(4):

(1) The larger of W or D is to be used.

(2) Where vertical ribs deeper than 1 m are present on the walls, the dimensions 0.1D and 0.1W must be changed to 0.2D and 0.2W and the negative value of C_p must be changed from -1.2 to -1.4.

A-4.1.7.8.(2) and (3) Exposure Factor for Dynamic Procedure.

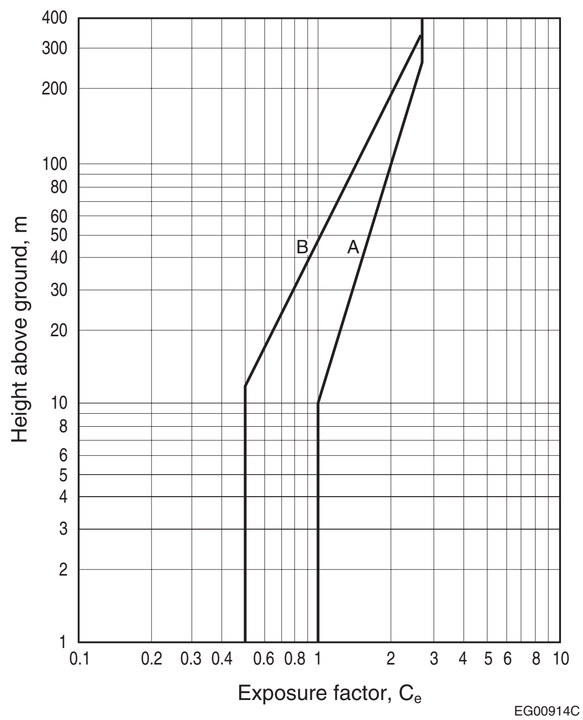

Figure A-4.1.7.8.(2) and (3)
Exposure factor, C_e, for dynamic procedure

Notes to Figure A-4.1.7.8.(2) and (3):

(1) Curve A represents C_e for open terrain, as defined in Clause 4.1.7.3.(5)(a).

(2) Curve B represents C_e for rough terrain, as defined in Clause 4.1.7.3.(5)(b).

A-4.1.7.8.(4) Peak Factor, Size Reduction Factor and Gust Energy Ratio.

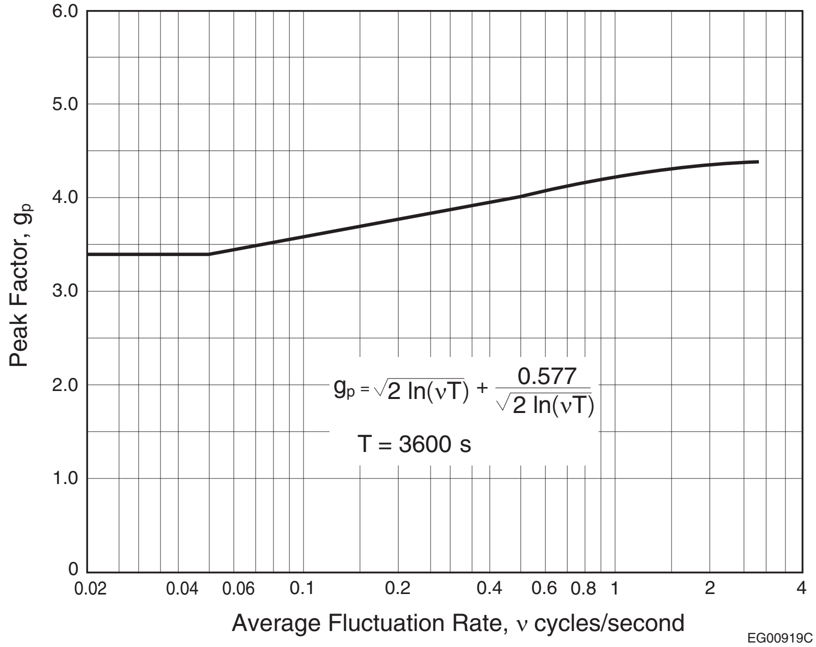

Figure A-4.1.7.8.(4)-A
Peak factor, g_p

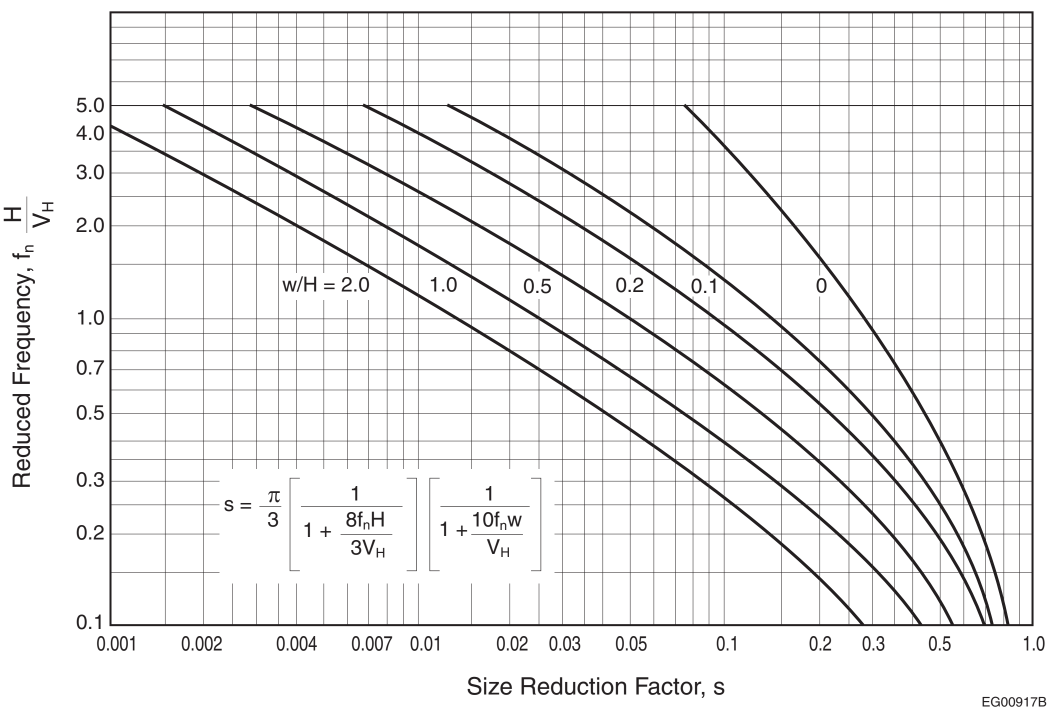

Figure A-4.1.7.8.(4)-B
Size reduction factor, s

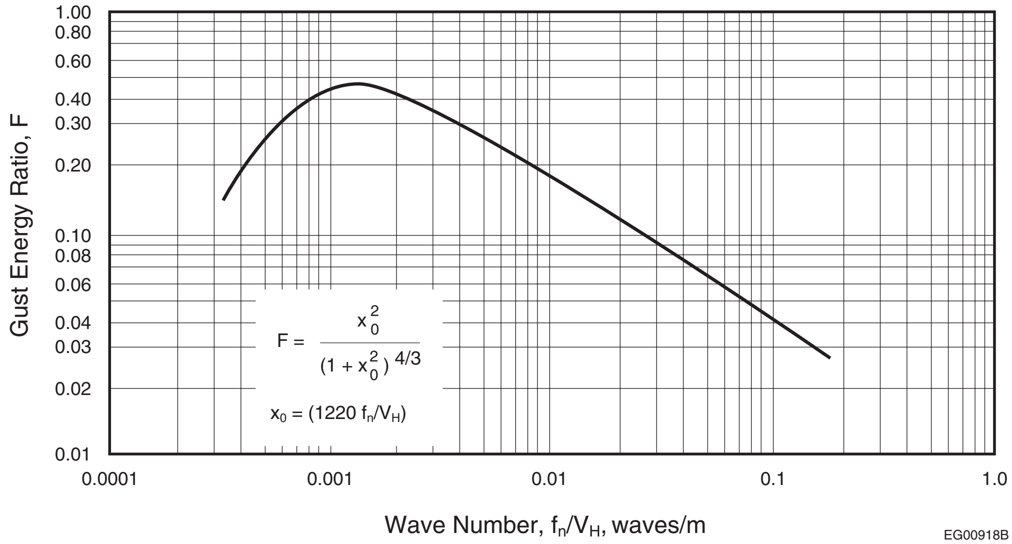

Figure A-4.1.7.8.(4)-C
Gust energy ratio, F

A-4.1.7.9.(1) Full and Partial Wind Loading. Information on full and partial loading under wind loads can be found in the Commentary entitled Wind Load and Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

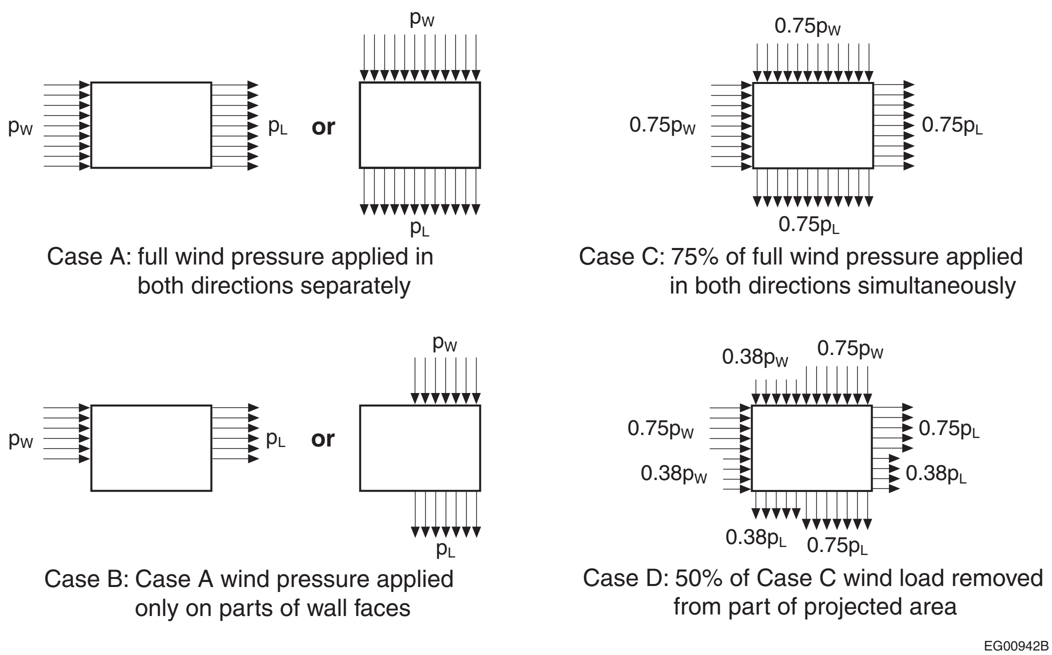

Figure A-4.1.7.9.(1)
Full and partial wind loading

A-4.1.7.11. Exterior Ornamentations, Equipment and Appendages. Appendages may increase the overall forces in the design of the building structure and need to be accounted for.

A-4.1.8.2.(1) Notation.

Definition of e_x

Information on the calculation of torsional moments can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

Definition of W

Information on the definition of dead load, W, can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.3.(4) General Design of the SFRS. Information on the general design requirements for the SFRS can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.3.(6) General Design of Stiff Elements. Information on the general design requirements for stiff elements can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.3.(7)(b) and (c) Stiffness Imparted to the Structure from Elements Not Part of the SFRS. Information on stiffness imparted to the structure from elements not part of the SFRS can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.3.(8) Structural Modelling. Information on structural modelling can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.4.(3) and Table 4.1.8.4.-A Site Class. Information on Site Class can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-Table 4.1.8.5. Serviceability Limit States for Earthquake. Information on serviceability limit states for earthquake can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-Table 4.1.8.6. Structural Irregularities.

Structural Irregularities

Information on structural irregularities can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

Gravity-Induced Lateral Demand – Type 9 Irregularity

Uncoupled concrete and masonry shear walls where a large fraction of the overturning resistance is provided by axial compression, rather than through yielding of the longitudinal reinforcement, are less susceptible to amplified displacements due to gravity-induced lateral demands because the axial loads have a self-centering effect on the shear walls. Walls that are stronger than the foundation and other systems such as coupled walls, braced frames, and moment frames are more susceptible to amplified displacements due to gravity-induced lateral demands. A lower limit on a is thus specified for such systems. Further information on the impacts of gravity-induced lateral demands on the seismic response of buildings can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.7.(1) Dynamic Analysis Procedures. Information on dynamic analysis procedures can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-Table 4.1.8.9. Industrial-Type Steel Structures. Guidance on the height limits, system restrictions and additional analysis and design requirements for steel SFRSs in industrial-type structures, intended essentially to support equipment, tanks or an industrial process, can be found in Annex M, Seismic Design of Industrial Steel Structures, of CSA S16, "Design of Steel Structures."

A-4.1.8.9.(4) Vertical Variations in R_dR_o. Information on vertical variations in R_dR_o can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.9.(5) R_dR_o and Equivalent Systems. Information on the R_dR_o of equivalent systems can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.10.(4) Mid-rise Timber SFRS. Information on structural irregularities in mid-rise wood construction and on how to determine the number of storeys for application in Sentence 4.1.8.10.(4) can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.10.(5) Gravity-Induced Lateral Demand – Type 9 Irregularity. Structural systems that include components such as inclined columns or horizontal floor cantilevers can induce lateral force demands on the SFRS under gravity loads. Buildings with such gravity-induced lateral demands on the SFRS are more likely to experience severe damage during strong ground shaking due to their tendency to drift only in one direction, leading to large residual displacements or instability. To determine if a building is susceptible to amplification of displacements due to gravity-induced lateral demands, the lateral resistance of the yielding mechanism to resist earthquake forces alone, Q_y, must be compared with the gravity-induced lateral demand, Q_G, at the same location. The force component selected for this comparison depends on the yielding mechanism for the SFRS. For example, for a coupled wall, the overturning moment resistance at the level of the expected plastic hinges should be compared with the overturning moment demand (at the same level) due to gravity loads alone, whereas for a steel-braced frame, the storey shear at the critical level of the yielding system should be compared with the storey shear demand (at the same level) due to the gravity loads alone. If the gravity-induced lateral demands exceed the limits prescribed in Sentence 4.1.8.10.(7), amplifications in seismic displacements due to gravity-induced lateral demands can only be identified through non-linear dynamic analyses using models that adequately represent the hysteretic behaviour of the SFRS. Further information on the impacts of gravity-induced lateral demands on the seismic response of buildings can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.10.(7) Gravity-Induced Lateral Demand – Non-Linear Dynamic Analysis. Information on non-linear dynamic analysis can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.11.(3) Determination of the Fundamental Period, T_a. Information on the determination of the fundamental period, T_a, can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.12.(1)(a) Linear Dynamic Analysis. Information on Linear Dynamic Analysis can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.12.(1)(b) Non-linear Dynamic Analysis. Information on Non-linear Dynamic Analysis can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.12.(3) Ground Motion Histories. Information on ground motion histories can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.12.(4)(a) Accidental Torsional Moments. Information on accidental torsional moments can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.13.(4) Deflections and Sway Effects. Information on deflections and sway effects can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.15.(1) Diaphragms and their Connections. Information on diaphragms and their connections can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.15.(3) Ductile Diaphragms. Information on the design of struts, collectors, chords and connections for ductile diaphragms can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.15.(4) Influence of Dynamic Diaphragm In-plane Response.

Clause 4.1.8.15.(4)(a)

In lieu of carrying out a special study as stated in Subclause 4.1.8.15.(4)(a)(iii), the anticipated total deformation demand on the vertical elements of the SFRS, including inelastic deformations, may be taken as equal to $R_oR_d(\Delta_B + \Delta_D) - R_o\Delta_D$, i.e., the difference between the total storey drift including inelastic deformation effects and diaphragm deformations, $R_oR_d(\Delta_B + \Delta_D)$, and the diaphragm deformation under R_o times the seismic load, where R_o may be replaced by the actual overstrength of the SFRS vertical elements. The design engineer must verify that the SFRS vertical elements have sufficient deformation capacity to accommodate the computed deformation demand. If the vertical elements of the SFRS do not have sufficient deformation capacity, the design forces for the vertical elements of the SFRS must be magnified by $R_d(1 + \Delta_D/\Delta_B)/(R_d + \Delta_D/\Delta_B)$. The calculation of the magnified design forces is iterative as the Δ_D/Δ_B ratio may change when using higher design forces for the vertical elements of the SFRS. Reducing the Δ_D/Δ_B ratio by increasing the stiffness of the roof diaphragm relative to that of the vertical elements of the SFRS may be considered to reduce the deformation demand on the vertical elements of the SFRS. Additional information can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

Clause 4.1.8.15.(4)(b)

The dynamic response of the diaphragm with the vertical elements of the SFRS under seismic excitation involves several modes of vibration that affect both the amplitude and distribution of in-plane shears and bending moments in the roof diaphragm. The shape of the fundamental mode of vibration resembles the deflected shape of the diaphragm/vertical SFRS elements under a distributed lateral load while higher modes involve increasing numbers of zero crossings of the deflected shapes along the length of the diaphragm, similar to the modes of a simply supported beam with distributed mass. Shears and bending moments therefore deviate from the values obtained from the equivalent static force procedure essentially due to higher mode response. Modal contributions to shears and bending moments in the diaphragms can be obtained from a Linear Dynamic Analysis. The contribution from the higher modes is generally more pronounced when the Δ_D/Δ_B ratio, the period in the first mode, or the ratio $S_a(0.2)/S_a(2.0)$ is increased. It also increases when the SFRS is designed with a higher R_d factor as inelastic deformations of the vertical elements of the SFRS attenuate the first mode response. Methods to take into account the inelastic higher mode effects on in-plane diaphragm shears and moments are discussed in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.15.(5) Discontinuities. Information on elements supporting discontinuities can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.15.(6) Vertical Variations in R_dR_o. Information on elements of the SFRS below the variation in R_dR_o can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.15.(7) Concurrent Yielding. Information on the effects of concurrent yielding of elements can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.15.(8) Design Force in Elements. Information on the design force in elements can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.16.(1) Foundation Movement. The bearing stress distribution in soil or rock that is used to determine the factored overturning resistance of the foundation influences the rotation of the foundation, which occurs due to the forces applied by the SFRS. Generally, all foundations will rotate on soil or rock. In particular, footings (a type of foundation unit) often undergo uplift at one end, and if the factored bearing stress at the other end is only over a short length, then the uplift and rotation of the footing can be significant. CSA A23.3, "Design of Concrete Structures," contains design requirements for footings that rotate and uplift; see also the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)" for guidance and methods to account for foundation movement.

A-4.1.8.16.(2) Actual Lateral Load Capacity of the SFRS. The actual lateral load capacity of the SFRS includes the effects of member overstrengths similar to those used to determine the R_o factors. The applicable CSA design standards include requirements on calculating the overstrengths and capacities, which may be based on the members' nominal or probable resistance. The actual capacities are larger than the factored loads and factored resistances and, in many cases, can be significantly larger. Note that the foundations designed to develop the capacity of the SFRS will undergo movements and Sentence 4.1.8.16.(1) still applies.

A-4.1.8.16.(4) Overturning Resistance of the Foundation. For the special case where the foundation is a footing, and where it and the attached SFRS are not constrained against rotation, it is permitted, with certain limitations, to size the footing to have a factored overturning resistance less than the overturning capacity of the supported SFRS. This approach results in a smaller footing, increased footing rotations, increased drifts in the structure, and increased soil stresses, all of which are over and above those associated with footings sized to have a factored overturning resistance equal to or greater than the overturning capacity of the SFRS. The footing itself must have a factored resistance capable of developing the required soil or rock reactions. An example of a footing and SFRS that are not constrained against rotation is an SFRS on a footing near the ground surface such that it can rotate freely and is attached to a gravity-load-resisting system (non-SFRS) that is laterally flexible and provides little lateral resistance. For this case, the SFRS is usually analyzed on its own and the resulting displacements are imposed on the non-SFRS elements in order to assess the effects on them. Cases where the footing and SFRS are attached to a system that has significant lateral stiffness require careful analysis and engineering judgement, or the footing can be capacity-designed.

Limiting the overturning moment on the foundation and the R_dR_o value provides some control on the increase in lateral displacement, drift and stress in the soil or rock. Cases that exceed these limits require special study.

For the common case where the SFRS and/or the footing are constrained in some way against rotation, the footing's factored resistance must be equal to or greater than the capacity of the supported SFRS. An example of an SFRS constrained against freely rotating with the footing is an SFRS attached to adjacent foundation walls by below-grade diaphragms. Examples of footings constrained against free rotation are footings that use soil anchors to resist overturning, footings on piles, and raft foundations. Note that Sentence 4.1.8.16.(1) still applies.

See CSA A23.3, "Design of Concrete Structures," and the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.16.(6)(a) Interconnection of Foundation Elements. Information on the interconnection of piles or pile caps, drilled piers, and caissons can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.16.(7) Earthquake Lateral Pressures from Backfill or Natural Ground. Information on methods of computing the seismic lateral pressures from backfill or natural ground can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.16.(8)(a) Cyclic Inelastic Behaviour of Foundation Elements. Information on the cyclic inelastic behaviour of piles or pile caps, drilled piers, and caissons can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.16.(9) Alternative Foundation Ties. Alternative methods of tying foundations together, such as a properly reinforced floor slab capable of resisting the required tension and compression forces, may be used. Passive soil pressure against buried pile caps may not be used to resist these forces.

A-4.1.8.16.(10) Liquefaction. Information on liquefaction can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.17.(1) Slope Stability. Information on slope instability can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.18. Elements of Structures, Non-structural Components and Equipment. Information on the requirements of Article 4.1.8.18. can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-Table 4.1.8.18. Non-structural Components and Equipment. The failure or detachment of non-structural components and equipment during an earthquake can present a major threat to life safety. The design requirements presented in Article 4.1.8.18. are intended to ensure that such components and their connections to the building will retain their integrity during strong ground shaking. Guidelines for the seismic risk reduction of such components are given in CAN/CSA-S832, "Seismic Risk Reduction of Operational and Functional Components (OFCs) of Buildings."

A-4.1.8.18.(14) Storage Racks. Free-standing steel pallet storage racks contain only materials typically loaded by forklift. They are designed to store loaded pallets, however in some cases, the stored material does not sit on a pallet. There is no occupancy within the racks. Information on racks can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.18.(15) and (16)(c) Glass Fallout and Failure. Information on glass fallout and testing for glass fallout can be found in AAMA 501.6, "Recommended Dynamic Test Method for Determining the Seismic Drift Causing Glass Fallout From Window Wall, Curtain Wall and Storefront Systems." Every surface other than inaccessible areas or areas where occupancy is prevented or access is prevented should be considered a "walking surface." Additional information can be found in ASCE/SEI 7, "Minimum Design Loads and Associated Criteria for Buildings and Other Structures," in FEMA P-750, "NEHRP Recommended Seismic Provisions for New Buildings and Other Structures," and FEMA 450-1, "NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures," and related commentaries, and in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.19.(2) Design Review. It is strongly recommended that a design review of the seismically isolated structure and its isolation system be carried out by an independent team of professional engineers and geoscientists experienced in seismic analysis methods and the theory and application of seismic isolation. The design review should include, but not be limited to, the following:

a) site-specific spectra,
b) ground motion time histories,
c) modeling and analyses,

d) testing program and results, and
e) final design of all structural framing elements and isolation system components.

A-4.1.8.19.(3)(a) Non-Linear Dynamic Analysis. Three-dimensional Non-Linear Dynamic Analysis is a complex process requiring special expertise. Guidance on Non-linear Dynamic Analysis can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.19.(4) Ground Motion Time Histories. Ground motion time histories and their horizontal and vertical components must be appropriately selected and scaled according to accepted practice. Further information on ground motion time histories can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.21.(2) Design Review. It is strongly recommended that a design review of the structure and the supplementary energy dissipation system be carried out by an independent team of professional engineers and geoscientists experienced in seismic analysis methods and the theory and application of supplementary energy dissipation. The design review should include, but not be limited to, the following:

a) ground motion time histories,
b) modeling and analyses,
c) testing program and results, and
d) final design of all structural framing elements and supplemental energy dissipation system components.

A-4.1.8.21.(4)(a) Non-linear Dynamic Analysis. Three-dimensional Non-linear Dynamic Analysis is a complex process requiring special expertise. Guidance on Non-linear Dynamic Analysis can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.1.8.21.(5) Ground Motion Time Histories. Ground motion time histories and their horizontal and vertical components must be appropriately selected and scaled according to accepted practice. Further information on ground motion time histories can be found in the Commentary entitled Design for Seismic Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.2.2.1.(1) Subsurface Investigation. Where acceptable information on subsurface conditions already exists, the investigation may not require further physical subsurface exploration or testing.

A-4.2.2.3.(1) Responsibilities of the Designer as Defined in Part 4. In certain situations, such as when the design is highly technical, it may be necessary for the "other suitably qualified person" to be someone responsible to the designer. In such cases the Chief Building Official may wish to order that the review be done by the designer.

A-4.2.4.1.(1) Innovative Designs. It is important that innovative approaches to foundation design be carried out by a person especially qualified in the specific method applied and that the design provide a level of safety and performance at least equivalent to that provided for or implicit in the design carried out by the methods referred to in Part 4. Provision must be made for monitoring the subsequent performance of such structures so that the long-term sufficiency of the design can be evaluated.

A-4.2.4.1.(3) Ultimate Limit States for Foundations. Information on ultimate limit states for foundations, including terminology and resistance factors, can be found in the Commentary entitled Foundations in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.2.4.1.(5) Design of Foundations for Differential Movements. Information on the design of foundations for differential movements can be found in the Commentary entitled Foundations in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.2.4.4.(1) Depth of Foundations. When adfreezing has occurred and subsequent freezing results in soil expansion beneath this area, the resulting uplift effect is sometimes referred to as frost jacking.

A heated building that is insulated to prevent heat loss through the foundation walls should be considered as an unheated structure unless the effect of the insulation is taken into account in determining the maximum depth of frost penetration.

A-4.2.5.1.(1) Excavations. Information on excavations can be found in the Commentary entitled Foundations in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.2.6.1.(1) Shallow Foundations. Information on shallow foundations can be found in the Commentary entitled Foundations in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.2.7.1.(1) Deep Foundation Units. A deep foundation unit can be pre-manufactured or cast-in-place; it can be driven, jacked, jetted, screwed, bored or excavated; it can be of wood, concrete or steel or a combination thereof.

A-4.2.7.2.(1) Deep Foundations. Information on deep foundations can be found in the Commentary entitled Foundations in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.2.7.2.(2) Load Testing of Piles. ASTM D1143/D1143M, "Deep Foundations Under Static Axial Compressive Load," defines routine load test procedures that have been extensively used.

A-4.3.1.1. Wood. The design criteria for wood, CAN/CSA 086 "Engineering Design in Wood", makes assumptions that the wood products being used are in a condition as intended by their grading. This includes the limits of moisture content as specified by the grade. However, conditions such as transportation, site storage, and construction conditions can impact the original design assumptions.

Design considerations should include and be specific to shrinkage that may occur due to changes in moisture content of the wood. This is of particular concern where the building height can be up to 6 storeys, such as being built under Article 3.2.2.50. and 3.2.2.58. The potential building movement due to shrinkage should be indicated to other design professionals for their considerations such as cladding systems, mechanical systems, hold-down devices for structural walls and connections to non-shrinking elements including firewalls and elevator shafts.

Many wood designs now incorporate mass timber elements as part of the primary structural elements or seismic force resistance systems. Such products may include glue or mechanically laminated wood elements such as Glulam, Cross and Dowel Laminated Timbers, or other proprietary products or systems which may not exhibit the properties assumed by the by-law or its referenced standards. Where such elements are used, compliance with CAN/CSA-O86 may not be sufficient to demonstrate compliance with the objective of the By-law. In such cases, where in the opinion of the Chief Building Official the potential consequence of failure is considered to be significant, they may require that such designs be supported by the third party review of the structural design under the most credible fire impaired or unimpaired scenarios. This will include the assessment of the performance of the specified materials, fire-protective features, and expected behavior of the structure under each of these scenarios.

A-4.3.3.1.(1) Precast Concrete. CSA A23.3, "Design of Concrete Structures," requires precast concrete members to conform to CSA A23.4, "Precast Concrete – Materials and Construction."

A-4.3.4.1.(1) Welded Construction. Qualification for fabricators and erectors of welded construction is found in Clause 24.3 of CSA S16, "Design of Steel Structures."

A-4.3.4.2.(1) Cold-Formed Stainless Steel Members. There is currently no Canadian standard for the design of cold-formed stainless steel structural members. As an interim measure, design may be carried out using the limit states design provisions of ASCE/SEI 8, "Design of Cold-Formed Stainless Steel Structural Members," except that load factors, load combinations and load combination factors shall be in accordance with Subsection 4.1.3.

A-4.3.6.1.(1) Design Basis for Glass. The load factors in Tables 4.1.3.2.-A and 4.1.3.2.-B must be applied to the adjusted wind load before designing in accordance with the referenced standard. Additional information is given in the Commentary entitled Wind Load and Effects in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."

A-4.4.2.1.(1) Design Basis for Parking Structures and Repair Garages. See the Commentary entitled Live Loads in the "User's Guide – NBC 2015, Structural Commentaries (Part 4 of Division B)."