Part 4

Structural Design

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Section 4.1. Structural Loads and Procedures

4.1.1. General

4.1.1.1. Scope

(1) The scope of this Part shall be as described in Subsection 1.1.2. of Division A.

4.1.1.2. Reserved

4.1.1.3. Design Requirements

(1) *Buildings* and their structural members and connections including formwork and falsework shall be designed to have sufficient structural capacity and structural integrity to safely and effectively resist all loads, effects of loads and influences that may reasonably be expected, having regard to the expected service life of *buildings*, and shall in any case satisfy the requirements of this Section. (See Appendix A.)

(2) *Buildings* and their structural members shall be designed for serviceability, in accordance with Articles 4.1.3.4. to 4.1.3.6. (See Appendix A.)

(3) All permanent and temporary structural members, including formwork and falsework of a *building*, shall be protected against loads exceeding the specified loads during the *construction* period except when, as verified by analysis or test, temporary overloading of a structural member would result in no impairment of that member or any other member.

(4) Precautions shall be taken during all stages of *construction* to ensure that the *building* is not damaged or distorted due to loads applied during *construction*.

4.1.1.4. Design Basis

(1) Except as provided in Sentence (2) and (3), *buildings* and their structural members shall be designed in conformance with the procedures and practices provided in this Part.

(2) Provided the design is carried out by a person especially qualified in the specific methods applied and provided the design demonstrates a level of safety and performance in accordance with the requirements of this Part, buildings and their structural components falling within the scope of this Part that are not amenable to analysis using a generally established theory may be designed by,
(a) evaluation of a full-scale structure or a prototype by a loading test, or
(b) studies of model analogues. (See Appendix A.)

(3) Communications towers, dish antennas and their supporting structures shall conform to CSA S37, "Antennas, Towers, and Antenna Supporting Structures".

4.1.2. Specified Loads and Effects

4.1.2.1. Loads and Effects (See Appendix A.)

(1) Except as provided in Article 4.1.2.2., the categories of loads, specified loads and effects set out in Table 4.1.2.1.A. shall be taken into consideration in the design of a *building* and its structural members and connections. (See ~~Appendix A.)~~

Table 4.1.2.1.A.
Categories of Loads, Specified Loads and Effects
Forming Part of Sentence 4.1.2.1.(1)

Symbol	Loads, Specified Loads, or Effects [1]
D	*dead load* - a permanent load [2] due to the weight of *building* components as specified in Subsection 4.1.4.
E	earthquake load and effects - a rare load [4] due to an earthquake, as specified in Subsection 4.1.8.
H	a permanent load [2] due to lateral earth pressure, including *groundwater*
L	*live load* - a variable load [3] due to intended use and *occupancy* (including loads due to cranes and the pressure of liquids in containers), as specified in Subsection 4.1.5.
P	permanent effects caused by prestress
S	variable load [3] due to snow including ice and associated rain, as specified in Article 4.1.6.2., or due to rain, as specified in Article 4.1.6.4.
T	effects due to contraction, expansion, or deflection caused by temperature changes, shrinkage, moisture changes, creep, ground settlement, or a combination of them.
W	wind load - a variable load [3] due to wind, as specified in Subsection 4.1.7.
Column 1	2

Notes to Table 4.1.2.1.A.:

(1) load means the imposed deformations (i.e. deflections, displacements or motions that induce deformations and forces in the structure), forces and pressures applied to the *building* structure,
(2) permanent load is a load that changes very little once it has been applied to the structure, except during repair,
(3) variable load is a load that frequently changes in magnitude, direction or location, and
(4) rare load is a load that occurs infrequently and for a short time only.

(2) Minimum specified values of the loads described in Sentence (1), as set forth in Subsections 4.1.4. to 4.1.8., shall be increased to account for dynamic effects where applicable.

(3) For the purpose of determining specified loads **S**, **W** or **E** in Subsections 4.1.6. to 4.1.8., *buildings* shall be assigned an Importance Category based on intended use and *occupancy*, in accordance with Table 4.1.2.1.B. (See Appendix A.)

4.1.2.2. Loads Not Listed

(1) Where a *building* or structural member can be expected to be subjected to loads, forces or other effects not listed in Article 4.1.2.1., such effects shall be taken into account in the design based on the most appropriate information available.

Table 4.1.2.1.B.
Importance Categories for Buildings
Forming Part of Sentence 4.1.2.1.(3)

Use and *Occupancy*	Importance Category
Buildings that represent a low direct or indirect hazard to human life in the event of failure, including: • low human-*occupancy buildings*, where it can be shown that collapse is not likely to cause injury or other serious consequences • minor storage *buildings*	Low[1]
All *buildings* except those listed in Importance Categories Low, High and Post-disaster	Normal
Buildings that are likely to be used as post-disaster shelters, including *buildings* whose primary use is: • as an elementary, middle or secondary school • as a community centre Manufacturing and storage facilities containing toxic, explosive or other hazardous substances in sufficient quantities to be dangerous to the public if released[1]	High
Post-disaster buildings	Post-disaster
Column 1	2

Notes to Table 4.1.2.1.B.:
(1) See Appendix A.

4.1.3. Limit States Design (See Appendix A.)

4.1.3.1. Definitions

(1) In this Part, the term,

(a) "limit states" means those conditions of a *building* structure that result in the *building* ceasing to fulfill the function for which it was designed (Those limit states concerning safety are called ultimate limit states and include exceeding the load-carrying capacity, overturning, sliding and fracture; those limit states that restrict the intended use and *occupancy* of the *building* are called serviceability limit states and include deflection, vibration, permanent deformation and local structural damage such as cracking; and those limit states that represent failure under repeated loading are called fatigue limit states),

(b) "specified loads (**D**, **E**, **H**, **L**, **P**, **S**, **T** and **W**)" mean those loads set out in Table 4.1.2.1.A.,

(c) "principal load" means the specified variable load or rare load that dominates in a given load combination,

(d) "companion load" means a specified variable load that accompanies the principal load in a given load combination,

(e) "service load" means a specified load used for the evaluation of a serviceability limit state,

(f) "principal-load factor" means a factor applied to the principal load in a load combination to account for the variability of the load and load pattern and the analysis of its effects,

(g) "companion-load factor" means a factor that, when applied to a companion load in the load combination, gives the probable magnitude of a companion load acting simultaneously with the factored principal load,

(h) "importance factor, I," means a factor applied in Subsections 4.1.6. to 4.1.8. to obtain the specified load and take into account the consequences of failure as related to the limit state and the use and *occupancy* of the *building*,

(i) "factored load" means the product of a specified load and its principal-load factor or companion-load factor,

(j) "effects" refers to forces, moments, deformations or vibrations that occur in the structure,

(k) "nominal resistance, R," of a member, connection or structure, is based on the geometry and on the specified properties of the structural materials,

(l) "resistance factor, ϕ," means a factor applied to a specified material property or to the resistance of a member, connection or structure, and that, for the limit state under consideration, takes into account the variability of dimensions and material properties, workmanship, type of failure and uncertainty in the prediction of resistance, and

(m) "factored resistance, ϕR," means the product of nominal resistance and the applicable resistance factor.

4.1.3.2. Strength and Stability

(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). $\phi R >$ effect of factored loads

(2) The effect of factored loads for a *building* or structural component shall be determined in accordance with the load combination cases listed in Table 4.1.3.2. and the requirements of this Article, the applicable combination being that which results in the most critical effect. (See Appendix A.)

(3) 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 Appendix A.)

(4) Except as provided in Sentence 4.1.8.16.(1), the counteracting factored *dead load*, 0.9**D** in load combination cases 2, 3 and 4 and 1.0**D** in load combination case 5, 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 Appendix A.)

(5) The principal-load factor 1.5 for *live load*, **L**, in Table 4.1.3.2. may be reduced to 1.25 for liquids in tanks. (See Appendix A.)

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(6) The companion-load factor 0.5 for *live load*, **L**, in Table 4.1.3.2. shall be increased to 1.0 for storage areas and for equipment areas and *service rooms* referred to in Table 4.1.5.3.

(7) The load factor 1.25 for *dead load*, **D**, in Table 4.1.3.2. for *soil*, superimposed earth, plants and trees 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 metres supported by the structure.

(8) Earthquake load, **E**, in load combination case 5 of Table 4.1.3.2. includes horizontal earth pressure due to earthquake determined in accordance with Sentence 4.1.8.16.(4).

Table 4.1.3.2.
Load Combinations for Ultimate Limit States
Forming Part of Sentence 4.1.3.2.(2)

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

Notes to Table 4.1.3.2.:
(1) See Sentences 4.1.3.2.(2) and (3).
(2) See Sentence 4.1.3.2.(7).
(3) See Sentence 4.1.3.2.(4).
(4) See Sentence 4.1.3.2.(5).
(5) See Article 4.1.5.5.
(6) See Sentence 4.1.3.2.(6).
(7) See Sentence 4.1.3.2.(8).
(8) See Appendix A.

(9) 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.

(10) 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.

4.1.3.3. Fatigue

(1) A *building* and its structural components, including connections, shall be checked for fatigue failure under the effect of the cyclical loads, as required in the standards listed in Section 4.3. (See Appendix A.)

(2) Where vibration effects, such as resonance and fatigue resulting from machinery and equipment, are likely to be significant, a dynamic analysis shall be carried out. (See Appendix A.)

4.1.3.4. Serviceability

(1) A *building* and its structural components shall be checked for serviceability limit states as defined in Clause 4.1.3.1.(1)(a) under the effect of service loads for serviceability criteria specified or recommended in Articles 4.1.3.5. and 4.1.3.6. and in the standards listed in Section 4.3. (See Appendix A.)

4.1.3.5. Deflection

(1) In proportioning structural members to limit serviceability problems resulting from deflections, consideration shall be given to,

(a) the intended use of the *building* or member,

(b) limiting damage to non-structural members made of materials whose physical properties are known at the time of design,

(c) limiting damage to the structure itself, and

(d) creep, shrinkage, temperature changes and prestress.

(See Appendix A.)

(2) The lateral deflection of *buildings* due to service wind and gravity loads shall be checked to ensure that structural elements and non-structural elements, whose nature is known at the time the structural design is carried out, will not be damaged.

(3) Except as provided in Sentence (4), the total drift per *storey* under service wind and gravity loads shall not exceed 1/500 of the *storey* height unless other drift limits are specified in the design standards referenced in Section 4.3. (See Appendix A.)

(4) The deflection limits required in Sentence (3) do not apply to industrial *buildings* or sheds if experience has proven that greater movement will have no significant adverse effects on the strength and function of the *building*.

(5) The *building* structure shall be designed for lateral deflection due to **E**, in accordance with Article 4.1.8.13.

4.1.3.6. Vibration

(1) Floor systems susceptible to vibration shall be designed so that vibrations will have no significant adverse effects on the intended *occupancy* of the *building*. (See Appendix A.)

(2) Where the fundamental vibration frequency of a structural system supporting an *assembly occupancy* used for rhythmic activities, such as dancing, concerts, jumping exercises or gymnastics, is less than 6 Hz, the effects of resonance shall be investigated by means of a dynamic analysis. (See Appendix A.)

(3) A *building* susceptible to lateral vibration under wind load shall be designed in accordance with Article 4.1.7.2. so that the vibrations will have no significant adverse effects on the intended use and *occupancy* of the *building*. (See Appendix A.)

4.1.4. Dead Loads

4.1.4.1. Dead Loads

(1) The specified *dead load* for a structural member consists of,
(a) the weight of the member itself,
(b) the weight of all materials of construction incorporated into the *building* to be supported permanently by the member,
(c) the weight of *partitions*,
(d) the weight of permanent equipment, and
(e) the vertical load due to earth, plants and trees

(2) Except as provided in Sentence (5), in areas of a *building* where *partitions* other than permanent *partitions* are shown on the drawings, or where *partitions* might be added in the future, allowance shall be made for the weight of such *partitions*.

(3) The *partition* weight allowance in Sentence (2) shall be determined from the actual or anticipated weight of the *partitions* placed in any probable position, but shall be not less than 1 kPa over the area of floor being considered.

(4) *Partition* loads used in design shall be shown on the drawings.

(5) In cases where the *dead load* of the *partition* is counteractive, the load allowances referred to in Sentences (2) and (3) shall not be included in the design calculations.

(6) Except for structures where the *dead load* of *soil* is part of the load- resisting system, where the *dead load* due to *soil*, superimposed earth, plants and trees is counteractive, it shall not be included in the design calculations. (See Appendix A.)

4.1.5. Live Loads Due to Use and Occupancy

4.1.5.1. Loads Due to Use of Floors and Roofs

(1) Except as provided in Sentence (2), the specified *live load* on an area of floor or roof depends on the intended use and *occupancy*, and shall not be less than the uniformly distributed load patterns in Article 4.1.5.3., the loads resulting from the intended use or the concentrated loads in Article 4.1.5.10., whichever produces the most critical effect.

(2) For *buildings* in the Low Importance Category as described in Table 4.1.2.1.B., a factor of 0.8 may be applied to the *live load*.

4.1.5.2. Uses Not Stipulated

(1) Except as provided in Sentence (2), where the use of an area of floor or roof is not provided for in Article 4.1.5.3., the specified *live loads* due to the use and *occupancy* of the area shall be determined from an analysis of the loads resulting from the weight of,
(a) the probable assembly of persons,
(b) the probable accumulation of equipment and furnishings, and
(c) the probable storage of materials.

(2) For *buildings* in the Low Importance Category as described in Table 4.1.2.1.B., a factor of 0.8 may be applied to the *live load*.

4.1.5.3. Full and Partial Loading

(1) The uniformly distributed *live load* shall be not less than the value listed in Table 4.1.5.3., which may be reduced as provided in Article 4.1.5.9., applied uniformly over the entire area, or on any portions of the area, whichever produces the most critical effects in the members concerned. (See Appendix A.)

Table 4.1.5.3.
Specified Uniformly Distributed Live Loads on an Area of Floor or Roof
Forming Part of Sentence 4.1.5.3.(1)

Use of Area of Floor or Roof	Minimum Specified Load, kPa
Assembly Areas (a) Except for those areas listed under (b) and (c), assembly areas with or without fixed seats including	4.8
Arenas	
Auditoria	
Churches and similar places of worship	
Dance floors	
Dining areas(1)	
Foyers and entrance halls	
Grandstands, reviewing stands and bleachers	
Gymnasia	
Museums	
Promenades	
Rinks	
Stadia	
Stages	
Theatres	
Other areas with similar uses	
(b) Assembly areas with fixed seats that have backs over at least 80 percent of the assembly area for the following uses:	2.4
Churches and similar places of worship	
Courtrooms	
Lecture halls	
Theatres	
(c) Classrooms with or without fixed seats	2.4
Attics	
Accessible by a stairway in *residential occupancies* only	1.4
Having limited accessibility so that there is no storage of equipment or materials(6)	0.5
Balconies	
Exterior	4.8
Interior and *mezzanines* that could be used for the assembly of people as a viewing area(6)	4.8
Interior and *mezzanines* other than above	(2)
Corridors, lobbies and aisles	
Other than those listed below	4.8
Not over 1 200 mm in width and all upper floor corridors of residential areas only of apartments, *hotels* and motels (that can not be used for the assembly of people as viewing area)(6)	(2)
In a Group B, Division 3 occupancy that contains sleeping accommodation for not more than 10 persons and not more than 6 occupants require assistance in evacuation in case of an emergency.	2.4
Column 1	2

Table 4.1.5.3. (Cont'd)
Specified Uniformly Distributed Live Loads on an Area of Floor or Roof
Forming Part of Sentence 4.1.5.3.(1)

Use of Area of Floor or Roof	Minimum Specified Load, kPa
Equipment areas and *service rooms* including	3.6[3]
Generator rooms	
Mechanical equipment exclusive of elevators	
Machine rooms	
Pump rooms	
Transformer vaults	
Ventilating or *air-conditioning* equipment	
Exits and fire escapes	4.8
Factories	6.0[3]
Footbridges	4.8
Garages for	
Passenger cars	2.4
Unloaded buses and light trucks	6.0
Loaded buses and trucks and all other trucking spaces	12.0
Kitchens (other than residential)	4.8
Libraries	
Stack rooms	7.2
Reading and study rooms	2.9
Office areas (not including record storage and computer rooms) located in	
Basement and *first storey*	4.8
Floors above *first storey*	2.4
Operating rooms and laboratories	3.6
Patients' bedrooms	1.9
Recreation areas that cannot be used for assembly purposes including	3.6
Billiard rooms	
Bowling alleys	
Pool rooms	
Residential areas (within the scope of Article 1.3.3.2. of Division A)	
Sleeping and living quarters in apartments, *hotels*, motels, boarding schools and colleges	1.9
Work areas within *live/work units*	2.4
Residential areas (within the scope of Article 1.3.3.3. of Division A)	
Bedrooms	1.4
Other areas	1.9
Stairs within *dwelling units*	1.9
Retail and wholesale areas	4.8
Roofs	1.0[4]
Sidewalks and driveways over areaways and *basements*	12.0
Storage areas, including locker rooms in apartment *buildings*	4.8[3]
Toilet areas	2.4
Underground slabs with earth cover	[5]
Warehouses	4.8[3]
Column 1	2

Notes to Table 4.1.5.3.:

(1) See Article 4.1.5.6.
(2) See Article 4.1.5.4.
(3) See Article 4.1.5.7.
(4) See Article 4.1.6.1.
(5) See Article 4.1.5.5.
(6) See Appendix A.

4.1.5.4. Loads for Occupancy Served

(1) The following shall be designed to carry not less than the specified load required for the *occupancy* they serve, provided they cannot be used by an assembly of people as a viewing area:
(a) corridors, lobbies and aisles not more than 1 200 mm wide,
(b) all corridors above the *first storey* of residential areas of apartments, *hotels* and motels, and
(c) interior balconies and *mezzanines*.

4.1.5.5. Loads on Exterior Areas

(1) Exterior areas accessible to vehicular traffic shall be designed for their intended use, including the weight of fire fighting equipment, but not for less than the snow and rain loads prescribed in Subsection 4.1.6.

(2) Except as provided in Sentences (3) and (4), roofs shall be designed for the uniform *live loads* specified in Table 4.1.5.3., the concentrated *live loads* listed in Table 4.1.5.10., or the snow and rain loads prescribed in Subsection 4.1.6., whichever produces the most critical effects in the members concerned..

(3) Exterior areas accessible to pedestrian traffic, but not vehicular traffic, shall be designed for their intended use, but not less than the greater of,
(a) the *live load* prescribed for assembly areas in Table 4.1.5.3., or
(b) the snow, and rain prescribed in Subsection 4.1.6.

(4) Roof parking decks shall be designed for the uniformly distributed *live loads* specified in Table 4.1.5.3., the concentrated *live loads* listed in Table 4.1.5.10., or the roof snow load, whichever produces the most critical effect in the members concerned.

4.1.5.6. Loads for Dining Areas

(1) The minimum specified *live load* listed in Table 4.1.5.3. for dining areas may be reduced to 2.4 kPa for areas in *buildings* that are being converted to dining areas, provided that the *floor area* does not exceed 100 m^2 and the dining area will not be used for other assembly purposes, including dancing.

4.1.5.7. Floor Loads Due to Intended Use

(1) Equipment areas and *service rooms*, factories, storage areas and warehouses shall be designed for the *live loads* due to their intended use but not less than the specified loads listed in Table 4.1.5.3.

4.1.5.8. More Than One Occupancy

(1) Where an area of floor or roof is intended for 2 or more *occupancies* at different times, the value to be used from Table 4.1.5.3. shall be the greatest value for any of the *occupancies* concerned.

4.1.5.9. Variation with Tributary Area (See Appendix A.)

(1) An area used for *assembly occupancies* designed for a *live load* of less than 4.8 kPa and roofs designed for the minimum loading specified in Table 4.1.5.3. shall have no reduction for tributary area.

(2) Where a structural member supports a tributary area of a floor or a roof, or a combination of them, that is greater than 80 m^2 and either used for *assembly occupancies* designed for a *live load* of 4.8 kPa or more, or used for storage, manufacturing, retail stores, garages or as a footbridge, the specified *live load* due to use and *occupancy* is the load specified in Article 4.1.5.3. multiplied by,

$$0.5 + \sqrt{20 / A}$$

where A is the tributary area in square metres for this type of use and *occupancy*.

(3) Where a structural member supports a tributary area of a floor or a roof or a combination of them, that is greater than 20 m^2 and used for any use or *occupancy* other than *assembly occupancies* and those indicated in Sentences (1) and (2), the specified *live load* due to use and *occupancy*, is the load specified in Article 4.1.5.3. multiplied by,

$$0.3 + \sqrt{9.8 / B}$$

where B is the tributary area in square metres for this type of use and *occupancy*.

(4) Where the specified *live load* for a floor is reduced in accordance with Sentences (2) or (3), the structural drawings shall indicate that a *live load* reduction factor for tributary area has been applied.

4.1.5.10. Concentrated Loads

(1) The specified *live load* due to possible concentrations of load resulting from the use of an area of floor or roof shall not be less than that listed in Table 4.1.5.10. applied over an area of 750 mm by 750 mm located so as to cause maximum effects, except that for *occupancies* not listed in Table 4.1.5.10., the concentrations of load shall be determined in accordance with Article 4.1.5.2. (See Appendix A.)

Table 4.1.5.10.
Specified Concentrated Live Loads on an Area of Floor or Roof
Forming Part of Sentence 4.1.5.10.(1)

Area of Floor or Roof	Minimum Specified Concentrated Load, kN
Roof surfaces	1.3
Floors of classrooms	4.5
Floors of offices, manufacturing *buildings*, hospital wards and *stages*	9.0
Floors and areas used by passenger cars	11
Floors and areas used by vehicles not exceeding 3600 kg gross weight	18
Floors and areas used by vehicles exceeding 3600 kg but not exceeding 9000 kg gross weight	36
Floors and areas used by vehicles exceeding 9000 kg gross weight(1)	54
Driveways and sidewalks over areaways and *basements*(1)	54
Column 1	2

Notes to Table 4.1.5.10.
(1) See Appendix A

4.1.5.11. Sway Forces in Assembly Occupancies

(1) The floor assembly and other structural elements that support fixed seats in any *building* used for *assembly occupancies* accommodating large numbers of people at one time, such as grandstands, stadia and *theatre* balconies, shall be designed to resist a horizontal force equal to not less than 0.3 kN for each metre length of seats acting parallel to each row of seats, and not less then 0.15 kN for each metre length of seats acting at right angles to each row of seats, based on the assumption that these forces are acting independently of each other.

4.1.5.12. Crane-Supporting Structures and Impact of Machinery and Equipment

(See Appendix A.)

(1) The minimum specified load due to equipment, machinery or other objects that may produce impact shall be the sum of the weight of the equipment or machinery and its maximum lifting capacity, multiplied by an appropriate factor listed in Table 4.1.5.12.

(2) Crane runway structures shall be designed to resist a horizontal force applied normal to the top of the rails equal to not less than 20% of the sum of the weights of the lifted load and the crane trolley, excluding other parts of the crane.

(3) The force described in Sentence (2) shall be equally distributed on each side of the runway and shall be assumed to act in either direction.

(4) Crane runway structures shall be designed to resist a horizontal force applied parallel to the top of the rails equal to not less than 10% of the maximum wheel loads of the crane.

Table 4.1.5.12.
Factors for the Calculation of Impact Loads
Forming Part of Sentence 4.1.5.12.(1)

Cause of Impact	Factor
Operation of cab or radio-operated cranes	1.25
Operation of pendant or hand-operated cranes	1.10
Operation of elevators	(1)
Supports for light machinery, shaft or motor-driven	1.20
Supports for reciprocating machinery (e.g. compressors)	1.50
Supports for power-driven units (e.g. piston engines)	1.50
Column 1	2

Notes to Table 4.1.5.12.:
(1) See CSA B44, "Safety Code for Elevators".

4.1.5.13. Bleachers

(1) Bleacher seats shall be designed for a uniformly distributed *live load* of 1.75 kN for each linear metre or for a concentrated load of 2.2 kN distributed over a length of 750 mm, whichever produces the most critical effect on the supporting members.

(2) Bleachers shall be checked by the erector after erection to ensure that all structural members, including bracing specified in the design, have been installed.

(3) Telescopic bleachers shall be provided with locking devices to ensure stability while in use.

4.1.5.14. Helicopter Landing Areas

(1) Helicopter landing areas on roofs shall be constructed in conformance with the requirements contained in "Canadian Aviation Regulations - Part III", published by Transport Canada.

4.1.5.15. Loads on Guards (See Appendix A.)

(1) The minimum specified horizontal load applied inward or outward at the top of every required *guard* shall be,
(a) 3.0 kN/m for *means of egress* in grandstands, stadia, bleachers and arenas,
(b) a concentrated load of 1.0 kN applied at any point for access ways to equipment platforms, contiguous stairs and similar areas where the gathering of many people is improbable, and
(c) 0.75 kN/m or a concentrated load of 1.0 kN applied at any point, whichever governs for locations other than those described in Clauses (a) and (b).

(2) Individual elements within the *guard*, including solid panels and pickets, shall be designed for a load of 0.5 kN applied over an area of 100 mm by 100 mm located at any point in the element or elements so as to produce the most critical effect.

(3) The loads required in Sentence (2) need not be considered to act simultaneously with the loads provided for in Sentences (1) and (4).

(4) The minimum specified load applied vertically at the top of every required *guard* shall be 1.5 kN/m and need not be considered to act simultaneously with the horizontal load provided for in Sentence (1).

(5) For loads on handrails, refer to Sentence 3.4.6.4.(9).

4.1.5.16. Loads on Vehicle Guardrails (See Appendix A.)

(1) Vehicle guardrails for *storage garages* shall be designed for a concentrated load of 22 kN applied horizontally outward at any point 500 mm above the floor surface.

4.1.5.17. Loads on Walls Acting As Guards

(1) Where the floor elevation on one side of a wall, including a wall around a shaft, is more than 600 mm higher than the elevation of the floor or ground on the other side, the wall shall be designed to resist the appropriate lateral design loads prescribed elsewhere in this Section or 0.5 kPa, whichever produces the more critical effect.

4.1.5.18. Firewalls (See Appendix A.)

(1) *Firewalls* shall be designed to resist the maximum effect due to,
(a) the appropriate lateral design loads prescribed elsewhere in this Section, or
(b) a factored lateral load of 0.5 kPa under fire conditions, as described in Sentence (2).

(2) Under fire conditions, where the *fire-resistance rating* of the structure is less than that of the *firewall*,
(a) lateral support shall be assumed to be provided by the structure on one side only, or
(b) another structural support system capable of resisting the loads imposed by a fire on either side of the *firewall* shall be provided.

4.1.6. Loads Due to Snow and Rain

4.1.6.1. Specified Load Due to Rain or to Snow and Associated Rain

(1) The specified load on a roof or any other *building* surface subject to snow and associated rain shall be the snow load specified in Article 4.1.6.2., or the rain load specified in Article 4.1.6.4., whichever produces the more critical effect.

4.1.6.2. Specified Snow Load (See Appendix A.)

(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 from the formula,

$$S = I_s [S_s (C_b C_w C_s C_a) + S_r]$$

where,

I_s = importance factor for snow load as provided in Table 4.1.6.2.,
S_s = 1-in-50-year ground snow load, in kPa, determined in accordance with Subsection 1.1.2.,
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), (6) and (7),
C_a = shape factor in Sentence (8), and
S_r = 1-in-50-year associated rain load, in kPa, determined in accordance with Subsection 1.1.2., but not greater than $S_s(C_b C_w C_s C_a)$.

Table 4.1.6.2.
Importance Factor for Snow Load, Is
Forming Part of Sentence 4.1.6.2.(1)

Importance Category	Importance Factor, I_s	
	ULS	SLS
Low	0.8	0.9
Normal	1	0.9
High	1.15	0.9
Post-disaster	1.25	0.9
Column 1	2	3

(2) The basic roof snow load-factor, C_b, shall be 0.8, except that for large roofs it shall be,
(a) $1.0 - (30/l_c)^2$, for roofs with $C_w = 1.0$ and l_c greater than or equal to 70 m, or
(b) $1.3 - (140/l_c)^2$, for roofs with $C_w = 0.75$ or 0.5 and l_c greater than or equal to 200 m,

where,

l_c = characteristic length of the upper or lower roof, defined as $2w - w^2/l$, in metres,
w = smaller plan dimension of the roof, in metres,
l = larger plan dimension of the roof, in metres.

(3) Except as provided for in Sentence (4), the wind exposure factor, C_w, shall be 1.0.

(4) For *buildings* in the Low and Normal Importance Categories as set out in Table 4.1.2.1.B., the wind exposure factor given in Sentence (3) may be reduced to 0.75, or to 0.5 in exposed areas north of the treeline, where,
(a) the *building* is exposed on all sides to wind over open terrain as defined in Clause 4.1.7.1.(5)(a) , and is expected to remain so during its life,
(b) the area of roof under consideration is 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 $C_b C_w S_s/\gamma$ metres, where γ is the unit weight of snow on roofs, and
(c) the loading does not involve the accumulation of snow due to drifting from adjacent surfaces.
(See Appendix A.)

(5) Except as provided for in Sentences (6) and (7), the slope factor, C_s, shall be,
(a) 1.0 where the roof slope, α, is equal to or less than 30°,
(b) (70° - α)/40° where α is greater than 30° but not greater than 70°, and
(c) 0 where α exceeds 70°.

(6) The slope factor, C_s, for unobstructed slippery roofs where snow and ice can slide completely off the roof shall be,
(a) 1.0 when the roof slope, α, is equal to or less than 15°,
(b) (60° - α)/45° when α is greater than 15°, but not greater than 60°, and
(c) 0 when α exceeds 60°.

(7) The slope factor, C_s, shall be 1.0 when used in conjunction with shape factors for increased snow loads as given in Clauses (8)(b) and (e).

(8) The shape factor, C_a, shall be 1.0, except that where appropriate for the shape of the roof, it shall be assigned other values that account for,
(a) non-uniform snow loads on gable, arched or curved roofs and domes,
(b) increased snow loads in valleys,
(c) 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,
(d) increased non-uniform snow loads on areas adjacent to roof projections, such as penthouses, large *chimneys* and equipment, and
(e) increased snow or ice loads due to snow sliding or meltwater draining from adjacent roofs.

4.1.6.3. Full and Partial Loading

(1) A roof or other *building* surface and its structural members subject to loads due to snow accumulation shall be designed for the specified load in Sentence 4.1.6.2.(1), distributed over the entire loaded area.

(2) In addition to the distribution in Sentence (1), flat roofs and shed roofs, gable roofs of 15° slope or less, and arched or curved roofs shall be designed for the specified uniform snow load indicated in Sentence 4.1.6.2.(1), which shall be calculated using $C_a = 1.0$, distributed on any one portion of the loaded area, and half of this load on the remainder of the loaded area, in such a way as to produce the most critical effects on the member concerned. (See Appendix A.)

4.1.6.4. Specified Rain Load

(1) Except as provided in Sentence (4), the specified load, S, due to the accumulation of rainwater on a surface whose position, shape and deflection under load make such an accumulation possible, is that resulting from the one-day rainfall determined in conformance with Subsection 1.1.2. and applied over the horizontal projection of the surface and all tributary surfaces. (See Appendix A.)

(2) The provisions of Sentence (1) apply whether or not the surface is provided with a means of drainage, such as rain water leaders.

(3) Except as provided for in Sentence 4.1.6.2.(1), loads due to rain need not be considered to act simultaneously with loads due to snow. (See Appendix A.)

(4) Where scuppers are provided and where the position, shape and deflection of the loaded surface make an accumulation of rainwater possible, the loads due to rain shall be the lesser of either the one-day rainfall determined in conformance with Subsection 1.1.2. or a depth of rainwater equal to 30 mm above the level of the scuppers, applied over the horizontal projection of the surface and tributary areas.

4.1.7. Wind Load

4.1.7.1. Specified Wind Load (See Appendix A.)

(1) The specified external pressure or suction due to wind on part or all of a surface of a *building* shall be calculated using the following formula:

$$p = I_w q C_e C_g C_p$$

where,

p = the specified external 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 = importance factor for wind load, as provided in Table 4.1.7.1.,
q = the reference velocity pressure as provided for in Sentence (4),
C_e = the exposure factor as provided for in Sentence (5),
C_g = the gust effect factor, as provided for in Sentence (6), and
C_p = the external pressure coefficient averaged over the area of the surface considered.

Table 4.1.7.1.
Importance Factor for Wind Load, L_w I_w
Forming Part of Sentence 4.1.7.1.(1) and (3)

Importance Category	Importance Factor, I_W	
	ULS	SLS
Low	0.8	0.75
Normal	1.0	0.75
High	1.15	0.75
Post-disaster	1.25	0.75
Column 1	2	3

(2) The net wind load for the *building* as a whole shall be the algebraic difference of the loads on the windward and the 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) The net specified pressure due to wind on part or all of a surface of a *building* shall be the algebraic difference of the external pressure or suction as provided for in Sentence (1) and the specified internal pressure or suction due to wind calculated from,

$$p_i = I_w q C_e C_{gi} C_{pi}$$

where,

p_i = specified internal pressure acting statically and in a direction normal to the surface, either as a pressure directed toward the surface or as a suction directed away from the surface,
I_w = importance factor for wind load, as provided in Table 4.1.7.1.,
q = the reference velocity pressure, as provided for in Sentence (4),
C_e = the exposure factor, as provided for in Sentence (5),
C_{gi} = internal gust effect factor, as provided for in Sentence (6), and
C_{pi} = the internal pressure coefficient.

(4) The reference velocity pressure, q, shall be the appropriate value determined in conformance with Subsection 1.1.2. based on a probability of being exceeded in any one year of 1-in-50.

(5) The exposure factor C_e, shall be,
(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, h being the reference height above *grade* in metres for the surface or part of the surface,
(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 10 times the *building height*, whichever is greater, h being the reference height above *grade* in metres for the surface or part of the surface,
(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 10 times the *building height* from a change in terrain conditions, whichever is greater, provided an appropriate interpolation method is used, or
(d) if a dynamic approach to the action of wind gusts is used, an appropriate value depending on both height and shielding.
(See Appendix A.)

(6) The gust effect factor, C_g, shall be one of the following values:
(a) for the *building* as a whole and main structural members, $C_g = 2.0$,
(b) for external pressures and suctions on small elements including cladding, $C_g = 2.5$,
(c) for internal pressures, $C_{gi} = 2.0$ or a value determined by detailed calculation that takes into account the sizes of the openings in the *building* envelope, the internal volume and the flexibility of the *building* envelope, or
(d) if a dynamic approach to wind action is used, C_g is a value that is appropriate for the turbulence of the wind and the size and natural frequency of the structure.
(See Appendix A.)

4.1.7.2. Dynamic Effects of Wind

(1) *Buildings* whose height is greater than 4 times their minimum effective width, which is defined in Sentence (2), or greater than 120 m and other *buildings* whose light weight, low frequency and low damping properties make them susceptible to vibration shall be designed by,
(a) experimental methods for the danger of dynamic overloading, vibration and the effects of fatigue, or
(b) using a dynamic approach to the action of wind gusts.

(2) The effective width, w, of a *building* shall be calculated using the formula,

$$w = \frac{\sum h_i w_i}{\sum h_i}$$

where,

the summations are over the height of the *building* for a given wind direction,
h_i is the height above *grade* to level i, as defined in Sentence 4.1.7.1.(5), and
w_i is the width normal to the wind direction at height h_i,
the minimum effective width is the lowest value of the effective width considering all possible wind directions.

4.1.7.3. Full and Partial Loading (See Appendix A.)

(1) *Buildings* and structural members shall be capable of withstanding the effects of,
(a) the full wind loads acting along each of the two principal horizontal axes considered separately,
(b) the wind loads as described in Clause (a) but with 100% of the load removed from any portion of the area,
(c) the wind loads as in Clause (a) but considered simultaneously at 75% of their full value, and
(d) the wind loads as described in Clause (c) but with 50% of these loads removed from any portion of the area.

4.1.7.4. Interior Walls and Partitions

(1) In the design of interior walls and *partitions*, due consideration shall be given to differences in air pressure on opposite sides of the wall or *partition* that may result from,

(a) pressure differences between the windward and leeward sides of a *building*,
(b) stack effects due to a difference in air temperature between the exterior and interior of the *building*, and
(c) air pressurization by the mechanical services of the *building*.

4.1.8. Earthquake Load and Effects

4.1.8.1. Analysis

(1) The deflections and specified loading due to earthquake motions shall be determined according to the requirements in this Subsection, except that the requirements in this Subsection need not be considered in design if S(0.2), as defined in Sentence 4.1.8.4.(6), is less than or equal to 0.12.

4.1.8.2. Notation (See Appendix A.)

(1) In this Subsection,

A_r = response amplification factor to account for type of attachment of mechanical/electrical equipment, as defined in Sentence 4.1.8.17.(1),
A_x = amplification factor at level x to account for variation of response of mechanical/electrical equipment with elevation within the *building*, as defined in Sentence 4.1.8.17.(1),
B_x = ratio at level x used to determine torsional sensitivity, as defined in Sentence 4.1.8.11.(9),
B = maximum value of B_x, as defined in Sentence 4.1.8.11.(9),
C_p = seismic coefficient for mechanical/electrical equipment, as defined in Sentence 4.1.8.17.(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,
F_a = acceleration-based site coefficient, as defined in Sentence 4.1.8.4.(4),
F_t = portion of V to be concentrated at the top of the structure, as defined in Sentence 4.1.8.11.(6),
F_v = velocity-based site coefficient, as defined in Sentence 4.1.8.4.(4),
F_x = lateral force applied to level x, as defined in Sentence 4.1.8.11.(6),
h_i, h_n, h_x = the height 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 = interstorey 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.(5)
J_X = numerical reduction coefficient for overturning moment at level x, as defined in Sentence 4.1.8.11.(7),
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 effect on base shear, as defined in Sentence 4.1.8.11.(5),
M_x = overturning moment at level x, as defined in Sentence 4.1.8.11.(7),
N = total number of *storeys* above exterior *grade* to level n,
$\overline{N}_{60}$ = Average Standard Penetration Resistance for the top 30 m, corrected to a rod energy efficiency of 60% of the theoretical maximum,
PGA = Peak Ground Acceleration expressed as a ratio to gravitational acceleration, as defined in Sentence 4.1.8.4.(1),
PI = plasticity index for clays,
R_d = ductility-related force modification factor reflecting the capability of a structure to dissipate energy through inelastic behaviour, as given 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.,
S_P = horizontal force factor for part or portion of a *building* and its anchorage, as given in Sentence 4.1.8.17.(1),
S(T) = design spectral response acceleration, expressed as a ratio to gravitational acceleration, for a period of T, as defined in Sentence 4.1.8.4.(6),
S_a(T) = 5% damped spectral response acceleration, expressed as a ratio to gravitational acceleration, for a period of T, as defined in Sentence 4.1.8.4.(1),

SFRS = Seismic Force Resisting System(s) is 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_u = average undrained shear strength in the top 30 m of *soil*,

T = period in seconds,

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

T_x = floor torque at level x, as defined in Sentence 4.1.8.11.(10),

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

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

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

V_P = lateral force on a part of the structure, as determined by Article 4.1.8.17.,

$\overline{V}_S$ = average shear wave velocity in the top 30 m of *soil* or *rock*,

W = *dead load*, as defined in Article 4.1.4.1., except that the minimum *partition* load as defined in Sentence 4.1.4.1.(3) need not exceed 0.5 kPa, plus 25% of the design snow load specified 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,

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,

δ_{ave} = average displacement of the structure at level x, as defined in Sentence 4.1.8.11.(9), and

δ_{max} = maximum displacement of the structure at level x, as defined in Sentence 4.1.8.11.(9).

4.1.8.3. General Requirements

(1) The *building* shall be designed to meet the requirements of this Subsection and of the design standards referenced in Section 4.3.

(2) Structures shall be designed with a clearly defined load path, or paths, that will transfer the inertial forces generated in an earthquake to the supporting ground.

(3) The structure shall have a clearly defined Seismic Force Resisting System(s) (SFRS), as defined in Article 4.1.8.2.

(4) The SFRS shall be designed to resist 100% of the earthquake loads and their effects. (See Appendix A.)

(5) All structural framing elements not considered to be part of the SFRS must be investigated and shown to behave elastically or to have sufficient non-linear capacity to support their gravity loads while undergoing earthquake-induced deformations calculated from the deflections determined in Article 4.1.8.13.

(6) Stiff elements that are not considered part of the SFRS, such as concrete, masonry, brick or pre-cast walls or panels, shall be,
(a) separated from all structural elements of the *building* such that no interaction takes place as the *building* undergoes deflections due to earthquake effects as calculated in this Subsection, or
(b) made part of the SFRS and satisfy the requirements of this Subsection.
(See Appendix A.)

(7) Stiffness imparted to the structure from elements not part of the SFRS, other than those described in Sentence (6), shall not be used to resist earthquake deflections but shall be accounted for,
(a) in calculating the period of the structure for determining forces if the added stiffness decreases the fundamental lateral period by more than 15%,
(b) in determining the irregularity of the structure, except the additional stiffness shall not be used to make an irregular SFRS regular or to reduce the effects of torsion, and
(c) in designing the SFRS if inclusion of the elements not part of the SFRS in the analysis has an adverse effect on the SFRS.
(See Appendix A.)

(8) Structural modelling shall be representative of the magnitude and spatial distribution of the mass of the *building* and of the stiffness of all elements of the SFRS, including stiff elements that are not separated in accordance with Sentence 4.1.8.3.(6), and shall account for,
(a) the effect of cracked sections in reinforced concrete and reinforced masonry elements,
(b) the effect of the finite size of members and joints,
(c) sway effects arising from the interaction of gravity loads with the displaced configuration of the structure, and
(d) other effects that influence the lateral stiffness of the *building*.
(See Appendix A.)

4.1.8.4. Site Properties

(1) The peak ground acceleration (PGA) and the 5% damped spectral response acceleration values, $S_a(T)$, for the reference ground conditions (Site Class C in Table 4.1.8.4.A.) for periods T of 0.2 s, 0.5 s, 1.0 s, and 2.0 s, shall be determined in accordance with Subsection 1.1.2. and are based on a 2% probability of exceedance in 50 years.

(2) Site classifications for ground shall conform to Table 4.1.8.4.A. and shall be determined using $\overline{V}_S$ except as provided in Sentence (3).

(3) If average shear wave velocity, $\overline{V}_S$, is not known, Site Class shall be determined from energy-corrected Average Standard Penetration Resistance, $\overline{N}_{60}$, or from *soil* average undrained shear strength, s_u, as noted in Table 4.1.8.4.A., $\overline{N}_{60}$ and s_u being calculated based on rational analysis. (See Appendix A.)

Table 4.1.8.4.A.
Site Classification for Seismic Site Response
Forming Part of Sentences 4.1.8.4.(2) and (3)

Site Class	Ground Profile Name	Average Properties in Top 30 m		
		Average Shear Wave Velocity, $\overline{V}_S$ (m/s)	Average Standard Penetration Resistance, $\overline{N}_{60}$	*Soil* Undrained Shear Strength, s_u
A	Hard *rock*	$\overline{V}_S > 1500$	n/a	n/a
B	*Rock*	$760 < \overline{V}_S \leq 1500$	n/a	n/a
C	Very dense *soil* and soft *rock*	$360 < \overline{V}_S < 760$	$\overline{N}_{60} > 50$	$s_u > 100$kPa
D	Stiff *soil*	$180 < \overline{V}_S < 360$	$15 \leq \overline{N}_{60} \leq 50$	$50 \text{ kPa} < s_u \leq 100 \text{ kPa}$
E	Soft *soil*	$\overline{V}_S < 180$	$\overline{N}_{60} < 15$	$s_u < 50$ kPa
		Any profile with more than 3 m of *soil* with the following characteristics: • plasticity index: PI>20 • moisture content w ≥40%, and • undrained shear strength: $s_u < 25$ kPa		
F	Other *soils*(1)	Site-specific evaluation required		
Column 1	2	3	4	5

Notes to Table 4.1.8.4.A.:
(1) Other *soils* include:
(a) liquefiable *soils*, quick and highly sensitive clays, collapsible weakly cemented *soils*, and other *soils* susceptible to failure or collapse under seismic loading,
(b) peat and/or highly organic clays greater than 3 m in thickness,
(c) highly plastic clays (PI > 75) more than 8 m thick, and
(d) soft to medium stiff clays more than 30 m thick.

(4) Acceleration- and velocity-based site coefficients, F_a and F_v, shall conform to Tables 4.1.8.4.B. and 4.1.8.4.C. using linear interpolation for intermediate values of $S_a(0.2)$ and $S_a(1.0)$.

(5) To determine F_a and F_v for Site Class F, site-specific geotechnical investigations and dynamic site response analysis shall be performed.

(6) The design spectral acceleration values of S(T) shall be determined as follows, using linear interpolation for intermediate values of T:

$$S(T) = F_a S_a(0.2) \text{ for } T \le 0.2 \text{ s}$$

= $F_v S_a(0.5)$ or $F_a S_a(0.2)$, whichever is smaller for $T = 0.5$ s
= $F_v S_a(1.0)$ for $T = 1.0$ s
= $F_v S_a(2.0)$ for $T = 2.0$ s
= $F_v S_a(2.0)/2$ for $T \ge 4.0$ s

Table 4.1.8.4.B
Values of F_a as a Function of Site Class and $S_a(0.2)$
Forming Part of Sentence 4.1.8.4.(4)

Site Class	Values of F_a				
	$S_a(0.2) \le 0.25$	$S_a(0.2)=0.5$	$S_a(0.2)=0.75$	$S_a(0.2)=1.00$	$S_a(0.2) \ge 1.25$
A	0.7	0.7	0.8	0.8	0.8
B	0.8	0.8	0.9	1	1
C	1	1	1	1	1
D	1.3	1.2	1.1	1.1	1
E	2.1	1.4	1.1	0.9	0.9
F	(1)	(1)	(1)	(1)	(1)
Column 1	2	3	4	5	6

Notes to Table 4.1.8.4.B.:
(1) See Sentence 4.1.8.4.(5)

Table 4.1.8.4.C
Values of F_v as a Function of Site Class and $S_a(0.1)$
Forming Part of Sentence 4.1.8.4.(4)

Site Class	Values of F_v				
	$S_a(1.0) \le 0.1$	$S_a(1.0)=0.2$	$S_a(1.0)=0.3$	$S_a(1.0)=0.4$	$S_a(1.0) \ge 0.5$
A	0.5	0.5	0.5	0.6	0.6
B	0.6	0.7	0.7	0.8	0.8
C	1	1	1	1	1
D	1.4	1.3	1.2	1.1	1.1
E	2.1	2	1.9	1.7	1.7
F	(1)	(1)	(1)	(1)	(1)
Column 1	2	3	4	5	6

Notes to Table 4.1.8.4.C.:
(1) See Sentence 4.1.8.4.(5)

4.1.8.5. Importance Factor

(1) The earthquake importance factor, I_E, shall be determined according to Table 4.1.8.5. (See Appendix A.)

Table 4.1.8.5.
Importance Factor for Earthquake Loads and Effects, I_E
Forming Part of Sentence 4.1.8.5.(1)

Importance Category	Importance Factor, I_E	
	ULS	SLS(1)
Low	0.8	(2)
Normal	1.0	(2)
High	1.3	(2)
Post-disaster	1.5	(2)
Column 1	2	3

Notes to Table 4.1.8.5.:
(1) See Article 4.1.8.13.
(2) See Appendix A.

4.1.8.6. Structural Configuration (See Appendix A.)

(1) Structures having any of the features listed in Table 4.1.8.6. shall be designated irregular.

(2) Structures not classified as irregular according to Sentence 4.1.8.6.(1) may be considered regular.

(3) Except as required by Article 4.1.8.10., in cases where $I_E F_a S_a(0.2)$ is equal to or greater than 0.35, structures designated as irregular must satisfy the provisions referenced in Table 4.1.8.6.

Table 4.1.8.6.
Structural Irregularities(1)
Forming Part of Sentence 4.1.8.6.(1)

Type	Irregularity Type and Definition	Notes
1	Vertical Stiffness Irregularity Vertical stiffness irregularity shall be considered to exist when the lateral stiffness of the SFRS in a *storey* is less than 70% of the stiffness of any adjacent *storey*, or less than 80% of the average stiffness of the three *storeys* above or below.	(2)(3)(7)
2	Weight (mass) Irregularity Weight irregularity shall be considered to exist where the weight, W_i, of any *storey* is more than 150% of the weight of an adjacent *storey*. A roof that is lighter than the floor below need not be considered.	(2)
3	Vertical Geometric Irregularity Vertical geometric irregularity shall be considered to exist where the horizontal dimension of the SFRS in any *storey* is more than 130% of that in an adjacent *storey*.	(2)(3)(4)(7)
4	In-Plane Discontinuity in Vertical Lateral-Force-Resisting Element An in-plane offset of a lateral-force-resisting element of the SFRS or a reduction in lateral stiffness of the resisting element in the *storey* below.	(2)(3)(4)(7)
Column 1	2	3

Table 4.1.8.6. (Cont'd)
Structural Irregularities[1]
Forming Part of Sentence 4.1.8.6.(1)

Type	Irregularity Type and Definition	Notes
5	Out-of-Plane Offsets Discontinuities in a lateral force path, such as out-of-plane offsets of the vertical elements of the SFRS.	(2)(3)(4)(7)
6	Discontinuity in Capacity - Weak *Storey* A weak *storey* is one in which the *storey* shear strength is less than that in the *storey* above. The *storey* shear strength is the total strength of all seismic- resisting elements of the SFRS sharing the *storey* shear fo the direction under consideration.	(3)
7	Torsional Sensitivity (to be considered when diaphragms are not flexible) Torsional sensitivity shall be considered to exist when the ratio B calculated according to Sentence 4.1.8.11.(9) exceeds 1.7.	(2)(3)(5)(7)
8	Non-orthogonal Systems A non-orthogonal system irregularity shall be considered to exist when the SFRS is not oriented along a set of orthogonal axes.	(6)(7)
Column 1	2	3

Notes to Table 4.1.8.6.:

(1) One-storey penthouses with a weight of less than 10% of the level below need not be considered in the application of this Table.
(2) See Article 4.1.8.7.
(3) See Article 4.1.8.10.
(4) See Article 4.1.8.15.
(5) See Sentences 4.1.8.11.(9), (10) and 4.1.8.12.(4).
(6) See Article 4.1.8.8.
(7) See Appendix A.

4.1.8.7. Methods of Analysis (See Appendix A.)

(1) Analysis for design earthquake actions shall be carried out in accordance with the Dynamic Analysis Procedure described in Article 4.1.8.12., except that the Equivalent Static Force Procedure described in Article 4.1.8.11. may be used for structures that meet any of the following criteria:
(a) in cases where $I_EF_aS_a(0.2)$ is less than 0.35,
(b) regular structures that are less than 60 m in height and have a fundamental lateral period, T_a, less than 2 s in each of two orthogonal directions as defined in Article 4.1.8.8., or
(c) structures with structural irregularity, of Type 1, 2, 3, 4, 5, 6 or 8 as defined in Table 4.1.8.6., that are less than 20 m in height and have a fundamental lateral period, T_a, less than 0.5 s in each of two orthogonal directions as defined in Article 4.1.8.8.

4.1.8.8. Direction of Loading

(1) Earthquake forces shall be assumed to act in any horizontal direction, except that the following shall be considered to provide adequate design force levels in the structure:
(a) where components of the SFRS are oriented along a set of orthogonal axes, independent analyses about each of the principal axes of the structure shall be performed,
(b) where the components of the SFRS are not oriented along a set of orthogonal axes and $I_EF_aS_a(0.2)$ is less than 0.35, independent analyses about any two orthogonal axes is permitted, or
(c) where the components of the SFRS are not oriented along a set of orthogonal axes and $I_EF_aS_a(0.2)$ is equal to or greater than 0.35, analysis of the structure independently in any two orthogonal directions for 100% of the prescribed earthquake loads applied in one direction plus 30% of the prescribed earthquake loads in the perpendicular direction, with the combination requiring the greater element strength being used in the design.

4.1.8.9. SFRS Force Reduction Factors, System Overstrength Factors, and General Restrictions

(1) The values of R_d and R_o and the corresponding system restrictions shall conform to Table 4.1.8.9. and the requirements of this Subsection.

(2) When a particular value of R_d is required by this Article, the corresponding R_o shall be used.

(3) For combinations of different types of SFRS acting in the same direction in the same *storey*, R_dR_o shall be taken as the lowest value of R_dR_o corresponding to these systems.

(4) For vertical variations of R_dR_o, excluding penthouses whose weight is less than 10% of the level below, the value of R_dR_o used in the design of any *storey* shall be less than or equal to the lowest value of R_dR_o used in the given direction for the *storeys* above, and the requirements of Sentence 4.1.8.15.(3) must be satisfied. (See Appendix A.)

(5) If it can be demonstrated through testing, research and analysis that the seismic performance of a structural system is at least equivalent to one of the types of SFRS mentioned in Table 4.1.8.9., then such a structural system will qualify for values of R_d and R_o corresponding to the equivalent type in that Table. (See Appendix A.)

Table 4.1.8.9.
SFRS Ductility-Related Force Modification Factors, R_d,
Overstrength-Related Force Modification Factors, R_o, and General Restrictions[1]
Forming Part of Sentence 4.1.8 9.(1)

Type of SFRS	R_d	R_o	Restrictions[2]				
			Cases Where $I_EF_aS_a(0.2)$				Cases Where $I_EF_vS_a(1.0)$
			<0.2	≥0.2 to <0.35	≥0.35 to ≤0.75	>0.75	>0.3
Steel Structures Designed and Detailed According to CAN/CSA-S16							
Ductile moment-resisting frames	5	1.5	NL	NL	NL	NL	NL
Moderately ductile moment-resisting frames	3.5	1.5	NL	NL	NL	NL	NL
Limited ductility moment-resisting frames	2	1.3	NL	NL	60	30	30
Moderately ductile concentrically braced frames							
Non-chevron braces	3	1.3	NL	NL	40	40	40
Chevron braces	3	1.3	NL	NL	40	40	40
Tension only braces	3	1.3	NL	NL	20	20	20
Limited ductility concentrically braced frames							
Non-chevron braces	2	1.3	NL	NL	60	60	60
Chevron braces	2	1.3	NL	NL	60	60	60
Tension only braces	2	1.3	NL	NL	40	40	40
Ductile eccentrically braced frames	4	1.5	NL	NL	NL	NL	NL
Ductile frame plate shear walls	5	1.6	NL	NL	NL	NL	NL
Moderately ductile plate shear walls	2	1.5	NL	NL	60	60	60
Conventional construction of moment frames, braced frames or shear walls	1.5	1.3	NL	NL	15	15	15
Other steel SFRS(s) not defined above	1	1	15	15	NP	NP	NP
Column 1	2	3	4	5	6	7	8

Table 4.1.8.9. (Cont'd)
SFRS Ductility-Related Force Modification Factors, R_d,
Overstrength-Related Force Modification Factors, R_o, and General Restrictions[1]
Forming Part of Sentence 4.1.8 9.(1)

Type of SFRS	R_d	R_o	Restrictions[2]				
			Cases Where $I_EF_aS_a(0.2)$				Cases Where $I_EF_vS_a(1.0)$
			<0.2	≥0.2 to <0.35	≥0.35 to ≤0.75	>0.75	>0.3
Concrete Structures Designed and Detailed According to CSA A23.3							
Ductile moment-resisting frames	4	1.7	NL	NL	NL	NL	NL
Moderately ductile moment-resisting frames	2.5	1.4	NL	NL	60	40	40
Ductile coupled walls	4	1.7	NL	NL	NL	NL	NL
Ductile partially coupled walls	3.5	1.7	NL	NL	NL	NL	NL
Ductile shear walls	3.5	1.6	NL	NL	NL	NL	NL
Moderately ductile shear walls	2	1.4	NL	NL	NL	60	60
Conventional construction Moment-resisting frames	1.5	1.3	NL	NL	15	NP	NP
Shear walls	1.5	1.3	NL	NL	40	30	30
Other concrete SFRS(s) not listed above	1	1	15	15	NP	NP	NP
Timber Structures Designed and Detailed According to CAN/CSA-O86							
Shear walls							
Nailed shear walls: wood-based panel	3	1.7	NL	NL	30	20	20
Shear walls: wood-based and gypsum panels in combination	2	1.7	NL	NL	20	20	20
Braced or moment-resisting frames with ductile connections							
Moderately ductile	2	1.5	NL	NL	20	20	20
Limited ductility	1.5	1.5	NL	NL	15	15	15
Other wood-or gypsum-based SFRS(s) not listed above	1	1	15	15	NP	NP	NP
Masonry Structures Designed and Detailed According to CSA S304.1							
Moderately ductile shear walls	2	1.5	NL	NL	60	40	40
Limited ductility shear walls	1.5	1.5	NL	NL	40	30	30
Conventional construction							
Shear walls	1.5	1.5	NL	60	30	15	15
Moment-resisting frames	1.5	1.5	NL	30	NP	NP	NP
Unreinforced masonry	1	1	30	15	NP	NP	NP
Other masonry SFRS(s) not listed above	1	1	15	NP	NP	NP	NP
Column 1	2	3	4	5	6	7	8

Notes to Table 4.1.8.9.:

(1) See Article 4.1.8.10.

(2) NP = system is not permitted.
NL = system is permitted and not limited in height as an SFRS; height may be limited in other Parts of the Code.
Numbers in Columns 4 to 8 are maximum height limits in m.
The most stringent requirement governs.

4.1.8.10. Additional System Restrictions

(1) Except as required by Clause (2)(b), structures with a Type 6 irregularity, Discontinuity in Capacity - Weak Storey, as described in Table 4.1.8.6., are not permitted unless $I_EF_aS_a(0.2)$ is less than 0.2 and the forces used for design of the SFRS are multiplied by R_dR_o.

(2) *Post disaster buildings* shall,
(a) not have any irregularities conforming to Types 1, 3, 4, 5 and 7 as described in Table 4.1.8.6., in cases where $I_E F_a S_a(0.2)$ is equal to or greater than 0.35,
(b) not have a Type 6 irregularity as described in Table 4.1.8.6., and
(c) have an SFRS with an R_d of 2.0 or greater.

(3) For *buildings* having fundamental lateral periods, T_a, of 1.0 s or greater, and where $I_E F_v S_a(1.0)$ is greater than 0.25, walls forming part of the SFRS shall be continuous from their top to the *foundation* and shall not have irregularities of Type 4 or 5 as described in Table 4.1.8.6.

4.1.8.11. Equivalent Static Force Procedure for Structures Satisfying the Conditions of Article 4.1.8.6.

(1) The static loading due to earthquake motion shall be determined according to the procedures given in this Article.

(2) The minimum lateral earthquake force, V, shall be calculated using the formula,

$$V = S(T_a) M_v I_E W / (R_d R_o)$$

except that V shall not be less than,

$$S(2.0) M_v I_E W / (R_d R_o)$$

and for an SFRS with an R_d equal to or greater than 1.5, V need not be greater than,

$$\tfrac{2}{3} S(0.2) I_E W / (R_d R_o)$$

(3) The fundamental lateral period, T_a, in the direction under consideration in Sentence (2) shall be determined as,
(a) for moment resisting frames that resist 100% of the required lateral forces and where the frame is not enclosed by or adjoined by more rigid elements that would tend to prevent the frame from resisting lateral forces, and where h_n is in metres,
  (i) $0.085 (h_n)^{3/4}$ for steel moment frames,
  (ii) $0.075 (h_n)^{3/4}$ for concrete moment frames, or
  (iii) 0.1 N for other moment frames,
(b) $0.025 h_n$ for braced frames where h_n is in metres,
(c) $0.05 (h_n)^{3/4}$ for shear wall and other structures where h_n is in metres, or
(d) other established methods of mechanics using a structural model that complies with the requirements of Sentence 4.1.8.3.(8), except that,
  (i) for moment resisting frames, T_a shall not be taken greater than 1.5 times that determined in Clause (a),
  (ii) for braced frames, T_a shall not be taken greater than 2.0 times that determined in Clause (b),
  (iii) for shear wall structures, T_a shall not be greater than 2.0 times that determined in Clause (c), and
  (iv) for the purpose of calculating the deflections, the period without the upper limit specified herein may be used.
(See Appendix A.)

(4) The weight, W, of the *building* shall be calculated using the formula,

$$W = \sum_{i=1}^{n} W_i$$

(5) The higher mode factor, M_v, and its associated base overturning moment reduction factor, J, shall conform to Table 4.1.8.11.

Table 4.1.8.11.
Higher Mode Factor, M_v, and Base Overturning Reduction Factor, J(1)(2)
Forming Part of Sentence 4.1.8.11.(5)

$S_a(0.2)/S_a(2.0)$	Type of Lateral Resisting System	M_v For $T_a \le 1.0$	M_v For $T_a \ge 2.0$	J For $T_a \le 0.5$	J For $T_a \ge 2.0$
< 8.0	Moment-resisting frames or coupled walls(3)	1	1	1	1
	Braced frames	1	1	1	0.8
	Walls, wall-frame systems, other systems(4)	1	1.2	1	0.7
≥8.0	Moment-resisting frames or coupled walls(3)	1	1.2	1	0.7
	Braced frames	1	1.5	1	0.5
	Walls, wall-frame systems, other systems(4)	1	2.5	1	0.4
Column 1	2	3	4	5	6

Notes to Table 4.1.8.11.:

(1) For values of M_v between fundamental lateral periods, T_a, of 1.0 and 2.0 s, the product $S(T_a) \cdot M_v$ shall be obtained by linear interpolation.
(2) Values of J between fundamental lateral periods, T_a, of 0.5 and 2.0 s shell be obtained by linear interpolation.
(3) A "coupled wall" is a wall system with coupling beams, where at least 66% of the base overturning moment resisted by the wall system is carried by the axial tension and compression forces resulting from shear in the coupling beams.
(4) For hybrid systems, values corresponding to walls must be used or a dynamic analysis must be carried out as per Article 4.1.8.12.

(6) The total lateral seismic force, V, shall be distributed such that a portion, F_t, shall be assumed to be concentrated at the top of the *building*, where F_t, is equal to $0.07\ T_aV$ but need not exceed 0.25 V and may be considered as zero, where the fundamental lateral period, T_a, does not exceed 0.7 s; the remainder, V - F_t, shall be distributed along the height of the *building*, including the top level, in accordance with the formula,

$$F_x = (V - F_t)\, W_x h_x \Big/ \left(\sum_{i=1}^{n} W_i h_i \right)$$

(7) The structure shall be designed to resist overturning effects caused by the earthquake forces determined in Sentence (6) and the overturning moment at level x, M_x, shall be determined using the formula,

$$M_x = J_x \sum_{i=1}^{n} F_i (h_i - h_x)$$

where,

$J_x = 1.0$ for $h_x \ge 0.6h_n$, and
$J_x = J + (1 - J)(h_x / 0.6h_n)$ for $h_x < 0.6h_n$

where,

J = base overturning moment reduction factor conforming to Table 4.1.8.11.

(8) Torsional effects that are concurrent with the effects of the forces mentioned in Sentence (6) and are caused by the following torsional moments shall be considered in the design of the structure according to Sentence (10):
(a) torsional moments introduced by eccentricity between the centres of mass and resistance and their dynamic amplification, or
(b) torsional moments due to accidental eccentricities.

(9) Torsional sensitivity shall be determined by calculating the ratio B_x for each level x according to the following equation for each orthogonal direction determined independently:

$$B_x = \delta_{max} / \delta_{ave}$$

where,

B = maximum of all values of B_x in both orthogonal directions, except that the B_x for one-*storey* penthouses with a weight less than 10% of the level below need not be considered,

δ_{max} = maximum *storey* displacement at the extreme points of the structure, at level x in the direction of the earthquake induced by the equivalent static forces acting at distances $\pm$ 0.10 D_{nx} from the centres of mass at each floor, and

δ_{ave} = average of the displacements at the extreme points of the structure at level x produced by the above mentioned forces.

(10) Torsional effects shall be accounted for as follows:

(a) for a *building* with $B \le 1.7$, by applying torsional moments about a vertical axis at each level throughout the *building* derived for each of the following load cases considered separately,
   (i) $T_x = F_x(e_x + 0.10\ D_{nx})$, and
   (ii) $T_x = F_x(e_x - 0.10\ D_{nx})$
   where F_x is the lateral force at each level determined according to Sentence (6) and where each element of the *building* is designed for the most severe effect of the above load cases, or

(b) for a *building* with $B \ge 1.7$, in cases where $I_E F_a S_a(0.2)$ is equal to or greater than 0.35, by a Dynamic Analysis Procedure as specified in Article 4.1.8.12.

4.1.8.12. Dynamic Analysis Procedure (See Appendix A.)

(1) The Dynamic Analysis Procedure shall be in accordance with one of the following methods:

(a) Linear Dynamic Analysis by either the Modal Response Spectrum Method or the Numerical Integration Linear Time History Method using a structural model that complies with the requirements of Sentence 4.1.8.3.(8), or

(b) Nonlinear Dynamic Analysis, in which case a special study shall be performed.

(2) The spectral acceleration values used in the Modal Response Spectrum Method shall be the design spectral acceleration values, S(T), defined in Sentence 4.1.8.4.(6).

(3) The ground motion histories used in the Numerical Integration Linear Time History Method shall be compatible with a response spectrum constructed from the design spectral acceleration values, S(T), defined in Sentence 4.1.8.4.(6).

(4) The effects of accidental torsional moments acting concurrently with the lateral earthquake forces that cause them shall be accounted for by the following methods:

(a) the static effects of torsional moments due to $(\pm\ 0.10\ D_{nx})F_x$ at each level x, where F_x is determined from Sentence 4.1.8.11.(6) or from the dynamic analysis, shall be combined with the effects determined by dynamic analysis, or

(b) if B, as defined in Sentence 4.1.8.11.(9), is less than 1.7, it is permitted to use a three-dimensional dynamic analysis with the centres of mass shifted by a distance of - 0.05 D_{nx} and + 0.05 D_{nx},

(5) The elastic base shear, V_e, obtained from a Linear Dynamic Analysis shall be multiplied by the importance factor, I_E, as determined in Article 4.1.8.5., and shall be divided by $R_d R_o$, as determined in Article 4.1.8.9., to obtain the base shear, V_d.

(6) Except as required by Sentence (7), if the base shear, V_d, obtained in Sentence (5) is less than 80% of the lateral earthquake design force, V, of Article 4.1.8.11., V_d shall be taken as 0.8 V.

(7) For irregular structures requiring dynamic analysis in accordance with Article 4.1.8.7., V_d shall be taken as the larger of the V_d determined in Sentence (5) and 100% of V.

(8) Except as required by Sentence (9), the values of elastic *storey* shears, *storey* forces, member forces, and deflections obtained from the Linear Dynamic Analysis shall be multiplied by V_d/V_e to determine their design values, where V_d is the base shear.

(9) For the purpose of calculating deflections, it is permitted to use a value for V based on the value for T_a determined in Clause 4.1.8.11.(3)(d) to obtain V_d in Sentences (6) and (7).

4.1.8.13. Deflections and Drift Limits

(1) Lateral deflections of a structure shall be calculated in accordance with the loads and requirements defined in this Subsection.

(2) Lateral deflections obtained from a linear elastic analysis using the methods given in Articles 4.1.8.11. and 4.1.8.12. and incorporating the effects of torsion, including accidental torsional moments, shall be multiplied by R_dR_o/I_E to give realistic values of anticipated deflections.

(3) Based on the lateral deflections calculated in Sentence (2), the largest interstorey deflection at any level shall be limited to 0.01 h_s for *post-disaster buildings*, 0.02 h_s for schools, and 0.025 h_s for all other *buildings*.

(4) The deflections calculated in Sentence (2) shall be used to account for sway effects as required by Sentence 4.1.3.2.(10). (See Appendix A.)

4.1.8.14. Structural Separation

(1) Adjacent structures shall either be separated by the square root of the sum of the squares of their individual deflections calculated in Sentence 4.1.8.13.(2), or shall be connected to each other.

(2) The method of connection required in Sentence (1) shall take into account the mass, stiffness, strength, ductility and anticipated motion of the connected *buildings* and the character of the connection.

(3) Rigidly connected *buildings* shall be assumed to have the lowest R_dR_o value of the *buildings* connected.

(4) *Buildings* with non-rigid or energy-dissipating connections require special studies.

4.1.8.15. Design Provisions (See Appendix A.)

(1) Diaphragms and their connections shall be designed so as not to yield, and the design shall account for the shape of the diaphragm, including openings, and for the forces generated in the diaphragm due to the following cases, whichever one governs:
(a) forces due to loads determined in Articles 4.1.8.11. or 4.1.8.12. applied to the diaphragm are increased to reflect the lateral load capacity of the SFRS, plus forces in the diaphragm due to the transfer of forces between elements of the SFRS associated with the lateral load capacity of such elements and accounting for discontinuities and changes in stiffness in these elements, or
(b) a minimum force corresponding to the design-based shear divided by N for the diaphragm at level x.

(2) In cases where $I_EF_aS_a(0.2)$ is equal to or greater than 0.35, the elements supporting any discontinuous wall, column or braced frame shall be designed for the lateral load capacity of the components of the SFRS they support.

(3) Where structures have vertical variations of R_dR_o satisfying Sentence 4.1.8.9.(4), the elements of the SFRS below the level where the change in R_dR_o occurs shall be designed for the forces associated with the lateral load capacity of the SFRS above that level.

(4) Where earthquake effects can produce forces in a column or wall due to lateral loading along both orthogonal axes, account shall be taken of the effects of potential concurrent yielding of other elements framing into the column or wall from all directions at the level under consideration and as appropriate at other levels.

(5) Except as provided in Sentence (6), the design forces need not exceed the forces determined in accordance with Sentence 4.1.8.7.(1), multiplied by R_dR_o.

(6) If *foundation* rocking is accounted for, the design forces for the SFRS need not exceed the maximum values associated with *foundation* rocking, provided that R_d and R_o for the type of SFRS used conform to Table 4.1.8.9. and that the *foundation* is designed in accordance with Sentence 4.1.8.16.(1).

4.1.8.16. Foundation Provisions

(1) *Foundations* shall be designed to resist the lateral load capacity of the SFRS, except that when the *foundations* are allowed to rock, the design forces for the *foundation* need not exceed those determined in Sentence 4.1.8.7.(1) using an R_dR_o equal to 2.0. (See Appendix A.)

(2) The design of *foundations* shall be such that they are capable of transferring earthquake loads and effects between the *building* and the ground without exceeding the capacities of the *soil* and *rock*.

(3) In cases where $I_EF_aS_a(0.2)$ is equal to or greater than 0.35, the following requirements shall be satisfied:
(a) *piles* or *pile* caps, drilled piers, and caissons shall be interconnected by continuous ties in no fewer than two directions,
(b) *piles*, drilled piers, and caissons shall be embedded a minimum of 100 mm into the *pile* cap or structure, and
(c) *piles*, drilled piers, and caissons, other than wood *piles*, shall be connected to the *pile* cap or structure for a minimum tension force equal to 0.15 times the factored compression load on the pile.
(See Appendix A.)

(4) At sites where $I_EF_aS_a(0.2)$ is equal to or greater than 0.35, *basement* walls shall be designed to resist earthquake lateral pressures from backfill or natural ground. (See Appendix A.)

(5) At sites where $I_EF_aS_a(0.2)$ is greater than 0.75, the following requirements shall be satisfied:
(a) *piles*, drilled piers, or caissons shall be designed and detailed to accommodate cyclic inelastic behaviour when the design moment in the element due to earthquake effects is greater than 75% of its moment capacity, and
(b) spread footings founded on *soil* defined as Site Class E or F shall be interconnected by continuous ties in no fewer than two directions.
(See Appendix A.)

(6) Each segment of a tie between elements that is required by Clauses (3)(a) or (5)(b) shall be designed to carry by tension or compression a horizontal force at least equal to the greatest factored *pile* cap or column vertical load in the elements it connects, multiplied by a factor of 0.10 $I_EF_aS_a(0.2)$, unless it can be demonstrated that equivalent restraints can be provided by other means. (See Appendix A.)

(7) The potential for liquefaction of the *soil* and its consequences, such as significant ground displacement and loss of *soil* strength and stiffness, shall be evaluated based on the ground motion parameters referenced in Subsection 1.1.2. and shall be taken into account in the design of the structure and its *foundations*. (See Appendix A.)

4.1.8.17. Elements of Structures, Non-Structural Components and Equipment

(1) Except as provided in Sentences (2) and (8), elements and components of *buildings* described in Table 4.1.8.17. and their connections to the structure shall be designed to accommodate the *building* deflections calculated in accordance with Article 4.1.8.13. and the element or component deflections calculated in accordance with Sentence (10), and shall be designed for a lateral force, V_P, applied through the centre of mass of the element or component that is equal to:

$$V_p = 0.3F_aS_a(0.2)\,I_ES_pW_p$$

where,

F_a = as defined in Table 4.1.8.4.B.,
$S_a(0.2)$ = spectral response acceleration value at 0.2 s, as defined in Sentence 4.1.8.4.(1),
I_E = importance factor for the *building*, as defined in Article 4.1.8.5.,

S_p = $C_pA_rA_x/R_p$ (the maximum value of S_p shall be taken as 4.0 and the minimum value of S_p shall be taken as 0.7), where,

C_p = element or component factor from Table 4.1.8.17.,

A_r = element or component force amplification factor from Table 4.1.8.17.,

A_x = height factor $(1 + 2\ h_x / h_n)$,

R_p = element or component response modification factor from Table 4.1.8.17., and

W_p = weight of the component or element.

(2) For *buildings* other than *post-disaster buildings*, where $I_EF_aS_a(0.2)$ is less than 0.35, the requirements of Sentence (1) need not apply to Categories 6 through 21 of Table 4.1.8.17.

(3) The values of C_p in Sentence (1) shall conform to Table 4.1.8.17.

(4) For the purpose of applying Sentence (1) and Categories 11 and 12 of Table 4.1.8.17., elements or components shall be assumed to be flexible or flexibly connected unless it can be shown that the fundamental period of the element or component and its connection is less than or equal to 0.06 s, in which case the element or component is classified as being rigid or rigidly connected.

(5) The weight of access floors shall include the *dead load* of the access floor and the weight of permanent equipment, which shall not be taken as less than 25% of the floor *live load*.

(6) When the mass of a tank plus its contents is greater than 10% of the mass of the supporting floor, the lateral forces shall be determined by rational analysis.

(7) Forces shall be applied in the horizontal direction that results in the most critical loading for design, except for Category 6 of Table 4.1.8.17., where the forces shall be applied up and down vertically.

(8) Connections to the structure of elements and components listed in Table 4.1.8.17. shall be designed to support the component or element for gravity loads, shall conform to the requirements of Sentence (1), and shall also satisfy these additional requirements:

(a) friction due to gravity loads shall not be considered to provide resistance to seismic forces,

(b) R_p for non-ductile connections, such as adhesives or power actuated fasteners, shall be taken as 1.0,

(c) R_p for anchorage using shallow expansion, chemical, epoxy or cast-in place anchors shall be 1.5, where shallow anchors are those with a ratio of embedment length to diameter of less than 8,

(d) power-actuated fasteners and drop-in anchors shall not be used for tension loads,

(e) connections for non-structural elements or components of Categories 1, 2 or 3 of Table 4.1.8.17. attached to the side of a *building* and above the first level above *grade* shall satisfy the following requirements:

(i) for connections where the body of the connection is ductile, the body shall be designed for values of C_P, A_r and R_p given in Table 4.1.8.17., and the fasteners, such as anchors, welds, bolts and inserts, shall also be designed for values of C_p and A_r given in this Table, and $R_p = 1.0$, and

(ii) connections where the body of the connection is not ductile shall be designed for values of $C_p=2.0$, $R_p = 1.0$ and A_r given in Table 4.1.8.17., and

(f) for the purpose of applying Clause (e), a ductile connection is one where the body of the connection yields at its design load. (See Appendix A.)

(9) Floors and roofs acting as diaphragms shall satisfy the requirements for diaphragms stated in Article 4.1.8.15.

(10) Lateral deflections of elements or components shall be based on the loads defined in Sentence (1) and lateral deflections obtained from an elastic analysis shall be multiplied by R_p/I_E to give realistic values of the anticipated deflections.

(11) The elements or components shall be designed so as not to transfer to the structure any forces unaccounted for in the design, and rigid elements such as walls or panels shall satisfy the requirements of Sentence 4.1.8.3.(6).

(12) Seismic restraint for suspended equipment, pipes, ducts, electrical cable trays, etc. shall be designed to meet the force and displacement requirements of this Article and be constructed in a manner that will not subject hanger rods to bending.

(13) Isolated suspended equipment and components, such as pendant lights, maybe designed as a pendulum system provided that adequate chains or cables capable of supporting 2.0 times the weight of the suspended component are provided and the deflection requirements of Sentence (11) are satisfied.

Table 4.1.8.17.
Elements of Structures and Non-Structural Components and Equipment
Forming Part of Sentence 4.1.8.17.(1)

Category	Part or portion of *Building*	C_p	A_r	R_p
1	All exterior and interior walls except those in Category 2 or 3[1]	1	1	2.5
2	Cantilever parapet and other cantilever walls except retaining walls[1]	1	2.5	2.5
3	Exterior and interior ornamentations and appendages[1]	1	2.5	2.5
4	Floors and roofs acting as diaphragms[2]	-	-	2.5
5	Towers, *chimneys*, smokestacks and penthouses when connected to or forming part of a *building*	1	2.5	2.5
6	Horizontally cantilevered floors, balconies, beams, etc.	1	1	2.5
7	Suspended ceilings, light fixtures and other attachments to ceilings with independent vertical support	1	1	2.5
8	Masonry veneer connections	1	1	1.5
9	Access floors	1	1	2.5
10	Masonry or concrete fences more than 1.8 m tall	1	1	2.5
11	Machinery, fixtures, equipment, ducts and tanks (including contents)			
	that are rigid and rigidly connected[3]	1	1	1.25
	that are flexible or flexibly connected[3]	1	2.5	2.5
12	Machinery, fixtures, equipment, ducts and tanks (including contents) containing toxic or explosive materials, materials having a *flash point* below 38°C or firefighting fluids			
	that are rigid and rigidly connected[3]	1.5	1	1.25
	that are flexible or flexibly connected[3]	1.5	2.5	2.5
13	Flat bottom tanks (including contents) attached directly to a floor at or below *grade* within a *building*	0.7	1	2.5
14	Flat bottom tanks (including contents) attached directly to a floor at or below *grade* within a *building* containing toxic or explosive materials, materials having a having a *flash point* below 38°C or firefighting fluids	1	1	3
15	Pipes, ducts, cable trays (including contents)	1	1	3
16	Pipes, ducts (including contents) containing toxic or explosive materials	1.5	1	3
17	Electrical cable trays, bus ducts, conduits	1	2.5	5
18	Rigid components with ductile material and connections	1	1	2.5
19	Rigid components with non-ductile material or connections	1	1	1
20	Flexible components with ductile material and connections	1	2.5	2.5
21	Flexible components with non-ductile material or connections	1	2.5	1
Column 1	2	3	4	5

Notes to Table 4.1.8.17.:

(1) See Sentence 4.1.8.17.(8).
(2) See Sentence 4.1.8.17.(9).
(3) See Sentence 4.1.8.17.(4).

Section 4.2. Foundations

4.2.1. General

4.2.1.1. Application

(1) This Section applies to *excavations* and *foundation* systems for *buildings*.

4.2.2. Subsurface Investigations and Reviews

4.2.2.1. Subsurface Investigation

(1) A *subsurface investigation*, including *groundwater* conditions, shall be carried out, by or under the direction of a person having knowledge and experience in planning and executing such investigations to a degree appropriate for the *building* and its use, the ground and the surrounding site conditions. (See Appendix A.)

4.2.2.2. Field Review

(1) A field review shall be carried out by the *designer* or by another suitably qualified person to ascertain that the subsurface conditions are consistent with the design and that *construction* is carried out in accordance with the design and good engineering practice.

(2) The review required in Sentence (1) shall be carried out,
(a) on a continuous basis,
  (i) during the *construction* of all *deep foundation units* with all pertinent information recorded for each *foundation unit*,
  (ii) during the installation and removal of retaining structures and related backfilling operations, and
  (iii) during the placement of engineered *fills* that are to be used to support the *foundation units*, and
(b) as required, unless otherwise directed by the *chief building official*,
  (i) in the *construction* of all *shallow foundation units*, and
  (ii) in excavating, dewatering and other related works.

4.2.2.3. Altered Subsurface Condition

(1) If during *construction*, the *soil*, *rock* or *groundwater* is found not to be of the type or in the condition used in design, and as indicated on the drawings, the design shall be reassessed by the *designer*.

(2) If during *construction*, climatic or any other conditions have changed the properties of the *soil*, *rock* or *groundwater*, the design shall be reassessed by the *designer*.

4.2.3. Materials Used in Foundations

4.2.3.1. Wood

(1) Wood used in *foundations* or in support of *soil* or *rock* shall conform to the appropriate requirements of Subsection 4.3.1.

4.2.3.2. Preservation Treatment of Wood

(1) Wood exposed to *soil* or air above the lowest anticipated *groundwater* table shall be treated with preservative in conformance with CSA O80 Series, "Wood Preservation", and the requirements of the appropriate commodity standard as follows:
(a) CSA-O80.2, "Preservative Treatment of Lumber, Timber, Bridge Ties and Mine Ties by Pressure Processes",
(b) CSA-O80.3, "Preservative Treatment of Piles by Pressure Processes", or
(c) CSA-O80.15, "Preservative Treatment of Wood for Building Foundation Systems, Basements and Crawl Spaces by Pressure Processes".

(2) Where timber has been treated as required in Sentence (1), it shall be cared for as provided in AWPA-M4, "Care of Preservative-Treated Wood Products", as revised by Clause 6 of CSA O80 Series, "Wood Preservation".

4.2.3.3. Plain and Reinforced Masonry

(1) Plain or reinforced masonry used in *foundations* or in support of *soil* or *rock* shall conform to the requirements of Subsection 4.3.2.

4.2.3.4. Prevention of Deterioration of Masonry

(1) Where plain or reinforced masonry in *foundations* or in structures supporting *soil* or *rock* may be subject to conditions conducive to deterioration, protection shall be provided to prevent such deterioration.

4.2.3.5. Concrete

(1) Plain, reinforced or prestressed concrete used in *foundations* or in support of *soil* or *rock* shall conform to the requirements of Subsection 4.3.3.

4.2.3.6. Protection Against Chemical Attack

(1) Where concrete in *foundations* may be subject to chemical attack, it shall be treated in conformance with the requirements in CAN/CSA-A23.1, "Concrete Materials and Methods of Concrete Construction".

4.2.3.7. Steel

(1) Steel used in *foundations* or in support of *soil* or *rock* shall conform with the appropriate requirements of Subsections 4.3.3. or 4.3.4., unless otherwise specified in this Section.

4.2.3.8. Steel Piles

(1) Where steel *piles* are used in *deep foundations* and act as permanent load-carrying members, the steel shall conform with one of the following standards:
(a) ASTM A252, "Welded and Seamless Steel Pipe Piles",
(b) ASTM A283 / A283M, "Low and Intermediate Tensile Strength Carbon Steel Plates",
(c) ASTM A1008 / A1008M , "Steel, Sheet, Cold Rolled, Carbon, Structural,High-Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability",
(d) ASTM A1011 / A1011M, "Steel, Sheet and Strip, Hot Rolled, Carbon, Structural, High Strength Low Alloy and High Strength Low Alloy with Improved Formability", or
(e) CAN/CSA-G40.21, "Structural Quality Steel".

4.2.3.9. High Strength Steel Tendons

(1) Where high strength steel is used for tendons in anchor systems used for the permanent support of a *foundation* or in the erection of temporary support of *soil* or *rock* adjacent to an *excavation*, it shall conform with the requirements of CAN/CSA-A23.1, "Concrete Materials and Methods of Concrete Construction".

4.2.3.10. Corrosion of Steel

(1) Where conditions are corrosive to steel, adequate protection of exposed steel shall be provided.

4.2.4. Design Requirements

4.2.4.1. Design Basis

(1) The design of *foundations*, *excavations* and *soil*- and *rock*-retaining structures shall be based on a *subsurface investigation* carried out by a person competent in this field of work, and on any of the following:
(a) application of generally accepted geotechnical and civil engineering principles by a person especially qualified in this field of work as provided in this Section and other Sections of this Part,
(b) established local practice where such practice includes successful experience both with *soils* and *rocks* of similar type and condition and with a *foundation* or *excavation* of similar type, *construction* method, size and depth, or
(c) in situ testing of *foundation units* such as the load testing of *piles*, anchors or footings carried out by a person competent in this field of work.
(See Appendix A.)

(2) The *foundations* of a *building* shall be capable of resisting all the loads stipulated in Section 4.1., in accordance with limit states design in Subsection 4.1.3.

(3) For the purpose of the application of the load combinations given in Table 4.1.3.2., the geotechnical components of loads and the factored geotechnical resistances at ULS shall be determined by a suitably qualified and experienced person. (See Appendix A.)

(4) Geotechnical components of service loads and geotechnical reactions for SLS shall be determined by a suitably qualified and person.

(5) The *foundation* of a *building* shall be designed to satisfy SLS requirements within the limits that the *building* is designed to accommodate, including total settlement and differential settlement, heave, lateral movement, tilt or rotation. (See Appendix A.)

(6) Communication, interaction and coordination between the *designer* and the person responsible for the geotechnical aspects of the project shall take place to a degree commensurate with the complexity and requirements of the project.

4.2.4.2. Subsurface Investigation

(1) A *subsurface investigation* shall be carried out to the depth and extent to which the *building* or *excavation* will significantly change the stress in the *soil* or *rock*, or to such a depth and extent as to provide all the necessary information for the design and *construction* of the *excavation* or the *foundations*.

4.2.4.3. Identification

(1) The identification and classification of *soil*, *rock* and *groundwater* and descriptions of their engineering and physical properties shall be in accordance with a widely accepted system.

4.2.4.4. Depth of Foundations

(1) Except as permitted in Sentence (2), the *bearing surface* of a *foundation* shall be below the level of potential damage, including damage resulting from *frost action*, and the *foundation* shall be designed to prevent damage resulting from *adfreezing* and frost jacking. (See Appendix A.)

(2) The *bearing surface* of a *foundation* need not be below the level of potential damage from frost where the *foundation*,
(a) is designed against *frost action*, or
(b) overlies material not susceptible to *frost action*.

4.2.4.5. Sloping Ground

(1) Where a *foundation* is to rest on, in or near sloping ground, this particular condition shall be provided for in the design.

4.2.4.6. Eccentric and Inclined Loads

(1) Where there is eccentricity or inclination of loading in *foundation units*, this effect shall be fully investigated and provided for in the design.

4.2.4.7. Dynamic Loading

(1) Where dynamic loading conditions apply, the effects shall be assessed by a special investigation of these conditions and provided for in the design.

4.2.4.8. Hydrostatic Uplift

(1) Where a *foundation* or any part of a *building* is subject to hydrostatic uplift the effects shall be provided for in the design.

4.2.4.9. Groundwater Level Charge

(1) Where proposed *construction* will result in a temporary or permanent change in the *groundwater level*, the effects of this change on adjacent *buildings* shall be fully investigated and provided for in the design.

4.2.4.10. Permafrost

(1) Where conditions of permafrost are encountered or proven to exist, the design of the *foundation* shall be based upon analysis of these conditions by a person especially qualified in that field of work.

4.2.4.11. Swelling and Shrinking Soils

(1) Where swelling or shrinking *soils*, in which movements resulting from moisture content changes may be sufficient to cause damage to a structure, are encountered or known to exist, such a condition shall be fully investigated and provided for in the design.

4.2.4.12. Expanding and Deteriorating Rock

(1) Where *rock* that expands or deteriorates when subjected to unfavourable environmental conditions or to stress release is known to exist, this condition shall be fully investigated and provided for in the design.

4.2.4.13. Construction on Fill

(1) *Buildings* may be placed on *fill* if it can be shown by *subsurface investigation* that,
(a) the *fill* is or can be made capable of safely supporting the *building*,
(b) detrimental movement of the *building* or services leading to the *building* will not occur, and
(c) explosive gases can be controlled or do not exist.

4.2.4.14. Structural Design

(1) The structural design of the *foundation* of a *building*, the procedures and *construction* practices shall conform with the appropriate Sections of this Code unless otherwise specified in this Section.

4.2.5. Excavations

4.2.5.1. Design of Excavations

(1) The design of *excavations* and of supports for the sides of *excavations* shall conform to the requirements of Subsection 4.2.4. and this Subsection. (See Appendix A.)

4.2.5.2. Excavation Construction

(1) Every *excavation* shall be undertaken in such a manner as to prevent movement that would cause damage to adjacent *buildings* at all phases of *construction*.

(2) Material shall not be placed nor shall equipment be operated or placed in or adjacent to an *excavation* in a manner that may endanger the integrity of the *excavation* or its supports.

4.2.5.3. Supported Excavations

(1) The sides of an *excavation* in *soil* or *rock* shall be supported by a retaining structure conforming with the requirements of Articles 4.2.5.1. and 4.2.5.2., except as permitted in Article 4.2.5.4.

4.2.5.4. Unsupported Excavations

(1) The sides of an *excavation* in *soil* or *rock* may be unsupported where a design is prepared by a person especially qualified in this field of work in conformance with the requirements of Articles 4.2.5.1. and 4.2.5.2.

4.2.5.5. Control of Water Around Excavations

(1) Surface water, all *groundwater*, *perched groundwater* and in particular *artesian groundwater* shall be kept under control at all phases of *excavation* and *construction*.

4.2.5.6. Loss of Ground

(1) At all phases of *excavation* and *construction*, loss of ground due to water or any other cause shall be prevented.

4.2.5.7. Protection and Maintenance at Excavations

(1) All sides of an *excavation*, supported and unsupported, shall be continuously maintained and protected from possible deterioration by *construction* activity or by the action of frost, rain and wind.

4.2.5.8. Backfilling

(1) Where an *excavation* is backfilled, the backfill shall be placed so as to,
(a) provide lateral support to the *soil* adjacent to the *excavation*, and
(b) prevent detrimental movements.

(2) The material used as backfill or *fill* supporting a footing, *foundation* or a floor on *grade* shall be of a type that is not subject to detrimental volume change with changes in moisture content and temperature.

4.2.6. Shallow Foundations

4.2.6.1. Design of Shallow Foundations

(1) The design of *shallow foundation*s shall be in conformance with the requirements of Subsection 4.2.4. and this Subsection. (See Appendix A.)

4.2.6.2. Support of Shallow Foundations

(1) Where a *shallow foundation* is to be placed on *soil* or *rock*, the *soil* or *rock* shall be cleaned of loose and unsound material and shall be adequate to support the *design load* taking into account temperature, precipitation, *construction* activities and other factors that may lead to changes of the properties of *soil* or *rock*.

4.2.6.3. Incorrect Placement of Shallow Foundations

(1) Where a *shallow foundation unit* has not been placed or located as indicated on the drawings,
(a) the error shall be corrected, or
(b) the design of the *foundation unit* shall be recalculated for the altered conditions by the *designer*.

4.2.6.4. Damaged Shallow Foundations

(1) Where a *shallow foundation unit* is damaged,
(a) it shall be repaired, or
(b) the *design* of the *foundation unit* shall be recalculated for the damaged condition by the *designer*.

4.2.7. Deep Foundations

4.2.7.1. General

(1) A *deep foundation unit* shall provide support for a *building* by transferring loads by end-bearing to a competent stratum at considerable depth below the structure, or by mobilizing resistance by adhesion or friction, or both, in the *soil* or *rock* in which it is placed. (See Appendix A.)

4.2.7.2. Design for Deep Foundations

(1) *Deep foundation units* shall be designed in conformance with Subsection 4.2.4. and this Subsection. (See Appendix A.)

(2) Where *deep foundation units* are load tested, as required in Clause 4.2.4.1.(1)(c), the determination of the number and type of load test and the interpretation of the results shall be carried out by a person especially qualified in this field of work. (See Appendix A.)

(3) The design of *deep foundations* shall be determined on the basis of geotechnical considerations taking into account,
(a) the method of installation,
(b) the degree of inspection,
(c) the spacing of *foundation units* and group effects,
(d) other requirements of this Subsection, and
(e) the appropriate structural requirements of Section 4.1. and Subsections 4.3.1., 4.3.3. and 4.3.4.

(4) The portion of a *deep foundation unit* permanently in contact with *soil* or *rock* shall be structurally designed as a laterally supported compression member.

(5) The portion of a *deep foundation unit* that is not permanently in contact with *soil* or *rock* shall be structurally designed as a laterally unsupported compression member.

(6) The structural design of prefabricated *deep foundation units* shall allow for all stresses resulting from driving, handling and testing.

4.2.7.3. Tolerance in Alignment and Location

(1) Permissible deviations from the design alignment and the location of the top of *deep foundation units* shall be determined by design analysis and shall be indicated on the drawings.

4.2.7.4. Incorrect Alignment and Location

(1) Where a *deep foundation unit* has not been placed within the permissible deviations referred to in Article 4.2.7.3., the condition of the *foundation* shall be assessed by the *designer*.

4.2.7.5. Installation of Deep Foundations

(1) *Deep foundation units* shall be installed in such a manner as not to impair
(a) the strength of the *deep foundation units* and the properties of the *soil* or *rock* on or in which they are placed beyond the calculated or anticipated limits,
(b) the integrity of previously installed *deep foundation units*, or
(c) the integrity of neighbouring *buildings*.

4.2.7.6. Damaged Deep Foundation Units

(1) Where inspection shows that a *deep foundation unit* is damaged or not consistent with design or good engineering practice,
(a) such a unit shall be reassessed by the *designer*, and
(b) any necessary changes shall be made and action taken as required.

4.2.8. Special Foundations

4.2.8.1. General

(1) Where special *foundation* systems are used, such systems shall conform to Subsection 4.2.4. and Sentence 4.1.1.4.(2).

4.2.8.2. Use of Existing Foundations

(1) Existing *foundations* may be used to support new or altered *buildings* provided they comply with all pertinent requirements of this Section.

Section 4.3. Design Requirements for Structural Materials

4.3.1. Wood

4.3.1.1. Design Basis for Wood

(1) *Buildings* and their structural members made of wood shall conform to CAN/CSA-O86, "Engineering Design in Wood".

4.3.1.2. Glue-Laminated Members

(1) Glued-laminated members shall be fabricated in plants conforming to CAN/CSA-O177-M, "Qualification Code for Manufacturers of Structural Glued-Laminated Timber".

4.3.1.3. Termites

(1) In areas known to be infested by termites, the requirements in Articles 9.3.2.9., 9.12.1.1. and 9.15.5.1. shall apply.

4.3.2. Plain and Reinforced Masonry

4.3.2.1. Design Basis for Plain and Reinforced Masonry

(1) *Buildings* and their structural members made of plain and reinforced masonry shall conform to CSA-S304.1, "Design of Masonry Structures".

4.3.3. Plain, Reinforced and Prestressed Concrete

4.3.3.1. Design Basis for Plain, Reinforced and Prestressed Concrete

(1) *Buildings* and their structural members made of plain, reinforced or prestressed concrete shall conform to CSA A23.3, "Design of Concrete Structures". (See Appendix A.)

4.3.4. Steel

4.3.4.1. Design Basis for Structural Steel

(1) *Buildings* and their structural members made of structural steel shall conform to CAN/CSA-S16, "Limit States Design of Steel Structures". (See Appendix A.)

4.3.4.2. Design Basis for Cold Formed Steel

(1) *Buildings* and their structural members made of cold formed steel shall conform to CAN/CSA-S136, "North American Specification for the Design of Cold-Formed Steel Structural Members". (See Appendix A.)

4.3.4.3. Steel Building Systems

(1) Steel *building* systems shall be manufactured by companies certified in accordance with the requirements of CSA-A660, "Certification of Manufacturers of Steel Building Systems".

4.3.5. Aluminum

4.3.5.1. Design Basis for Aluminium

(1) *Buildings* and their structural members made of aluminum shall conform to CAN3-S157, "Strength Design in Aluminum", using the loads stipulated in Section 4.1., in accordance with limit states design in Subsection 4.1.3.

4.3.6. Glass

4.3.6.1. Design Basis for Glass

(1) Glass used in *buildings* shall be designed in conformance with CAN/CGSB-12.20-M, "Structural Design of Glass for Buildings".

Section 4.4. Design Requirements for Special Structures

4.4.1. Air-Supported Structures

4.4.1.1. Design Basis for Air-Supported Structures

(1) The structural design of *air-supported structures* shall conform to CAN3-S367-M, "Air-Supported Structures" using the loads stipulated in Section 4.1., in accordance with limit states design in Subsection 4.1.3.

4.4.2. Parking Structures

4.4.2.1. Design Basis for Parking Structures

(1) Parking structures shall be designed in conformance with CAN/CSA-S413, "Parking Structures".

4.4.3. Guards Over Retaining Walls

4.4.3.1. Guards Over Retaining Walls

(1) Every retaining wall that is designated in Sentence 1.1.1.1.(1) of Division A shall be protected by *guards* on all open sides where the public has access to open space at the top of the retaining wall.

4.4.4. Anchor Systems on Building Exterior

4.4.4.1. Anchor Systems on Building Exterior

(1) Where maintenance and window cleaning operations are intended to be carried out on the exterior of a *building* described in Article 1.3.2.2. of Division A, anchor systems shall be provided where any portion of the roof is more than 8 m above adjacent ground level.

(2) Except as provided in Sentence (3), the anchor systems in Sentence (1) shall be designed, installed and tested in conformance with CSA Standard Z91, " Safety Code for Window Cleaning Operations".

(3) Other anchor systems may be used where such systems provide an equal level of safety.

(4) The anchor system material shall be made of stainless steel, or other corrosion resistant base material, or from steel that is hot dipped galvanised, in accordance with CAN/CSA-G164-M, "Hot Dip Galvanising of Irregularly Shaped Articles".

4.4.5. Manure Storage Tanks

4.4.5.1. Manure Storage Tanks

(1) Except as provided in this Subsection, manure storage tanks shall comply with the requirements of the National Farm Building Code of Canada.

(2) Manure storage tanks shall be constructed of steel, reinforced concrete or prestressed concrete.

(3) Manure storage tank walls, bases and appurtenances, including piping for the conveyance of manure and associated connections and joints, shall be designed and constructed to prevent leakage of contents.

(4) Concrete for manure storage tanks shall,
(a) be manufactured from Type 50 cement,
(b) have a 28-day strength of at least 32 MPa, and
(c) have a water/cement materials ratio of not more than 0.45.

(5) Manure storage tanks shall be placed on undisturbed soil free of any organic, deleterious and extraneous materials and capable of supporting the superimposed design loads from the tanks.

(6) Where granular fills are used between the bases of manure storage tanks and the undisturbed soil, the granular fills shall be compacted to a Standard Proctor density of not less than 95 per cent.