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Part 4
Structural Design

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 Section 2.1.

4.1.1.2. Definitions

(1) Reserved.

4.1.1.3. Design Requirements

(1) Buildings and their structural members including formwork and falsework shall be designed to have sufficient structural capacity and structural integrity to resist safely and effectively all loads and 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) 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.

(3) Reserved.

(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) Buildings and their structural members shall be designed by one of the following methods:

(a) standard design procedures and practices provided by this Part and any standards and specifications referred to therein, except in cases of conflict the provisions of the building code shall govern, or
(b) one of the following three bases of design,
   (i) analysis based on generally established theory,
   (ii) evaluation of a given full-scale structure or a prototype by a loading test, or
   (iii) studies of model analogues,

provided the design is carried out by a person qualified in the specific method applied and provided the design ensures a level of safety and performance at least equivalent to that provided for or implicit in design carried out by the methods referred to in Clause (a).

(2) Communications towers, dish antennas and their supporting structures shall conform to CAN/CSA-S37-M, "Antennas, Towers, and Antenna Supporting Structures".

4.1.1.5. Deflections

(1) In proportioning structural members to limit deflection, consideration shall be given to
(a) the intended use of the building or member,
(b) limiting damage to non-structural members and materials whose physical properties are known at the time of the design,
(c) limiting damage to the structure itself, and
(d) creep, shrinkage and temperature.

(See Appendix A.)

(2) 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.

(3) The lateral deflection of buildings due to design wind and gravity loads shall be checked to ensure that nonstructural elements whose nature is known at the time the structural design is carried out will not be damaged.
(4) Except as provided in Sentence (5), the total drift per storey under specified 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.)

(5) The deflection limits required in Sentence (4) do not apply to industrial buildings or sheds if it is known by experience that greater movement will have no significantly adverse effect on the strength and function of the building.

4.1.1.6. Vibrations

(1) Floor systems susceptible to vibrations shall be designed so that there will be no significantly adverse effects on the intended occupancy of the building from vibrations. (See Appendix A.)

(2) Unusually flexible buildings and buildings whose ratio of height to minimum effective width exceeds 4 to 1 shall be designed so that there will be no significant adverse effects on the intended occupancy of the building from vibrations under dynamic wind load. (See Appendix A.)

4.1.1.7. Stability

(1) Provision shall be made to ensure adequate stability of a structure as a whole, and adequate lateral, torsional and local stability of all structural parts.

4.1.1.8. Reserved.

4.1.2. Specified Loads and Effects

4.1.2.1. Loads, Forces and Effects

(1) Except as provided for in Article 4.1.2.2., the following specified loads, forces and effects shall be considered in the design of a building and its structural members and connections:

- D - dead loads as provided for in Subsection 4.1.5.,
- E - live load due to earthquake as specified in Subsection 4.1.9.,
- L - live load due to static or inertia forces arising from intended use and occupancy (includes vertical loads due to cranes); snow, ice and rain; earth and hydrostatic pressure,
- T - effects due to contraction or expansion caused by temperature changes, shrinkage, moisture changes, creep in component materials, movement due to differential settlement or combination thereof, (See Appendix A.)

W - live load due to wind as specified in Subsection 4.1.8.

(2) Minimum specified values of these loads, as set forth in Subsections 4.1.5. to 4.1.10., shall be increased to account for dynamic effects where applicable.

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.

(2) If it can be shown by engineering principles, or if it is known from experience, that neglect of some or all of the effects due to T do not affect the structural safety and serviceability, they need not be considered in the calculations.

4.1.2.3. Structural Design

(1) Structural design shall be carried out in accordance with Subsection 4.1.4., Working Stress Design or Subsection 4.1.3., Limit States Design.

4.1.3. Limit States Design

4.1.3.1. Definitions

(1) In this Subsection, the term limit states means those conditions of a building structure in which the building ceases to fulfill the function for which it was designed. (Those states concerning safety are called ultimate limit states and include exceeding the load carrying capacity, overturning, sliding, fracture and fatigue, while those states which restrict the intended use and occupancy of the building are called serviceability limit states, and include deflection, vibration, permanent deformation and cracking.)

(b) specified loads (D, E, L, T and W) mean those loads defined in Article 4.1.2.1. and given in this Section,

(c) load factor, α, means a factor in Sentence 4.1.3.2.(4) applied to a specified load which, for the limit states under consideration, takes into account the variability of the loads and load patterns and analysis of their effects,

(d) factored load means the product of a specified load and its load factor,
(e) load combination factor, $\psi$, means a factor in Sentences 4.1.3.2.(5) and (6) applied to the factored loads other than dead load to take into account the reduced probability of a number of loads from different sources acting simultaneously.

(f) importance factor, $\gamma$, means a factor in Sentence 4.1.3.2.(7) applied to the factored loads other than dead load to take into account the consequences of collapse as related to the use and occupancy of the building.

(g) resistance, $R$, of a member, connection, structure or foundation, is based on the dimensions and on the specified properties of the structural materials,

(h) resistance factor, $\phi$, means a factor applied to a specified material property or to the resistance of a member, connection, structure or foundation, which 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

(i) factored resistance means the product of resistance and the applicable resistance factor.

4.1.3.2. Safety Check for Strength and Stability

(1) A building and its structural components shall be designed to have sufficient strength and stability so that the factored resistance is greater than or equal to the effect of factored loads, as required in Sentences (3) or (8).

(2) In cases of overturning, uplift and sliding, anchorage is required if the effect of loads tending to cause overturning, uplift or sliding, multiplied by load factors greater than 1.0 given in Sentence (4), is greater than the stabilizing effect of dead load multiplied by a load factor of 0.85 as given in Sentence (4).

(3) For load combinations not including earthquake, the effect of factored loads is the structural effect due to the specified loads multiplied by load factors, $\alpha$, in Sentence (4), a load combination factor, $\psi$, in Sentences (5) and (6) and an importance factor, $\gamma$, in Sentence (7), and the factored load combinations shall be taken as

$$\alpha_D + \gamma \psi [\alpha_L \psi + \alpha_W W + \alpha_T T]$$

(4) The load factors, $\alpha$, shall be equal to

(a) $\alpha_D = 1.25$, except that when the dead load resists overturning, uplift or reversal of load effect, $\alpha_D = 0.85$,

(b) $\alpha_L = 1.5$,

(c) $\alpha_W = 1.5$, and

(5) The load combination factor, $\psi$, shall be equal to

(a) 1.0 when only 1 of the loads $L, W$ and $T$ in Sentence 4.1.2.1.(1) acts,

(b) 0.70 when 2 of the loads $L, W$ and $T$ in Sentence 4.1.2.1.(1) act, and

(c) 0.60 when all of the loads $L, W$ and $T$ in Sentence 4.1.2.1.(1) act.

(6) The most unfavourable effect shall be determined by considering the loads $L, W$ and $T$ in Sentence 4.1.2.1.(1) acting alone with $\psi = 1.0$ or in combination with $\psi = 0.70$ or 0.60.

(7) The importance factor, $\gamma$, shall be not less than 1.0 for all buildings, except that for buildings where it can be shown that collapse is not likely to cause injury or other serious consequences, it shall be not less than 0.8. (See Appendix A.)

(8) For load combinations including earthquake, the factored load combinations shall be taken as

(a) $1.0D + \gamma(1.0E)$ and either,

(b) $1.0D + \gamma(1.0L + 1.0E)$ for storage and assembly occupancies, or

(c) $1.0D + \gamma(0.5L + 1.0E)$ for all other occupancies.

4.1.3.3. Serviceability and Fatigue

(1) A building and its structural components shall be checked for serviceability limit states as defined in Clause 4.1.4.1.(1)(a) and fatigue under the effect of the specified loads as required in the standards described in Section 4.3.

(2) Where more than one load contributes to the stress in a member, the combination of loads shall be assumed to be:

$$D + \psi[L + W + T]$$

where $\psi$ is in conformance with Sentences 4.1.3.2.(5) and (6).

4.1.4. Working Stress Design

4.1.4.1. Load Combinations

(1) In designing buildings and their structural members, all of the loads listed in Article 4.1.2.1. shall be considered to act in the following combinations, whichever combination produces the most unfavourable effects in the building, foundation or structural member concerned, when
appropriately reduced according to Article 4.1.4.2.:  
(a) D  
(b) D + L  
(c) D + (W or 2/3E)  
(d) D + T  
(e) D + L + (W or 2/3E)  
(f) D + L + T  
(g) D + (W or 2/3E) + T  
(h) D + L + (W or 2/3E) + T

4.1.4.2. Load Combination Factors

(1) The total of the combined load effects may be multiplied by the following load combination factors:
(a) 1.0 for the combinations in Clauses 4.1.4.1.(1)(a) to (d),  
(b) 0.75 for the combinations in Clauses 4.1.4.1.(1)(e) to (g), and  
(c) 0.66 for the combination in Clause 4.1.4.1.(1)(h).

4.1.4.3. Stress Reversal

(1) When loads other than D counteract D in a structural member or joint, special caution shall be exercised by the designer to ensure adequate safety for possible stress reversal. (See Appendix A.)

4.1.4.4. Overturning and Sliding

(1) A building shall be proportioned to resist an overturning moment and sliding force of not less than twice that due to the loads acting on the structure when the structure is considered as an entire unit acting on or anchored to its bearing stratum or supporting structure.

(2) The resistance to overturning shall be calculated as the sum of the stabilizing moment of the dead load only, plus the ultimate resistance of any anchoring devices.

4.1.5. Dead Loads

4.1.5.1. 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 building to be supported permanently by the member,  
(c) the weight of partitions,  
(d) the weight of permanent equipment, and  
(e) forces due to prestressing.

(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 (20 psf) over the area of floor being considered.

(4) Partition loads used in design shall be shown on the drawings in sufficient detail to enable the loads due to materials of construction incorporated in the building to be determined.

(5) In cases where the dead load is counteractive, the load allowances as provided in Sentences (2) and (3) shall not be included in the design calculations.

4.1.6. Live Loads Due to Use and Occupancy

4.1.6.1. Loads Due to Use of Floors and Roofs

(1) 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 4.1.6.3., the loads resulting from the intended use or the concentrated loads in Article 4.1.6.10., whichever produces the most critical effect.

4.1.6.2. Uses Not Stipulated

(1) Where the use of an area of floor or roof is not provided for in Article 4.1.6.3., the specified live loads due to the use and occupancy of the area shall be determined from an analysis of the loads resulting from  
(a) the weight of the probable assembly of persons,  
(b) the weight of the probable accumulation of equipment and furnishings, and  
(c) the weight of the probable storage of materials.

4.1.6.3. Full and Partial Loading

(1) The uniformly distributed load shall be not less than the value listed in Table 4.1.6.3., reduced as may be provided for in Article 4.1.6.9., applied uniformly over the entire area, or on any portions of the area, whichever produces the most critical effects in the members concerned.
### Table 4.1.6.3.
Specified Uniformly Distributed Live Loads on an Area of Floor or Roof
Forming Part of Sentence 4.1.6.3.(1)

<table>
<thead>
<tr>
<th>Use of Area of Floor or Roof</th>
<th>Minimum Specified Load, kPa (psf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly Areas</td>
<td></td>
</tr>
<tr>
<td>(a) Except for those areas listed under (b) and (c), assemble areas with or without fixed seats including</td>
<td></td>
</tr>
<tr>
<td>Arenas</td>
<td></td>
</tr>
<tr>
<td>Auditoria</td>
<td></td>
</tr>
<tr>
<td>Churches</td>
<td></td>
</tr>
<tr>
<td>Dance floors</td>
<td></td>
</tr>
<tr>
<td>Dining areas (1)</td>
<td></td>
</tr>
<tr>
<td>Foyers and entrance halls</td>
<td></td>
</tr>
<tr>
<td>Grandstands, reviewing stands and bleachers</td>
<td></td>
</tr>
<tr>
<td>Gymnasium</td>
<td></td>
</tr>
<tr>
<td>Museums</td>
<td></td>
</tr>
<tr>
<td>Promenades</td>
<td></td>
</tr>
<tr>
<td>Rinks</td>
<td></td>
</tr>
<tr>
<td>Stadia</td>
<td></td>
</tr>
<tr>
<td>Stages</td>
<td></td>
</tr>
<tr>
<td>Theatres</td>
<td></td>
</tr>
<tr>
<td>and other areas with similar uses</td>
<td></td>
</tr>
<tr>
<td>(b) Assembly areas with fixed seats that have backs over at least 80 percent of the assembly area for the following uses:</td>
<td></td>
</tr>
<tr>
<td>Churches</td>
<td></td>
</tr>
<tr>
<td>Courtrooms</td>
<td></td>
</tr>
<tr>
<td>Lecture halls</td>
<td></td>
</tr>
<tr>
<td>Theatres</td>
<td></td>
</tr>
<tr>
<td>(c) Classrooms with or without fixed seats</td>
<td></td>
</tr>
<tr>
<td>Attics</td>
<td></td>
</tr>
<tr>
<td>Accessible by a stairway in residential occupancies only</td>
<td>1.4 (30)</td>
</tr>
<tr>
<td>Having limited accessibility so that there is no storage of equipment or materials</td>
<td>0.5 (10)</td>
</tr>
<tr>
<td>Balconies</td>
<td></td>
</tr>
<tr>
<td>Exterior</td>
<td></td>
</tr>
<tr>
<td>Interior and mezzanines that could be used for the assembly of people as a viewing area (2)</td>
<td>4.8 (100)</td>
</tr>
<tr>
<td>Interior and mezzanines other than above</td>
<td></td>
</tr>
<tr>
<td>Corridors, lobbies and aisles</td>
<td></td>
</tr>
<tr>
<td>Other than those listed below</td>
<td></td>
</tr>
<tr>
<td>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) (3)</td>
<td>4.8 (100)</td>
</tr>
<tr>
<td>(3)</td>
<td></td>
</tr>
<tr>
<td>Equipment areas and service rooms including</td>
<td></td>
</tr>
<tr>
<td>Generator rooms</td>
<td></td>
</tr>
<tr>
<td>Mechanical equipment exclusive of elevators</td>
<td></td>
</tr>
<tr>
<td>Machine rooms</td>
<td></td>
</tr>
<tr>
<td>Pump rooms</td>
<td></td>
</tr>
<tr>
<td>Transformer vaults</td>
<td></td>
</tr>
<tr>
<td>Ventilating or air-conditioning equipment</td>
<td>3.6(3)(75)</td>
</tr>
<tr>
<td>Column 1</td>
<td>2</td>
</tr>
</tbody>
</table>
### Table 4.1.6.3. (Cont'd)
**Specified Uniformly Distributed Live Loads on an Area of Floor or Roof**
Forming Part of Sentence 4.1.6.3.(1)

<table>
<thead>
<tr>
<th>Use of Area of Floor or Roof</th>
<th>Minimum Specified Load, kPa (psf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exits and fire escapes</td>
<td>4.8 (100)</td>
</tr>
<tr>
<td>Factories</td>
<td>6.0&lt;sup&gt;(a)&lt;/sup&gt; (125)</td>
</tr>
<tr>
<td>Footbridges</td>
<td>4.8 (100)</td>
</tr>
<tr>
<td>Garages for</td>
<td></td>
</tr>
<tr>
<td>Passenger cars</td>
<td>2.4 (50)</td>
</tr>
<tr>
<td>Unloaded buses and light trucks</td>
<td></td>
</tr>
<tr>
<td>Loaded buses and trucks and all other trucking spaces</td>
<td>6.0 (125)</td>
</tr>
<tr>
<td>Kitchens (other than residential)</td>
<td></td>
</tr>
<tr>
<td>Libraries</td>
<td></td>
</tr>
<tr>
<td>Stack rooms</td>
<td>7.2 (150)</td>
</tr>
<tr>
<td>Reading and study rooms</td>
<td>2.9 (60)</td>
</tr>
<tr>
<td>Office areas (not including record storage and computer rooms) located in</td>
<td></td>
</tr>
<tr>
<td>Basement and first storey</td>
<td>4.8 (100)</td>
</tr>
<tr>
<td>Floors above first storey</td>
<td>2.4 (50)</td>
</tr>
<tr>
<td>Operating rooms and laboratories</td>
<td></td>
</tr>
<tr>
<td>Patients' bedrooms</td>
<td>1.9 (40)</td>
</tr>
<tr>
<td>Recreation areas that cannot be used for assembly purposes including</td>
<td></td>
</tr>
<tr>
<td>Billiard rooms</td>
<td></td>
</tr>
<tr>
<td>Bowling alleys</td>
<td></td>
</tr>
<tr>
<td>Pool rooms</td>
<td>3.6 (75)</td>
</tr>
<tr>
<td>Residential areas (within the scope of Article 2.1.1.2.)</td>
<td></td>
</tr>
<tr>
<td>Sleeping and living quarters in apartments, hotels, motels, boarding schools and colleges</td>
<td>1.9 (40)</td>
</tr>
<tr>
<td>Work areas within live/work units</td>
<td></td>
</tr>
<tr>
<td>Residential areas (within the scope of Article 2.1.1.3.)</td>
<td></td>
</tr>
<tr>
<td>Bedrooms</td>
<td>1.4 (30)</td>
</tr>
<tr>
<td>Other areas</td>
<td>1.8 (40)</td>
</tr>
<tr>
<td>Stairs within dwelling units</td>
<td>1.9 (40)</td>
</tr>
<tr>
<td>Retail and wholesale areas</td>
<td>4.8 (100)</td>
</tr>
<tr>
<td>Roofs</td>
<td>1.0&lt;sup&gt;(a)&lt;/sup&gt; (20)</td>
</tr>
<tr>
<td>Sidewalks and driveways over areaways and basements</td>
<td>12.0 (250)</td>
</tr>
<tr>
<td>Storage areas, including locker rooms in apartment buildings</td>
<td>4.8&lt;sup&gt;(a)&lt;/sup&gt; (100)</td>
</tr>
<tr>
<td>Toilet areas</td>
<td>2.4 (50)</td>
</tr>
<tr>
<td>Underground slabs with earth cover</td>
<td>(4)</td>
</tr>
<tr>
<td>Warehouses</td>
<td>4.8&lt;sup&gt;(a)&lt;/sup&gt; (100)</td>
</tr>
</tbody>
</table>

**Notes to Table 4.1.6.3.:**

<sup>(a)</sup> See Article 4.1.6.6.
<sup>(b)</sup> See Appendix A.
<sup>(c)</sup> See Article 4.1.6.4.
<sup>(d)</sup> See Article 4.1.6.7.
<sup>(e)</sup> See Article 4.1.7.1.
4.1.6.4. Loads for Occupancy Served

(1) The following shall be designed to carry not less than the specified load required for the occupancy they serve:
   (a) corridors, lobbies and aisles not over 1 200 mm (3 ft 11 in) in wide,
   (b) all corridors above the first storey of residential areas of apartments, hotels and motels, and
   (c) interior balconies and mezzanines, provided they cannot be used by an assembly of people as a viewing area.

4.1.6.5. 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 less than the live loads due to snow, ice and rain prescribed in Subsection 4.1.7.

(2) Exterior areas accessible to pedestrian traffic, but not vehicular traffic, shall be designed for their intended use, but not less than
   (a) the live load prescribed for assembly areas in Table 4.1.6.3., and
   (b) the live loads due to snow, ice and rain as prescribed in Subsection 4.1.7.

4.1.6.6. Loads for Dining Areas

(1) The minimum specified load in Table 4.1.6.3. for dining areas may be reduced to 2.4 kPa (50 psf) for dining areas in buildings that have been converted for such purposes provided that the floor area does not exceed 100 m² (1080 ft²) and use of the dining area for other assembly purposes including dancing is precluded.

4.1.6.7. Floor Loads Due to Intended Use

(1) Equipment areas and service rooms, factories, storage areas and warehouses shall be designed for the loads due to their intended use but not less than the specified loads listed in Table 4.1.6.3.

4.1.6.8. 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 4.1.6.3. shall be the greatest value for any of the occupancies concerned.

4.1.6.9. Variation with Tributary Area

(1) An area used for assembly occupancies designed for a live load of less than 4.8 kPa (100 psf) shall have no reduction for tributary area.

(2) Where a structural member supports a tributary area of floor, roof or combination thereof greater than 80 m² (860 ft²) used for assembly occupancies designed for a live load of 4.8 kPa (100 psf) or more, or for storage, manufacturing, retail stores, garages or as a footbridge, the specified live load due to use and occupancy, excluding snow, is the load provided for in Article 4.1.6.3. multiplied by

\[
0.5 + \sqrt{\frac{20}{A}}
\]

where A is the tributary area in square metres for this type of use and occupancy, excluding the area supporting snow.

(3) Where a structural member supports a tributary area of floor, roof or combination of these greater than 20 m² (215 ft²) 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, excluding snow, is the load provided for in Article 4.1.6.3. multiplied by

\[
0.3 + \sqrt{\frac{9.8}{B}}
\]

where B is the tributary area in square metres for this type of use and occupancy, excluding the area supporting snow.

(See Appendix A.)

4.1.6.10. Concentrated Loads

(1) The specified 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 4.1.6.10. applied over an area of 750 mm (2 ft 6 in) by 750 mm (2 ft 6 in) located so as to cause maximum effects, except that for occupancies not listed in Table 4.1.6.10. the concentrations of load shall be determined in accordance with Article 4.1.6.2.

4.1.6.11. Bleacher Seats

(1) Bleacher seats shall be designed for a uniformly distributed load of 1.75 kN (400 lb) for each linear metre or for a concentrated load of 2.2 kN (500 lb) distributed over a length of 750 mm (2 ft 6 in), whichever produces the greatest effect on the supporting members.

4.1.6.12. Helicopter Landing Areas

(1) Helicopter landing areas on roofs shall be constructed in conformance with "Heliport and Helideck..."

4.1.6.13. Roof Parking Decks

(1) Roof parking decks shall be designed for the uniformly distributed loads in Table 4.1.6.3., the concentrated loads in Table 4.1.6.10. or the roof snow load, whichever produces the greatest effect in the members concerned.

Table 4.1.6.10.
Specified Concentrated Live Loads on an Area of Floor or Roof
Forming Part of Sentence 4.1.6.10.(1)

<table>
<thead>
<tr>
<th>Area of Floor or Roof</th>
<th>Minimum Specified Concentrated Load, kN (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof surfaces</td>
<td>1.3 (900)</td>
</tr>
<tr>
<td>Floors of classrooms</td>
<td>4.5 (1000)</td>
</tr>
<tr>
<td>Floors of offices, manufacturing buildings, hospital wards and stages</td>
<td>9.0 (2000)</td>
</tr>
<tr>
<td>Floors and areas used by passenger cars</td>
<td>11 (2500)</td>
</tr>
<tr>
<td>Floors and areas used by vehicles not exceeding 3800 kg gross weight</td>
<td>18 (4000)</td>
</tr>
<tr>
<td>exceeding 3800 kg but not exceeding 9000 kg gross weight</td>
<td>36 (8000)</td>
</tr>
<tr>
<td>Floors and areas used by vehicles exceeding 9000 kg gross weight</td>
<td>54 (12,000)</td>
</tr>
<tr>
<td>Driveways and sidewalks over areaways and basements</td>
<td>54 (12,000)</td>
</tr>
</tbody>
</table>

Notes to Table 4.1.6.10.
(1) See Appendix A.

4.1.7. Live Loads Due to Snow, Ice and Rain (See Appendix A.)

4.1.7.1. Specified Snow Loading

(1) The specified loading, $S$, due to snow accumulation on a roof or any other building surface subject to snow accumulation shall be calculated from the formula

$$ S = S_i(C_sC_wC_rC_p) + S_i $\]

where $S_i$ is the ground snow load in kPa, determined in accordance with Subsection 2.5.1.,

$S_r$ is the associated rain load in kPa determined in accordance with Subsection 2.5.1., but not greater than $S_i(C_sC_wC_rC_p)$,

$C_s$ is the basic roof snow load factor of 0.8,

$C_w$ is the wind exposure factor in Sentences (2) and (3),

$C_r$ is the slope factor in Sentences (4), (5) and (6), and

$C_p$ is the accumulation factor in Sentence (7).

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

(3) The wind exposure factor in Sentence (2) may be reduced to 0.75, or in exposed areas north of the treeline to 0.5, where

(a) the building is in an exposed location, so that the roof is exposed to the winds on all sides, with no obstructions higher than the roof located closer to the building than a distance equal to 10 times the height of the obstruction above the roof,

(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 $C_sC_wS_i/\gamma$ metres, where $\gamma$ is the unit weight of snow on roofs, and

(c) the loading does not involve accumulation of snow due to drifting from adjacent surfaces.

(4) Except as provided for in Sentences (5) and (6), the slope factor, $C_r$, shall be

(a) 1.0 when the roof slope, $\alpha$, is equal to or less than $30^\circ$,

(b) $(70^\circ - \alpha)/40^\circ$ when $\alpha$ is greater than $30^\circ$, but not greater than $70^\circ$, and

(c) 0 when $\alpha$ exceeds $70^\circ$, and

(5) The slope factor, $C_r$, for unobstructed slippery roofs where snow and ice can slide completely off the roof shall be

(a) 1.0 when the roof slope, $\alpha$, is equal to or less than $15^\circ$.

(b) $(60^\circ - \alpha)/45^\circ$ when $\alpha$ is greater than $15^\circ$, but not greater than $60^\circ$, and

(c) 0 when $\alpha$ exceeds $60^\circ$.

(6) The slope factor, $C_r$, shall be 1.0 when used in conjunction with accumulation factors for increased snow load as given in Subclauses (7)(c)(ii) and (7)(c)(v).

(7) The accumulation factor, $C_a$,

(a) shall be 1.0, except that
for large flat upper or lower roofs it shall be
(i) 1.2 \[1 - (\frac{30}{l'})^2\] but not less than 1.0, for roofs with \(C_w = 1.0\), or
(ii) 1.6 \[1 - (\frac{120}{l'})^2\] but not less than 1.0, for roofs with \(C_w = 0.75\) or 0.5

where
\[l' = \text{the characteristic length of the upper or lower roof defined as } l' = 2w - w^2/l, \text{ in meters,}\]
\[w = \text{the smaller plan dimension of the roof, in meters,}\]
\[l = \text{the larger plan dimension of the roof, in meters,}\]

and

where appropriate for the shape of the roof, shall be assigned other values which account for
(i) non-uniform snow loads on gable, arched or curved roofs and domes,
(ii) increased snow loads in valleys,
(iii) increased non-uniform snow loads due to snow drifting onto a roof which is at a level lower than other parts of the same building or at a level lower than another building within 5 m (16 ft 5 in) of it,
(iv) increased non-uniform snow loads on areas adjacent to roof projections, such as penthouses, large chimneys and equipment, and
(v) increased snow or ice loads due to snow sliding or drainage of meltwater from adjacent roofs.

(See Appendix A.)

4.1.8.2. 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 4.1.7.1.1(1), distributed over the entire loaded area.

(2) In addition to the distribution in Sentence (1), flat roofs and shed roofs, gable roofs of \(15^\circ\) slope or less and arched or curved roofs shall be designed for the specified uniform snow load in Sentence 4.1.7.1.1(1), computed using \(C_w = 1.0\), 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 greatest effects on the member concerned. (See Appendix A.)

4.1.7.3. Specified Rain Load

(1) The specified load due to the accumulation of rain water on a surface, whose position and shape and deflection under load is such as to make such an accumulation possible, is that resulting from the 24 h rainfall determined in conformance with Subsection 2.5.1. 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 drainage, such as rain water leaders.

(3) Except as provided for in Sentence 4.1.7.1.1(1) and except where a roof is intended to provide rain water retention, loads due to rain need not be considered to act simultaneously with loads due to snow.

4.1.8. Live Loads Due to Wind

4.1.8.1. Specified Wind Loading

(1) The specified external pressure or suction due to wind on part or all of a surface of a building shall be calculated from

\[p = qC_wC_p\]

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,
\(q\) = the reference velocity pressure as provided for in Sentence (4),
\(C_w\) = the exposure factor as provided for in Sentence (5),
\(C_p\) = 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. (See Appendix A.)

(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 products of the external pressures or suctions and the areas of the surfaces over which they are averaged as provided in Sentence (1). (See Appendix A.)

(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

\[p = qC_wC_p\]
\[ p_i = qC_eC_gC_p \]

where \( p_i \) = the specified internal pressure acting statically and in a direction normal to the surface either as a pressure (directed outwards) or as a suction (directed inwards),

\( q \) = the reference velocity pressure, as provided for in Sentence 4,

\( C_e \) = the exposure factor, as provided for in Sentence 5, evaluated at the building mid-height instead of the height of the element considered,

\( C_g \) = the gust effect factor, as provided for in Sentence (6), and

\( C_p \) = the internal pressure coefficient.

(4) The reference velocity pressure, \( q \), is the appropriate value determined in conformance with Subsection 2.5.1. for the following conditions:

(a) the reference velocity pressure, \( q \), for the design of cladding shall be based on a probability of being exceeded in any one year of 1 in 10,

(b) the reference velocity pressure, \( q \), for the design of structural members for deflection and vibration shall be based on a probability of being exceeded in any one year of 1 in 10,

(c) for all buildings, except those listed in Clause (d), the reference velocity pressure, \( q \), for the design of structural members for strength shall be based on a probability of being exceeded in any one year of 1 in 30, and

(d) the reference velocity pressure, \( q \), for the design of structural members for strength for post-disaster buildings shall be based on a probability of being exceeded in any one year of 1 in 100.

(5) The exposure factor \( C_e \) shall be

(a) the value shown in Table 4.1.8.1. for the appropriate reference height for the surface or part of the surface,

(b) the value of the function \((h/10)^{1/5}\) but not less than 0.9 where \( h \) is the reference height above grade in metres for the surface or part of the surface, or

(c) 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 \( C_g \) is one of the following values:

(a) 1.0 or 2.0 for internal pressures as appropriate, (See Appendix A.)

(b) 2.0 for the building as a whole and main structural members,

(c) 2.5 for small elements including cladding, or

(d) if a dynamic approach to the action of wind gusts is used, an appropriate value depending on the turbulence of the wind and the size and natural frequency of the structure. (See Appendix A.)

<table>
<thead>
<tr>
<th>Height, m (ft-in)</th>
<th>Exposure Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 0 to ≤ 6 (0 to 19'-8&quot;)</td>
<td>0.9</td>
</tr>
<tr>
<td>&gt; 6 to ≤ 12 (19'-8&quot; to 39'-4&quot;)</td>
<td>1.0</td>
</tr>
<tr>
<td>&gt; 12 to ≤ 20 (39'-4&quot; to 65'-7&quot;)</td>
<td>1.1</td>
</tr>
<tr>
<td>&gt; 20 to ≤ 30 (65'-7&quot; to 98'-5&quot;)</td>
<td>1.2</td>
</tr>
<tr>
<td>&gt; 30 to ≤ 44 (98'-5&quot; to 144'-4&quot;)</td>
<td>1.3</td>
</tr>
<tr>
<td>&gt; 44 to ≤ 64 (144'-4&quot; to 210'-0&quot;)</td>
<td>1.4</td>
</tr>
<tr>
<td>&gt; 64 to ≤ 85 (210'-0&quot; to 278'-10&quot;)</td>
<td>1.5</td>
</tr>
<tr>
<td>&gt; 85 to ≤ 140 (278'-10&quot; to 459'-0&quot;)</td>
<td>1.6</td>
</tr>
<tr>
<td>&gt; 140 to ≤ 240 (459'-0&quot; to 787'-0&quot;)</td>
<td>1.8</td>
</tr>
<tr>
<td>&gt; 240 to ≤ 400 (787'-0&quot; to 1312'-0&quot;)</td>
<td>2.0</td>
</tr>
</tbody>
</table>

### 4.1.8.2. Dynamic Effects of Wind

(1) Buildings whose height is greater than 4 times their minimum effective width or greater than 120 m (394 ft) and other buildings whose light weight, low frequency and low damping properties make them susceptible to vibration shall be

(a) designed by experimental methods for the danger of dynamic overloading and vibration and the effects of fatigue, or

(b) designed using a dynamic approach to the action of wind gusts. (See Appendix A.)

### 4.1.8.3. Full and Partial Loading

(1) Buildings and structural members shall be capable of withstanding the effects of

(a) the full winds acting along each of the two principal axes considered separately,

(b) the wind loads as described in (a) but with 25% of the load removed from any portion of the area,

(c) the wind loads as in (a) but considered simultaneously at 75% of their full value, and

(d) the wind loads as described in (c) but with 25 percent of these loads removed from any portion of the area. (See Appendix A.)
4.1.8.4. **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 which 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.

4.1.9. **Live Loads Due to Earthquakes**

4.1.9.1. **Analysis**

(1) The specified loading due to earthquake motion shall be determined by the analysis given in this Subsection.

(2) In this Subsection

\[ A_r = \text{response amplification to account for type of attachment of mechanical/electrical equipment, as defined in Sentence 4.1.9.1.(19),} \]

\[ A_x = \text{amplification factor at level } x \text{ to account for variation of response of mechanical/electrical equipment with elevation within the building, as defined in Sentence 4.1.9.1.(19),} \]

\[ C_p = \text{seismic coefficient for mechanical/electrical equipment, as defined in Sentence 4.1.9.1.(19),} \]

\[ D = \text{the dimension of the building in a direction parallel to the applied forces,} \]

\[ D_n = \text{plan dimension of the building at level } x \text{ perpendicular to the direction of seismic loading being considered,} \]

\[ D_i = \text{dimension of wall or braced frame which constitutes the main lateral-load-resisting system in a direction parallel to the applied forces,} \]

\[ e_x = \text{distance measured perpendicular to the direction of seismic loading between centre of mass and centre of rigidity at the level being considered, (See Appendix A.)} \]

\[ F = \text{foundation factor as given in Sentence 4.1.9.1.(11),} \]

\[ F_t = \text{portion of } V \text{ to be concentrated at the top of the structure as defined in Sentence 4.1.9.1.(13),} \]

\[ F_x = \text{lateral force applied to level } x, \]

\[ h_i, h_n, h_x = \text{the height above the base (i = 0) to level i, n, or } x, \text{ respectively, where the base of the structure is that level at which the horizontal earthquake motions are considered to be imparted to the structure,} \]

\[ h_x = \text{interstorey height (} h_i - h_{i-1}) \text{,} \]

\[ I = \text{seismic importance factor of the structure, as described in Sentence 4.1.9.1.(10),} \]

\[ J = \text{numerical reduction coefficient for base overturning moment as defined in Sentence 4.1.9.1.(23),} \]

\[ J_x = \text{numerical reduction coefficient for moment at level } x \text{ as defined in Sentence 4.1.9.1.(24),} \]

\[ \text{Level } i = \text{any level in the building, } i = 1 \text{ for first level above the base,} \]

\[ \text{Level } n = \text{that level which is uppermost in the main portion of the structure,} \]

\[ \text{Level } x = \text{that level which is under design consideration,} \]

\[ N = \text{total number of storeys above exterior grade to level } n, \text{ (} N \text{ is usually numerically equal to } n.) \]

\[ R = \text{force modification factor that reflects the capacity of a structure to dissipate energy through inelastic behaviour, as given in Sentence 4.1.9.1.(8),} \]

\[ S = \text{seismic response factor, for unit value of zonal velocity ratio, as defined in Sentence 4.1.9.1.(6),} \]

\[ S_p = \text{horizontal force factor for part or portion of a building and its anchorage, as given in Table 4.1.9.1.D. and Sentences 4.1.9.1.(17) and (19),} \]

\[ T = \text{fundamental period of vibration of the building or structure in seconds in the direction under consideration,} \]

\[ T_x = \text{floor torque at level } x \text{ as defined in Sentence 4.1.9.1.(28),} \]

\[ U = \text{factor representing level of protection based on experience, as specified in Sentence 4.1.9.1.(4),} \]

\[ V = \text{zonal velocity ratio = the specified zonal horizontal ground velocity expressed as a ratio to } 1 \text{ m/s (3.3 ft/s),} \]

\[ V = \text{minimum lateral seismic force at the base of the structure, to be used with a load factor } \alpha_e = 1.0, \]

\[ V_e = \text{equivalent lateral force at the base of the structure representing elastic response, as specified in Sentence 4.1.9.1.(5),} \]

\[ V_p = \text{lateral force on a part of the structure,} \]

\[ W = \text{dead load plus 25% of the design snow load} \]
specified in Subsection 4.1.7. plus 60% of the storage load for areas used for storage and the full contents of any tanks, (See Appendix A.)

\[ W_i, W_x = \text{the portion of } W \text{ which is located at or is assigned to level } i \text{ or } x, \text{ respectively,} \]

\[ W_p = \text{the weight of a part or portion of a structure, e.g. cladding, partitions and appendages,} \]

\[ Z_a = \text{acceleration-related seismic zone,} \]

\[ Z_v = \text{velocity-related seismic zone.} \]

(3) Earthquake forces shall be assumed to act in any horizontal direction, except that independent design about each of the principal axes shall be considered to provide adequate resistance in the structure for earthquake forces applied in any direction. (See Appendix A.)

(4) The minimum lateral seismic force, \( V \), shall be calculated in accordance with the following formula:

\[ V = (V_o/R)U \]

where \( U = 0.6 \).

(5) The equivalent lateral seismic force representing elastic response, \( V_e \), shall be calculated in accordance with the following formula:

\[ V_e = V \cdot S \cdot I \cdot F \cdot W \]

where \( v \) is the zonal velocity ratio determined in conformance with Subsection 2.5.1., except when \( Z_v = 0 \) and \( Z_e > 0 \) the value of \( Z_v \) shall be taken as 1 and \( v \) as 0.05 in all requirements of Subsection 4.1.9.

(6) The seismic response factor, \( S \), shall conform to Table 4.1.9.1.A.

(7) The fundamental period, \( T \), in Sentence (6) shall be determined by

(a) the formula \( 0.1 N \) for any moment-resisting frame, or by the formulae \( 0.085(h_e)^{1/4} \) for a steel moment-resisting frame or \( 0.075(h_e)^{1/4} \) for a concrete moment-resisting frame, where the moment-resisting system is a frame which resists 100% of the required lateral forces and 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 \( h_e \) is in metres,

(b) the formula \( 0.09 h_e/(D_e)^{1/2} \) for other structures, where \( h_e \) and \( D_e \) are in metres, and \( D_e = \text{length of wall or braced frame which constitutes the main lateral-force-resisting system in the direction parallel to the applied forces; if the main lateral-force-resisting system does not have a well-defined length, then } D_e \text{ shall be used in lieu of } D_e \text{ or}

(c) other established methods of mechanics; the value of \( V_e \) used for design shall be not less than 0.80 of the value computed using the period calculated in Clause (a) or (b).

(8) Except as provided for in Sentences 4.1.9.3.(1), (2) and (3), values of the force modification factor, \( R \), shall conform to Table 4.1.9.1.B. (See Appendix A.)

(9) For the purpose of applying Table 4.1.9.1.B.

(a) a ductile moment-resisting frame shall mean a frame that is designed to resist the specified seismic forces and that, in addition, has adequate ductility or energy-absorptive capacity;

(b) for combinations of different types of lateral-load-resisting systems acting in the same direction, \( R \) shall be taken as the lowest value of \( R \) corresponding to these systems except as given in Clause (c);

(c) if one of the lateral-force-resisting systems of the structure is designed to take 100% of the lateral force, \( R \) can be selected as appropriate for the system; the components of the structure not considered to be part of the lateral-force-resisting system must be capable of resisting their gravity loads under seismically induced deformations calculated in accordance with Sentence 4.1.9.2.(2);

(d) if it can be demonstrated through research or experience that the seismic performance of a structural system is at least equivalent to one of Cases 1-8, 10-14, 16-18 or 20-21 in Table 4.1.9.1.B., then such a structural system will qualify

---

**Table 4.1.9.1.A.**

**Seismic Response Factors**

Forming Part of Sentence 4.1.9.1.(6)

<table>
<thead>
<tr>
<th>( T )</th>
<th>( Z_a/Z_v )</th>
<th>( S )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \leq 0.25 )</td>
<td>( &gt; 1.0 )</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>&lt; 1.0</td>
<td>2.1</td>
</tr>
<tr>
<td>( &gt; 0.25 ) but ( &lt; 0.50 )</td>
<td>( &gt; 1.0 )</td>
<td>4.2 - 8.4(( T - 0.25 ))</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>3.0 - 3.8(( T - 0.25 ))</td>
</tr>
<tr>
<td></td>
<td>&lt; 1.0</td>
<td>2.1</td>
</tr>
<tr>
<td>( \geq 0.50 )</td>
<td>All values</td>
<td>1.5(( T ))^{1/3}</td>
</tr>
</tbody>
</table>

Column 1: 2

Column 3: 3
for a value of R corresponding to the equivalent case in that Table.

### Table 4.1.9.1.B.
#### Force Modification Factors
Forming Part of Sentence 4.1.9.1.(8)

<table>
<thead>
<tr>
<th>Case</th>
<th>Type of Lateral Load Resisting System</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Steel Structures Designed and Detailed According to CAN/CSA-S16.1-M</td>
<td>4.0</td>
</tr>
<tr>
<td>2</td>
<td>ductile moment-resisting frame</td>
<td>4.0</td>
</tr>
<tr>
<td>3</td>
<td>ductile eccentrically braced frame</td>
<td>4.0</td>
</tr>
<tr>
<td>4</td>
<td>ductile steel plate shear wall</td>
<td>3.0</td>
</tr>
<tr>
<td>5</td>
<td>moment-resisting frame with nominal ductility</td>
<td>3.0</td>
</tr>
<tr>
<td>6</td>
<td>nominally ductile steel plate shear wall</td>
<td>3.0</td>
</tr>
<tr>
<td>7</td>
<td>braced frame with nominal ductility</td>
<td>2.0</td>
</tr>
<tr>
<td>8</td>
<td>ordinary steel plate shear wall</td>
<td>2.0</td>
</tr>
<tr>
<td>9</td>
<td>other lateral-force-resisting systems not defined in Cases 1 to 8</td>
<td>1.5</td>
</tr>
<tr>
<td>10</td>
<td>Reinforced Concrete Structures Designed and Detailed According to CAN/CSA-A23.3-M</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>ductile moment-resisting frame</td>
<td>4.0</td>
</tr>
<tr>
<td>12</td>
<td>ductile coupled wall</td>
<td>4.0</td>
</tr>
<tr>
<td>13</td>
<td>other ductile wall systems</td>
<td>3.5</td>
</tr>
<tr>
<td>14</td>
<td>moment-resisting frame with nominal ductility</td>
<td>2.0</td>
</tr>
<tr>
<td>15</td>
<td>wall with nominal ductility</td>
<td>2.0</td>
</tr>
<tr>
<td>16</td>
<td>other lateral-force-resisting systems not defined in Cases 10 to 14</td>
<td>1.5</td>
</tr>
<tr>
<td>17</td>
<td>Timber Structures Designed and Detailed According to CSA-086.1</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>nailed shear panel with plywood, waferboard or OSB</td>
<td>3.0</td>
</tr>
<tr>
<td>19</td>
<td>Concentrically braced heavy timber frame with ductile connections</td>
<td>2.0</td>
</tr>
<tr>
<td>20</td>
<td>Masonry Structures Designed and Detailed According to CSA-S304.1</td>
<td>1.5</td>
</tr>
<tr>
<td>21</td>
<td>moment-resisting wood frame with ductile connections</td>
<td>2.0</td>
</tr>
<tr>
<td>22</td>
<td>reinforced masonry wall with nominal ductility</td>
<td>2.0</td>
</tr>
<tr>
<td>23</td>
<td>unreinforced masonry</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>other Lateral-force-resisting Systems not Defined in Cases 1 to 22</td>
<td>1.0</td>
</tr>
</tbody>
</table>

| Column 1 | 2 | 3 |

Notes to Table 4.1.9.1.B.:
(1) See Appendix A.

### Table 4.1.9.1.C.
#### Foundation Factors
Forming Part of Sentence 4.1.9.1.(11)

<table>
<thead>
<tr>
<th>Categories</th>
<th>Type and Depth of Rock and Soil Measured from the Foundation or Pile Cap Level</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rock, dense and very dense coarse-grained soils, very stiff and hard fine-grained soils, compact coarse-grained soils and firm and stiff fine-grained soils from 0 to 15 m (0 to 49 ft 3 in) deep</td>
<td>1.0</td>
</tr>
<tr>
<td>2</td>
<td>Compact coarse-grained soils, firm and stiff fine-grained soils with a depth greater than 15 m; very loose and loose coarse-grained soils and very soft and soft fine-grained soils from 0 to 15 m (0 to 49 ft 3 in) deep</td>
<td>1.3</td>
</tr>
<tr>
<td>3</td>
<td>Very loose and loose coarse-grained soils, with depth greater than 15 m (49 ft 3 in)</td>
<td>1.5</td>
</tr>
<tr>
<td>4</td>
<td>Very soft and soft fine-grained soils with depth greater than 15 m (49 ft 3 in)</td>
<td>2.0</td>
</tr>
<tr>
<td>Column 1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Notes to Table 4.1.9.1.C.:
(1) See Appendix A.
(10) The seismic importance factor, I, shall equal 1.5 for post-disaster buildings, 1.3 for schools and 1.0 for all other buildings.

(11) The foundation factor, Ff, shall conform to Table 4.1.9.1.C., except that the product Ff·S does not exceed 3.0 where Zs does not exceed Zf and need not exceed 4.2 where Zs is greater than Zf. (See Appendix A.)

(12) The weight, W, of the building shall be calculated in accordance with the following formula:

\[ W = \sum_{i=1}^{n} W_i \]

(13) The total lateral seismic force, V, shall be distributed as follows:

(a) a portion, Fx, shall be assumed to be concentrated at the top of the building and equal to 0.07 TV, except that Fx need not exceed 0.25 V and may be considered as zero where T does not exceed 0.7 s; the remainder, V - Fx, shall be distributed along the height of the building, including the top level, in accordance with the formula

\[ F_x = (V - F_x) W_i h_i / \sum_{i=1}^{n} W_i h_i \]

or

(b) by dynamic analysis, with the seismic effects scaled such that the base shear from the dynamic analysis equals \( V \) as given in Sentence 4.1.9.1.(4). (See Appendix A.)

(14) The total shear in any horizontal plane shall be distributed to the various elements of the lateral-force-resisting system in proportion to their rigidities according to rational analysis, with due regard to the capacities and stiﬀnesses of the nonstructural elements and to the effects of torsion as required by Sentence 4.1.9.1.(28).

(15) Except as provided for in Sentence (16), parts of buildings as described in Tables 4.1.9.1.D. and 4.1.9.1.E. and their anchorage shall be designed to accommodate the deflections defined in Article 4.1.9.2., and for a lateral force, \( V_p \), equal to \( v \cdot I \cdot S_p \cdot W_p \), distributed according to the distribution of mass of the element under consideration, where \( v \) is determined in conformance with Subsection 2.5.1., and I is the same importance factor as used for the building.

(16) For non post-disaster buildings in zones where \( Z_s \) and \( Z_s \) are equal to or less than 1.0 and \( F_f \) is equal to or less than 1.3, the requirements of Sentence (15) shall not apply to Table 4.1.9.1.E. or to cases 7, 8, and 9 of Table 4.1.9.1.D.

(17) Except as provided for in Sentence (21), the values \( \star \) of \( S_p \) in Sentences (15) and (16) for architectural components shall conform to Table 4.1.9.1.D.

---

Table 4.1.9.1.D.

<table>
<thead>
<tr>
<th>Category</th>
<th>Architectural Part or Portion of Building</th>
<th>Direction of Force</th>
<th>Value of ( S_p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>All exterior and interior walls except those of Categories 2 and 3</td>
<td>Normal to flat surface</td>
<td>1.5</td>
</tr>
<tr>
<td>2</td>
<td>Cantilever parapet and other cantilever walls except retaining walls;</td>
<td>Normal to flat surface</td>
<td>6.5</td>
</tr>
<tr>
<td>3</td>
<td>Exterior and interior ornamentations and appendages</td>
<td>Any direction</td>
<td>6.5</td>
</tr>
<tr>
<td>4</td>
<td>Connections/attachments for Categories 1, 2 and 3</td>
<td>Any direction</td>
<td>2.5(^{(\dag)})</td>
</tr>
<tr>
<td></td>
<td>The body of ductile connections/attachments</td>
<td>Any direction</td>
<td>15.0</td>
</tr>
<tr>
<td></td>
<td>All fasteners and anchors in the ductile connection, such as bolts, inserts, welds or dowels</td>
<td>Any direction</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>Non-ductile connections/attachments</td>
<td>Any direction</td>
<td>4.5</td>
</tr>
<tr>
<td>5</td>
<td>Floors and roofs acting as diaphragms(^{(\dagger)})</td>
<td>Any direction</td>
<td>4.5</td>
</tr>
<tr>
<td>6</td>
<td>Towers, chimneys, smokestacks and penthouses when connected to or forming part of a building(^{(\ddagger)})</td>
<td>Vertical</td>
<td>2.0</td>
</tr>
<tr>
<td>7</td>
<td>Horizontally cantilevered floors, balconies, beams, etc.</td>
<td>Any direction</td>
<td>5.0</td>
</tr>
<tr>
<td>8</td>
<td>Suspended ceilings, light fixtures and other attachments to ceilings with independent vertical support</td>
<td>Normal to flat surface</td>
<td>5.0</td>
</tr>
<tr>
<td>9</td>
<td>Masonry veneer connections</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Col. 1  | 2 | 3 | 4 |

Notes to Table 4.1.9.1.D.:

(\dag) See Sentence 4.1.9.1.(18).
(\dagger) See Sentence 4.1.9.1.(21).
(\ddagger) See Appendix A.
Table 4.1.9.1.E.

Values of $C_p$ for Mechanical/Electrical Parts or Portions of Buildings
Forming Part of Sentence 4.1.9.1.(15)

<table>
<thead>
<tr>
<th>Category</th>
<th>Mechanical/Electrical Part or Portion of Building</th>
<th>Direction of Force</th>
<th>Value of $C_p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Machinery, fixtures, equipment, ducts, tanks and pipes (including contents) except as noted elsewhere in this table(*)</td>
<td>Any direction</td>
<td>1.0</td>
</tr>
<tr>
<td>2</td>
<td>Machinery, fixtures, equipment, ducts, tanks and pipes (including contents) containing toxic or explosive materials, materials having a flash point below 38°C (100°F) or fire fighting fluids.</td>
<td>Any direction</td>
<td>1.5</td>
</tr>
<tr>
<td>3</td>
<td>Flat bottom tanks (including contents) attached directly to a floor at or below grade within a building.</td>
<td>Any direction</td>
<td>0.7</td>
</tr>
<tr>
<td>4</td>
<td>Flat bottom tanks (including contents) attached directly to a floor at or below grade within a building containing toxic or explosive materials having a flash point below 38°C (100°F) or fire fighting fluids.</td>
<td>Any direction</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Notes to Table 4.1.9.1.E.:
(*) See Appendix A.

(18) All fasteners and anchors in a ductile connection, such as bolts, inserts, welds, or dowels, shall be capable of developing 3 times the yield load of the body of the connection.

(19) The values of $S_p$ in Sentences (15) and (16) for mechanical/electrical components shall be equal to:

$$S_p = C_p A_r A_x$$

where:

- $C_p$ = seismic coefficient for components of mechanical and electrical equipment as given Table 4.1.9.1.E.
- $A_r$ = 1.0 for components that are both rigid and rigidly connected and for non-brittle pipes and ducts,
  - = 1.5 for components located on the ground that are flexible or flexibly connected except for non-brittle pipes and ducts,
  - = 3.0 for all other cases,
- $A_x$ = $1.0 + (h_i/h_o)$.

(20) For the purpose of applying Sentence (19)
(a) components that are both rigid and rigidly connected are defined as those having a fundamental period for the component and connection less than or equal to 0.06 s, and
(b) flexible components or connections are defined as those having a fundamental period greater than 0.06 s.

(21) Floors and roofs acting as diaphragms shall be designed for a minimum force corresponding to a value of $S_p$ equal to 0.7 applied to loads tributary from that storey, unless a greater force $F_s$ is assigned to the level under consideration as in Sentences (13) and (14).

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

(23) The overturning moment, $M$, at the base of the structure shall be multiplied by a reduction coefficient, $J$, where
(a) $J = 1$ where $T$ is less than 0.5,
(b) $J = (1 - 0.2T)$ where $T$ is not less than 0.5, but not more than 1.5, and
(c) $J = 0.8$ where $T$ is greater than 1.5.

(24) The overturning moment $M_x$ at any level $x$ shall be multiplied by $J_x$, where
(a) $J_x = J + (1 - J)(h_x/h_o)^3$, and
(b) distributed as required in Sentences (25), (26) and (27).

(25) The incremental changes in the design overturning moments, in the storey under consideration, shall be distributed to the various resisting elements in the same proportion as the distribution of shears in the resisting system.

(26) Where other vertical members are provided which are capable of partially resisting the overturning moments, a
redistribution may be made to these members if framing members of sufficient strength and stiffness to transmit the required loads are provided.

(27) Where a vertical-resisting element is discontinuous, the overturning moment carried by the lowest storey of that element shall be carried down as loads to the foundation.

(28) Torsional moments about a vertical axis of the building shall be calculated as:
   (a) for an analysis carried out in accordance with Clause 4.1.9.1.(13)(a), the torsional moments applied at each level throughout the building shall be derived for each of the following load cases considered separately
      (i)  \( T_x = F_x(1.5e_x + 0.1 D_x) \)
      (ii) \( T_y = F_x(1.5e_x - 0.1 D_x) \)
      (iii) \( T_z = F_x(0.5e_x + 0.1 D_x) \)
      (iv) \( T_y = F_x(0.5e_x - 0.1 D_x) \)
   where \( F_x \) is the lateral floor force at each level as given by Clause 4.1.9.1.(13)(a) and the term 0.1 \( D_x \) represents the accidental torsional moment applied at each level and where each element in the building is designed for the most severe effect of the above load cases, or
   (b) the effects of accidental torsional moments applied at each level throughout the building shall be derived for each of the following load cases considered separately and shall be added to the effects of a three dimensional dynamic analysis
      (i)  \( T_x = + 0.1 D_x F_x \)
      (ii) \( T_y = - 0.1 D_x F_x \)

and where each element in the building is designed for the most severe effect of the above load cases and \( F_x \) is the lateral floor force at each level as given by Clause 4.1.9.1.(13)(a).
(See Appendix A.)

(29) The building design shall take full account of the possible effects of setbacks. (See Appendix A.)

4.1.9.2. Deflections

(1) Lateral deflections of a structure shall be calculated in accordance with accepted practice and based on the loads and requirements defined in this Section.

(2) Lateral deflections obtained from an elastic analysis using the loads given in Sentences 4.1.9.1.(13) and (14) and incorporating the effects of torsion shall be multiplied by \( R \) to give realistic values of anticipated deflections.

(3) The interstorey deflections based on the lateral deflections as calculated in Sentence (2) shall be limited to 0.01\( h \), for post-disaster buildings and 0.02\( h \), for all other buildings.

(4) All portions of the structure shall be designed to act as integral units in resisting horizontal forces, unless separated by adequate clearances which permit horizontal deflections of the structure consistent with values of deflections calculated in accordance with Sentence (2).

(5) The nonstructural components shall be designed so as not to transfer to the structural system any forces unaccounted for in the design, and any interaction of rigid elements such as walls and the structural system shall be designed so that the capacity of the structural system is not impaired by the action or failure of the rigid elements.

(6) Adjacent structures shall either be separated by the sum of their individual deflections as calculated in Sentence (2), or shall be connected to each other.

(7) The method of connection in Sentence (6) shall take into account the mass, stiffness, strength, ductility and anticipated motion of the connected buildings and the character of the connection.

(8) The deflections as calculated in Sentence (2) shall be used to account for sway effects due to seismic loading as required by Sentence 4.1.1.5.(2).

(9) The connected buildings in Sentence (6) shall be assumed to have the lowest \( R \) value of the buildings connected, unless the use of a higher value can be justified by rational analysis.

4.1.9.3. Special Provisions

(1) Buildings more than 3 storeys in building height in velocity- or acceleration-related seismic zones of 2 and higher shall have a structural system as described in Cases 1-8, 10-14, 16-18 or 20-21 in Table 4.1.9.1.B.

(2) For buildings more than 60 m in height with a structural system having \( R = 2.0 \) or \( R = 1.5 \) as determined from Table 4.1.9.1.B. or as determined from Clause 4.1.9.1.(9)(b), the value of \( V \) shall be increased by 50% in velocity-related seismic zones of 4 and higher.

(3) Elevated tanks plus full contents not supported by a building, shall be designed using \( R = 1 \) in the formula in Sentence 4.1.9.1.(4), with the conditions
   (a) the minimum and maximum value of the product \( S \)
shall be taken as 1.5 and 3.0, respectively.
(b) the overturning moment reduction coefficient, J, as set forth in Sentence 4.1.9.1.(2) shall be 1.0, and
(c) the torsional requirements of Sentence 4.1.9.1.(28)
shall apply.

(4) For buildings in velocity- or acceleration-related
seismic zones of 2 and higher in which discontinuities in
columns or shear walls occur, special design provisions shall
be made to ensure that failure at the point of discontinuity
will not occur before the capacity of the remaining portion of
the structure has been realized.

(5) In velocity- or acceleration-related seismic zones of
2 and higher, reinforcement conforming to Clause 6.3.3. of
CSA-S304.1, "Masonry Design for Buildings (Limit States
Design)" shall be provided for masonry construction in
(a) loadbearing and lateral load-resisting masonry,
(b) masonry enclosing elevator shafts and stairwells, or
used as exterior cladding, and
(c) masonry partitions, except for partitions which,
    (i) do not exceed 200 kg/m² (40 lb/ft²) in weight, and
    (ii) do not exceed 3 m (9 ft 10 in) in height and
are laterally supported at the top.

4.1.9.4. Foundation Provisions

(1) Foundations shall be designed so that yielding will
occur first in the superstructure and not the foundations,
unless the design specifically provides otherwise.

(2) Except in velocity-related seismic Zone 0, individual
pile footings, drilled piers and caissons shall be
 interconnected by ties in at least 2 directions.

(3) Ties in Sentence (2) shall be designed to carry by
tension or compression a horizontal force equal to the greatest
factored pile cap loadings multiplied by a factor 0.5 v, but not
exceeding 10% of the greatest factored pile cap load, unless it
can be demonstrated that equivalent restraints can be provided
by other means.

(4) Except in velocity-related seismic Zone 0, piles shall
be connected to the pile cap or structure by reinforcement
having sufficient anchorage to develop the yield strength of
the reinforcement, and the top of the piles (below the pile
cap) shall be reinforced to allow ductile behaviour if the
design depends upon such action.

(5) Except in velocity-related seismic Zones 0 and 1,
basement walls shall be designed to resist seismic lateral
pressures from backfill or natural ground.

(See Appendix A.)

4.1.10. Other Effects

4.1.10.1. 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 (200 lb/ft) for means of egress in
grandstands, stadia, bleachers and arenas,
(b) a concentrated load of 1.0 kN (225 lb) applied at any
point for access walkways to equipment platforms,
contiguous stairs and similar areas where the
gathering of many people is improbable, and
(c) 0.75 kN/m (50 lb/ft) or a concentrated load of 1.0
kN (225 lb) applied at any point, whichever governs,
for locations other than described in Clauses (a) and
(b).

(2) Individual elements within the guard, including solid
panels and pickets, shall be designed for a concentrated load
of 0.5 kN (113 lb) at any point in the element.

(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 (100 lb/ft) and
need not be considered to act simultaneously with the
horizontal load provided for in Sentence (1).

4.1.10.2. Loads on Vehicle Guardrails

(1) Vehicle guardrails for parking garages shall be
designed for a concentrated load of 22 kN (5000 lb) applied
horizontally outward at any point 500 mm (19 1/4 in) above the
floor surface. (See Appendix A.)

4.1.10.3. 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 (23% in)
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 (10 psf), whichever produces the greatest effect.

4.1.10.4. Firewalls

(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 (10 psf) under fire conditions as described in Sentence (2).

(2) Under fire conditions, when 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.

(See Appendix A.)

4.1.10.5. Vibrations and Impact of Machinery and Equipment

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

(2) 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 4.1.10.5.

<table>
<thead>
<tr>
<th>Impact Due to</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation of cab or radio operated cranes</td>
<td>1.25</td>
</tr>
<tr>
<td>Operation of pendant or hand operated cranes</td>
<td>1.10</td>
</tr>
<tr>
<td>Operation of elevators</td>
<td>(n)</td>
</tr>
<tr>
<td>Supports for light machinery, shaft or motor driven</td>
<td>1.20</td>
</tr>
<tr>
<td>Supports for reciprocating machinery (e.g. compressors)</td>
<td>1.50</td>
</tr>
<tr>
<td>Supports for power driven units (e.g. piston engines)</td>
<td>1.50</td>
</tr>
</tbody>
</table>

Table 4.1.10.5.
Factors for the Calculation of Impact Loads
Forming Part of Sentence 4.1.10.5.(2)

Notes to Table 4.1.10.5.
See CAN/CSA-B44-M, Clauses 2.6.2. and 2.10.3.

(3) Crane runway structures shall be designed to resist a horizontal force applied parallel to the top of the rail 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).

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

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

4.1.10.6. Resonances and Sway Forces

(1) 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.)

(2) The floor assembly and other structural elements that support fixed seats in any building used for assembly occupancies to accommodate 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 (70 lbs) for each metre length of seats acting parallel to each row of seats, and not less than 0.15 kN (35 lbs) for each metre length of seat acting at right angles to each row of seats, assuming such forces to be acting independently of each other.

4.1.10.7. Bleachers

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

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

4.1.10.8. 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 2.1.1.2, anchor systems shall be provided where any portion of the roof is more than 8 m (26 ft 3 in) 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, aluminum, or other corrosion resistant base material, or from steel that is hot dipped galvanised, in accordance with CSA Standard G164-M81, “Hot Dip Galvanising of Irregularly Shaped Articles”.

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 shall be carried out, which shall include groundwater conditions. (See Appendix A.)

4.2.2.2. Reserved.

4.2.2.3. Review

(1) A 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. (See Appendix A.)

(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 unit, and

(ii) during the installation and removal of retaining structures and related backfilling operations, 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.

4.2.2.4. Altered Subsurface Condition

(1) Where 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) Where 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 with 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 CAN/CSA-O80-M, "Wood Preservation" and the requirements of the appropriate commodity standard as follows:

(a) CSA-O80.2-M, "Preservative Treatment of Lumber, Timber, Bridge Ties and Mine Ties by Pressure Processes",

(b) CSA-O80.3-M, "Preservative Treatment of Piles by Pressure Processes", or

(c) CSA-O80.15-M, "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 Standard M4, "Care of Preservative Treated Wood Products" as revised by Clause 6 of CAN/CSA-O80, "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 with 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 with the requirements of Subsection 4.3.3.

4.2.3.6. Chemical Attack of Concrete

(1) Where concrete in foundations may be subject to chemical attack, it shall be treated in conformance with the requirements in CAN3-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) CAN3-G40.21-M, "Structural Quality Steels",
   (b) ASTM A252, "Welded and Seamless Steel Pipe Piles",
   (c) ASTM A283/A283M, "Low and Intermediate Tensile Strength Carbon Steel Plates",
   (d) ASTM A570/A570M, "Steel, Sheet and Strip, Carbon, Hot-Rolled, Structural Quality", or
   (e) ASTM A611, "Steel Sheet, Carbon, Cold-Rolled Sheet, Structural Quality".

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 CAN3-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. (See Section

2.7. for use of other materials)

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 one 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 Part 4,
   (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.)

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. Loads on Foundations

(1) The foundation of a building shall be capable of resisting all loads as stipulated in Section 4.1., in accordance with limit states design in Subsection 4.1.3. or working stress design in Subsection 4.1.4. (See Appendix A.)

4.2.4.5. Differential Movements

(1) The foundation of a building shall be proportioned so that the estimated total and differential movements of the foundation are not greater than the movements that the
building is designed to accommodate. (See Appendix A.)

4.2.4.6. 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.

4.2.4.7. 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.

4.2.4.8. 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.

4.2.4.9. 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.

4.2.4.10. 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.

4.2.4.11. 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 property shall be fully investigated and provided for in the design.

4.2.4.12. 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.

4.2.4.13. 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.

4.2.4.14. Expanding and Deteriorating

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

4.2.4.15. 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.

4.2.4.16. 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 with the requirements of Subsection 4.2.4. and with 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 which would cause damage to adjacent property, existing structures, utilities, roads and sidewalks 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 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 foundations shall be in conformance with Subsection 4.2.4. and the requirements of 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 which 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) Where deep foundation units are not load tested as outlined in Clause 4.2.4.1.(1)(c), and where well established local practice as outlined in Clause 4.2.4.1.(1)(b) is not applicable, the design shall be carried out in conformance with Clause 4.2.4.1.(1)(a).

(4) 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.

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

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

(7) 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 person responsible for the design, any necessary changes made and action taken as required.

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 structures and services.

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.

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-O86.1-M, "Engineering Design in Wood (Limit States Design)".

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
(a) CAN3-S304-M, "Masonry Design for Buildings", or
(b) CSA-S304.1, "Masonry Design for Buildings" (Limit States Design).

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 CAN/CSA-A23.3-M, "Design of Concrete Structures for Buildings". (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-S16.1-M, "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-M, "Cold Formed Steel Structural Members". (See Appendix A.)

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-M, "Strength Design in Aluminum".

4.3.6. Glass

4.3.6.1. Design Basis for Glass

(1) Glass 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".

4.4.2. Parking Structures

4.4.2.1. Design Basis for Parking Structures

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

4.4.3. Guards Over Retaining Walls

4.4.3.1. Guards Over Retaining Walls

(1) Every retaining wall which is a designated structure in Subsection 2.1.2. shall be protected by guards on all open sides where the public has access to open space at the top of the retaining wall.
Part 5
Wind, Water and Vapour Protection

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