NBC SEISMIC DESIGN DATA

Table 6 – Seismic Design Data for Selected Locations in Canada (NBC

Province and Location	Seismic Data							
	$S_a(0.2)$	$S_a(0.5)$	$S_a(1.0)$	$S_a(2.0)$	$S_a(5.0)$	$S_a(10.0)$	PGA	PGV
Trout Creek	0.186	0.116	0.065	0.033	0.0084	0.0035	0.115	0.093
Uxbridge	0.139	0.089	0.052	0.027	0.0067	0.0028	0.086	0.070
Vaughan (Woodbridge)	0.167	0.096	0.053	0.026	0.0065	0.0027	0.105	0.074
Vittoria	0.139	0.083	0.046	0.023	0.0056	0.0024	0.086	0.064
Walkerton	0.083	0.062	0.039	0.021	0.0052	0.0021	0.048	0.050
Wallaceburg	0.098	0.064	0.037	0.018	0.0044	0.0018	0.058	0.048
Waterloo	0.118	0.075	0.044	0.023	0.0056	0.0022	0.072	0.059
Watford	0.095	0.064	0.038	0.019	0.0049	0.0020	0.056	0.050
Wawa	0.062	0.043	0.026	0.013	0.0030	0.0014	0.036	0.031
Welland	0.308	0.150	0.069	0.031	0.0074	0.0028	0.199	0.115
West Lorne	0.118	0.072	0.041	0.021	0.0050	0.0021	0.072	0.056
Whitby	0.203	0.112	0.059	0.029	0.0071	0.0028	0.130	0.089
Whitby (Brooklin)	0.176	0.102	0.056	0.028	0.0070	0.0028	0.111	0.080
White River	0.060	0.041	0.024	0.011	0.0025	0.0013	0.035	0.030
Wiarton	0.080	0.062	0.040	0.021	0.0052	0.0022	0.046	0.050
Windsor	0.096	0.063	0.035	0.017	0.0041	0.0017	0.057	0.048
Wingham	0.083	0.061	0.039	0.020	0.0050	0.0021	0.048	0.048
Woodstock	0.118	0.075	0.043	0.022	0.0055	0.0022	0.071	0.058
Wyoming	0.090	0.061	0.037	0.019	0.0047	0.0020	0.053	0.048
Quebec								
Acton-Vale	0.254	0.160	0.091	0.047	0.013	0.0051	0.159	0.138
Alma	0.785	0.416	0.196	0.089	0.022	0.0075	0.486	0.339
Amos	0.109	0.078	0.049	0.026	0.0067	0.0028	0.064	0.063
Asbestos	0.200	0.137	0.082	0.043	0.012	0.0049	0.123	0.118
Aylmer	0.415	0.225	0.113	0.054	0.014	0.0053	0.265	0.186
Baie-Comeau	0.425	0.219	0.107	0.051	0.013	0.0051	0.275	0.182
Baie-Saint-Paul	1.62	0.872	0.406	0.179	0.043	0.012	0.986	0.735
Beauport	0.509	0.275	0.138	0.067	0.018	0.0065	0.327	0.233
Bedford	0.358	0.204	0.107	0.053	0.014	0.0053	0.228	0.170
Beloeil	0.522	0.272	0.131	0.062	0.016	0.0059	0.333	0.225
Brome	0.236	0.152	0.087	0.045	0.012	0.0049	0.147	0.130
Brossard	0.587	0.306	0.145	0.067	0.017	0.0062	0.374	0.251
Buckingham	0.491	0.257	0.125	0.058	0.015	0.0056	0.316	0.213
Campbell's Bay	0.387	0.208	0.105	0.050	0.013	0.0051	0.248	0.173
Chambly	0.550	0.286	0.137	0.064	0.017	0.0059	0.352	0.236
Coaticook	0.193	0.129	0.077	0.040	0.011	0.0045	0.119	0.110
Contrecoeur	0.473	0.251	0.124	0.059	0.016	0.0058	0.303	0.207
Cowansville	0.273	0.168	0.094	0.048	0.013	0.0051	0.172	0.142
Deux-Montagnes	0.596	0.313	0.149	0.069	0.018	0.0062	0.380	0.258
Dolbeau	0.484	0.255	0.125	0.058	0.015	0.0055	0.308	0.211
Drummondville	0.273	0.167	0.094	0.048	0.013	0.0052	0.172	0.144
Farnham	0.369	0.208	0.109	0.054	0.015	0.0055	0.235	0.174

Table 4.1.8.4.-A
Site Classification for Seismic Site Response
Forming Part of Sentences 4.1.8.4.(1) to (3)

Site Class	Ground Profile Name	Average Properties in Top 30 m, as per Note A-4.1.8.4.(3) and Table 4.1.8.4.-A		
		Average Shear Wave Velocity, $\bar{V}_{s30}$, m/s	Average Standard Penetration Resistance, $\bar{N}_{60}$	*Soil* Undrained Shear Strength, s_u
A	Hard *rock*[1][2]	$\bar{V}_{s30} > 1500$	n/a	n/a
B	*Rock*[1]	$760 < \bar{V}_{s30} \le 1500$	n/a	n/a
C	Very dense *soil* and soft *rock*	$360 < \bar{V}_{s30} < 760$	$\bar{N}_{60} > 50$	$s_u > 100$ kPa
D	Stiff *soil*	$180 < \bar{V}_{s30} < 360$	$15 \le \bar{N}_{60} \le 50$	50 kPa $< s_u \le$ 100 kPa
E	Soft *soil*	$\bar{V}_{s30} < 180$	$\bar{N}_{60} < 15$	$s_u < 50$ 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*[3]	Site-specific evaluation required		

Notes to Table 4.1.8.4.-A:

(1) Site Classes A and B, hard *rock* and *rock*, are not to be used if there is more than 3 m of softer materials between the *rock* and the underside of footing or mat *foundations*. The appropriate Site Class for such cases is determined on the basis of the average properties of the total thickness of the softer materials (see Note A-4.1.8.4.(3) and Table 4.1.8.4.-A).

(2) Where $\bar{V}_{s30}$ has been measured in-situ, the F(T) values for Site Class A derived from Tables 4.1.8.4.-B to 4.1.8.4.-G are permitted to be multiplied by the factor $0.04 + (1500/\bar{V}_{s30})^{1/2}$.

(3) 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.

Table 4.1.8.4.-B
Values of F(0.2) as a Function of Site Class and PGA_{ref}
Forming Part of Sentences 4.1.8.4.(4) and (5)

Site Class	Values of F(0.2)				
	$PGA_{ref} \le 0.1$	$PGA_{ref} = 0.2$	$PGA_{ref} = 0.3$	$PGA_{ref} = 0.4$	$PGA_{ref} \ge 0.5$
A	0.69	0.69	0.69	0.69	0.69
B	0.77	0.77	0.77	0.77	0.77
C	1.00	1.00	1.00	1.00	1.00
D	1.24	1.09	1.00	0.94	0.90
E	1.64	1.24	1.05	0.93	0.85
F	(1)	(1)	(1)	(1)	(1)

Same

Notes to Table 4.1.8.4.-B:

(1) See Sentence 4.1.8.4.(6).

Table 4.1.8.4.-C
Values of F(0.5) as a Function of Site Class and PGA_{ref}
Forming Part of Sentences 4.1.8.4.(4) and (5)

Site Class	Values of F(0.5)				
	$PGA_{ref} \le 0.1$	$PGA_{ref} = 0.2$	$PGA_{ref} = 0.3$	$PGA_{ref} = 0.4$	$PGA_{ref} \ge 0.5$
A	0.57	0.57	0.57	0.57	0.57
B	0.65	0.65	0.65	0.65	0.65
C	1.00	1.00	1.00	1.00	1.00
D	1.47	1.30	1.20	1.14	1.10
E	2.47	1.80	1.48	1.30	1.17
F	(1)	(1)	(1)	(1)	(1)

Notes to Table 4.1.8.4.-C:

(1) See Sentence 4.1.8.4.(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)(4)
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)(5)
4	**In-Plane Discontinuity in Vertical Lateral-Force-Resisting Element** Except for braced frames and moment-resisting frames, an in-plane discontinuity shall be considered to exist where there is an 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)(5)
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)(5)
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 for the direction under consideration.	(2)(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.(10) exceeds 1.7.	(2)(3)(4)(6)
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.	(2)(4)(7)
9	**Gravity-Induced Lateral Demand Irregularity** Gravity-induced lateral demand irregularity on the SFRS shall be considered to exist where the ratio, α, calculated in accordance with Sentence 4.1.8.10.(5), exceeds 0.1 for an SFRS with self-centering characteristics and 0.03 for other systems.	(2)(3)(4)(7)

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 Note A-Table 4.1.8.6.
(5) See Article 4.1.8.15.
(6) See Sentences 4.1.8.11.(10), (11) and 4.1.8.12.(4).
(7) See Article 4.1.8.8.

- Equivalent static lateral force procedures assume that the structure is “regular” in plan and vertical geometry, stiffness and mass. Structures with “irregularities” may behave quite differently and a dynamic analysis (response spectrum analysis or time history analysis) is required.

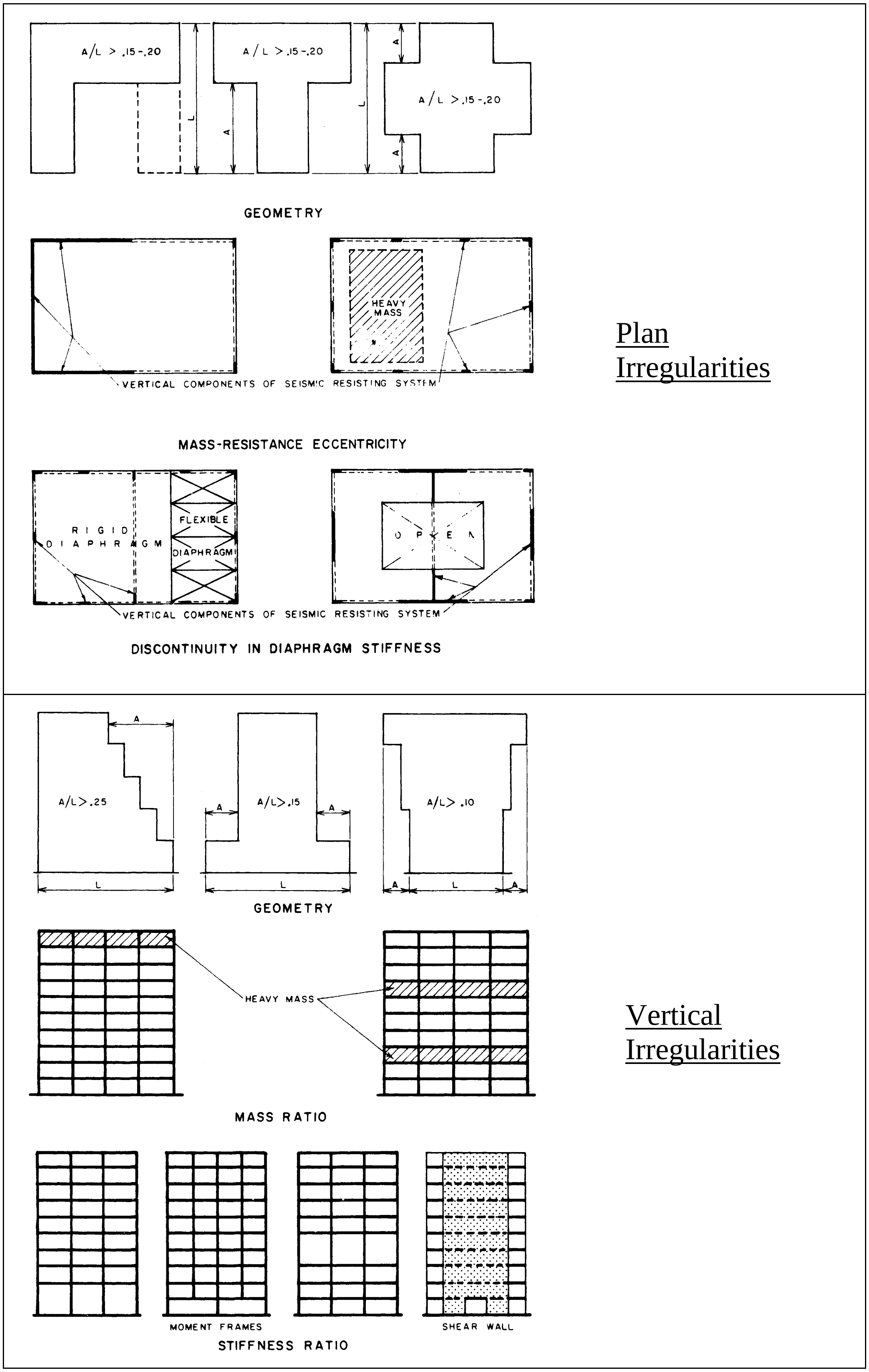

Figure 11 – Structural Irregularities in Buildings[10]

Higher Mode Factor, M_v

- The basic formula for static lateral force procedures is based on a single-degree of freedom system (SDOF).
- Transformation of the minimum lateral force for a SDOF to a multi-DOF structure is done using the *higher mode factor*, M_v, that accounts for the participation of higher modes in the dynamic response.
- M_v is given in Table 4.1.8.11 as a function of the type of structural system, structure fundamental period and the shape of the site-specific design spectral response acceleration curve [S(0.2)/S(5.0)].

Table 4.1.8.11.
Higher Mode Factor, M_v, and Base Overturning Reduction Factor, J(1)(2)(3)(4)
Forming Part of Sentence 4.1.8.11.(6)

$M_v \leftarrow \quad \rightarrow J$

S(0.2)/S(5.0)	M_v for $T_a \le 0.5$	M_v for $T_a = 1.0$	M_v for $T_a = 2.0$	M_v for $T_a \ge 5.0$	J for $T_a \le 0.5$	J for $T_a = 1.0$	J for $T_a = 2.0$	J for $T_a \ge 5.0$
Moment-Resisting Frames								
5	1	1	1	(5)	1	0.97	0.92	(5)
20	1	1	1	(5)	1	0.93	0.85	(5)
40	1	1	1	(5)	1	0.87	0.78	(5)
65	1	1	1.03	(5)	1	0.80	0.70	(5)
Coupled Walls(6)								
5	1	1	1	1(7)	1	0.97	0.92	0.80(8)
20	1	1	1	1.08(7)	1	0.93	0.85	0.65(8)
40	1	1	1	1.30(7)	1	0.87	0.78	0.53(8)
65	1	1	1.03	1.49(7)	1	0.80	0.70	0.46(8)
Braced Frames								
5	1	1	1	(5)	1	0.95	0.89	(5)
20	1	1	1	(5)	1	0.85	0.78	(5)
40	1	1	1	(5)	1	0.79	0.70	(5)
65	1	1.04	1.07	(5)	1	0.71	0.66	(5)
Walls, Wall Frame Systems								
5	1	1	1	1.25(7)	1	0.97	0.85	0.55(8)
20	1	1	1.18	2.30(7)	1	0.80	0.60	0.35(8)
40	1	1.19	1.75	3.70(7)	1	0.63	0.46	0.28(8)
65	1	1.55	2.25	4.65(7)	1	0.51	0.39	0.23(8)
Other Systems								
5	1	1	1	(5)	1	0.97	0.85	(5)
20	1	1	1.18	(5)	1	0.80	0.60	(5)
40	1	1.19	1.75	(5)	1	0.63	0.46	(5)
65	1	1.55	2.25	(5)	1	0.51	0.39	(5)

Notes to Table 4.1.8.11.:

(1) For intermediate values of the spectral ratio S(0.2)/S(5.0), M_v and J shall be obtained by linear interpolation.

(2) For intermediate values of the fundamental lateral period, T_a, $S(T_a)M_v$ shall be obtained by linear interpolation using the values of M_v obtained in accordance with Note (1).

(3) For intermediate values of the fundamental lateral period, T_a, J shall be obtained by linear interpolation using the values of J obtained in accordance with Note (1).

(4) For a combination of different seismic force resisting systems (SFRS) not given in Table 4.1.8.11. that are in the same direction under consideration, use the highest M_v factor of all the SFRS and the corresponding value of J.

(5) For fundamental lateral periods, T_a, greater than 2.0 s, use the 2.0 s values obtained in accordance with Note (1). See Clause 4.1.8.11.(2)(b).

(6) 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.

(7) For fundamental lateral periods, T_a, greater than 4.0 s, use the 4.0 s values of $S(T_a)M_v$ obtained by interpolation between 2.0 s and 5.0 s using the value of M_v obtained in accordance with Note (1). See Clause 4.1.8.11.(2)(a).

(8) For fundamental lateral periods, T_a, greater than 4.0 s, use the 4.0 s values of J obtained by interpolation between 2.0 s and 5.0 s using the value of J obtained in accordance with Note (1). See Clause 4.1.8.11.(2)(a).

Force Modification Factors, R_d and R_o

- The ductility-related force modification factor, R_d, accounts for the ability of the structure to dissipate energy through inelastic response. Values are given in Table 4.1.8.9 based on the structural system and structural material. These values are determined based on experience and observed performance of structures in earthquakes. Structures with greater ductility are assigned higher values of R_d.

- The overstrength-related force modification factor, R_o, accounts for fact that structures are designed to have factored resistances that are equal to or exceed the factored force effects → structure possesses overstrength. Values are given in Table 4.1.8.9 based on the structural system and structural material. Values reflect the dependable or minimum overstrength that arises from application of the design/detailing provisions contained in CSA Design Standards. Structures with greater overstrength are assigned higher values of R_o.

- Values of R_d and R_o are interdependent → must use values in Table 4.1.8.9 together.

Where the SFRS contains more than one type of system, the lowest product of R_dR_o must be used

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 CSA S16(3)(4)							
Ductile moment-resisting frames	5.0	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	2.0	1.3	NL	NL	60	30	30
Moderately ductile concentrically braced frames							
Tension-compression braces	3.0	1.3	NL	NL	40	40	40
Tension only braces	3.0	1.3	NL	NL	20	20	20
Limited ductility concentrically braced frames							
Tension-compression braces	2.0	1.3	NL	NL	60	60	60
Tension only braces	2.0	1.3	NL	NL	40	40	40
Ductile buckling-restrained braced frames	4.0	1.2	NL	NL	40	40	40
Ductile eccentrically braced frames	4.0	1.5	NL	NL	NL	NL	NL
Ductile plate walls	5.0	1.6	NL	NL	NL	NL	NL
Limited ductility plate walls	2.0	1.5	NL	NL	60	60	60
Conventional construction of moment-resisting frames, braced frames or plate walls							
Assembly occupancies	1.5	1.3	NL	NL	15	15	15
Other *occupancies*	1.5	1.3	NL	NL	60	40	40
Other steel SFRS(s) not defined above	1.0	1.0	15	15	NP	NP	NP

•Values of R_d recognize:
–ability to absorb energy without excessive deformation or failure
–presence of multiple or alternate load paths (redundancy)
–ability of members and connections to undergo inelastic, cyclic deformations
–contribution of non-structural components to damping

•Values of R_o recognize:[6]
–difference between nominal and factored resistances
–ratio of actual yield strength to minimum specified yield strength
–effect of strain hardening
–effect of mobilizing the full capacity of the structural system by the formation of a collapse mechanism.

Table 4.1.8.9. (Continued)

→F(1.0)

NL → no limit
NP → not permitted
→ max height

Type of SFRS	R_d	R_o	Restrictions[2]				
			Cases Where $I_EF_aS_a(0.2)$ F(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	4.0	1.7	NL	NL	NL	NL	NL
Moderately ductile moment-resisting frames	2.5	1.4	NL	NL	60	40	40
Ductile coupled walls	4.0	1.7	NL	NL	NL	NL	NL
Moderately ductile coupled walls	2.5	1.4	NL	NL	NL	60	60
Ductile partially coupled walls	3.5	1.7	NL	NL	NL	NL	NL
Moderately ductile partially coupled walls	2.0	1.4	NL	NL	NL	60	60
Ductile shear walls	3.5	1.6	NL	NL	NL	NL	NL
Moderately ductile shear walls → 8 st	2.0	1.4	NL	NL	NL	60	60
Conventional construction							
Moment-resisting frames	1.5	1.3	NL	NL	20	15	10[5]
Shear walls	1.5	1.3	NL	NL	40	30	30
Two-way slabs without beams	1.3	1.3	20	15	NP	NP	NP
Tilt-up construction							
Moderately ductile walls and frames	2.0	1.3	30	25	25	25	25
Limited ductility walls and frames	1.5	1.3	30	25	20	20	20[6]
Conventional walls and frames	1.3	1.3	25	20	NP	NP	NP
Other concrete SFRS(s) not listed above	1.0	1.0	15	15	NP	NP	NP
Timber Structures Designed and Detailed According to CSA O86							
Shear walls							
Nailed shear walls: wood-based panel	3.0	1.7	NL	NL	30	20	20
Shear walls: wood-based and gypsum panels in combination	2.0	1.7	NL	NL	20	20	20
Braced or moment-resisting frames with ductile connections							
Moderately ductile	2.0	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	1.0	1.0	15	15	NP	NP	NP
Masonry Structures Designed and Detailed According to CSA S304							
Ductile shear walls	3.0	1.5	NL	NL	60	40	40
Moderately ductile shear walls	2.0	1.5	NL	NL	60	40	40
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	1.0	1.0	30	15	NP	NP	NP
Other masonry SFRS(s) not listed above	1.0	1.0	15	NP	NP	NP	NP
Cold-Formed Steel Structures Designed and Detailed According to CSA S136							
Shear walls							
Screw-connected shear walls – wood-based panels	2.5	1.7	20	20	20	20	20
Screw-connected shear walls – wood-based and gypsum panels in combination	1.5	1.7	20	20	20	20	20
Diagonal strap concentrically braced walls							
Limited ductility	1.9	1.3	20	20	20	20	20
Conventional construction	1.2	1.3	15	15	NP	NP	NP
Other cold-formed SFRS(s) not defined above	1.0	1.0	15	15	NP	NP	NP

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.
Numbers in this Table are maximum height limits above *grade*, in m.
Height may be limited in other Parts of the Code.
The most stringent requirement governs.
(3) Higher design force levels are prescribed in CSA S16 for some heights of *buildings*.
(4) See Note A-Table 4.1.8.9.
(5) Frames limited to a maximum of 2 *storeys*.
(6) Frames limited to a maximum of 3 *storeys*.

Distribution of Shear Forces – Typical Buildings

- For typical, *regular* buildings without plan or vertical irregularities or discontinuities in stiffness or mass, the following assumptions are made:
  - The building is vibrating primarily in its fundamental mode, which is assumed to be linear in shape.
  - The inertial forces, F_x, at any level, x, in the building are proportional to the weight of the structure at that level.
  - The total lateral seismic force, V, is distributed over the height of the structure according to the function below and illustrated in Figure 12.

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

where

F_x = lateral force applied at level x

V = minimum lateral seismic force or base shear (determined previously)

F_t = concentrated force at top of structure: accounts for contributions of higher modes in tall structures

= $0.07\, T_a\, V \leq 0.25\, V$

= 0 if $T \leq 0.7$ seconds

W_x = weight of level x

h_x = height of level x

n = number of levels

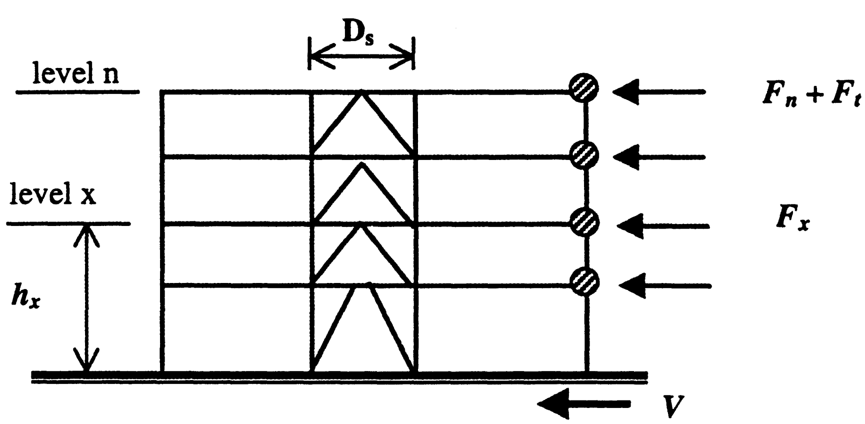

Figure 12 – Distribution of Lateral Forces