SEISMIC DESIGN GUIDE FOR MASONRY BUILDINGS

CHAPTER 3

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Canadian Concrete Masonry Producers Association

Canadian Concrete Masonry Producers Association
Region 6 of the National Concrete Masonry Association
CCMPA
Building Strength

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Objective: *to provide background and commentary for CSA S304.1-04 seismic design provisions related to reinforced concrete masonry walls, and discuss the revisions in CSA S304.1-04 seismic design requirements with regard to the 1994 edition*		**DETAILED MASONRY DESIGN PROVISIONS**

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3 Summary of Changes in NBCC 2005 and CSA S304.1-04 Seismic Design Requirements for Masonry Buildings

3.1 Introduction

This chapter summarizes the differences in seismic design provisions contained in the 1995 and 2005 editions of the NBCC, and the 1994 and the 2004 editions of CSA S304.1. Chapter 1 provides background on the seismic response of structures, seismic analysis methods, and the key NBCC 2005 seismic provisions of relevance for masonry design. Appendix A presents the NBCC 1995 seismic provisions and discusses changes in the two editions of the code. Chapter 2 provides an overview of the CSA S304.1 seismic design requirements for reinforced masonry walls.

This chapter also presents the results of a case study of a hypothetical warehouse building located in three Canadian cities characterized by different seismic risk (Vancouver, Calgary, and Toronto), based on both the NBCC 1995 and NBCC 2005.

3.2 Comparison of the Seismic Load Requirements of the 2005 and 1995 Editions of NBCC

NBCC 1995 and 2005 classified masonry shear walls based on their seismic performance requirements, as summarized in
Table 3-1.

Table 3-1. Classes of Reinforced Masonry Walls Based on Seismic Performance Requirements

NBCC 1995 Table 4.1.9.1.B and CSA S304.1-94	NBCC 2005 Table 4.1.8.9 and CSA S304.1-04	Comments
Unreinforced masonry R ***=1.0***	R_d =1.0 R_o =1.0	Slight difference in where unreinforced masonry could be used
Reinforced masonry R ***=1.5***	Shear walls with conventional construction R_d =1.5 R_o =1.5	No major changes in seismic design requirements in S304.1-04
Not defined	Limited ductility shear walls R_d =1.5 R_o =1.5	New class introduced in NBCC 2005 and S304.1-04
Reinforced masonry with nominal ductility R ***=2.0***	Moderately ductile shear walls R_d =2.0 R_o =1.5	No major changes in seismic design requirements in S304.1-04
Not defined	Moderately ductile squat shear walls R_d =2.0 R_o =1.5	New class introduced in NBCC 2005 and S304.1-04

Note that squat shear walls (height/length ratio less than unity) are common in low-rise masonry buildings, such as warehouses, schools and fire halls. Some of these buildings (e.g. fire halls), are defined as post-disaster facilities by NBCC 2005. A new restriction has been introduced in NBCC 2005 (Cl.4.1.8.10.2), that requires post-disaster facilities to have an SFRS with a R_d of

2.0 or higher. This provision means that squat masonry shear walls in post-disaster buildings must be designed to the CSA S304.1-04 provisions for “moderately ductile squat shear walls”. A comparison of NBCC 1995 and NBCC 2005 seismic design provisions is presented in Table 3-2.

Table 3-2. Comparison of NBCC 1995 and NBCC 2005 Seismic Design Provisions - Equivalent Static Force Procedure

Provision	NBCC 1995	NBCC 2005
Analysis method	***Cl.4.1.9.1.(7c)*** Static method is the default method. Dynamic method may allow a decrease in the base shear.	***Cl.4.1.8.7*** Dynamic method is the default method; static method is restricted to certain structures and seismic hazard.
Seismic force	***Cl.4.1.9.1.(4,5)*** **V = vS(T)IFW / (R/U)**	***Cl.4.1.8.11*** **$V = S(T)M_vI_eW / (R_dR_o)$**
Base response spectrum	***Cl.4.1.9.1.(6)*** **v S** **v** – amplitude **S** – shape, dependent on ratio of Z_a/Z_v	***Cl.4.1.8.4*** **$S(T)=F_aS_a(T)$ or $F_vS_a(T)$** **$S_a(T)$** based on UHS
Site conditions	***Cl.4.1.9.1.(11)*** **F** Independent of **T** and **v**	***Cl.4.1.8.4*** **F_a or F_v** Depends on **T** and **S_a**
Importance of structure	***Cl.4.1.9.1.(10)*** **I**	***Cl.4.1.8.5*** **I_E** Same as NBCC1995
Inelastic response	***Cl.4.1.9.1.(8,9)*** **R/U** Implied overstrength	***Cl.4.1.8.9*** **R_dR_o** Explicit overstrength
MDOF Forces from higher modes	***Cl.4.1.9.1.(6)*** Increase **S** in long period range **S** decreases slowly with **T** beyond 0.5 seconds	***Cl.4.1.8.11*** **M_v** multiplier on base shear Depends on period, type of structure and shape of **$S_a(T)$**
MDOF Distribution of forces	***Cl.4.1.9.1.(13)*** **F_t** Higher force in top storey	***Cl.4.1.8.11.(6)*** **F_t** Same as NBCC 1995
MDOF Overturning forces	***Cl.4.1.9.1.(23)*** **J** Moment reduction factor	***Cl.4.1.8.9.(7)*** **J** Revised for consistency with **M_v**
Eccentricity	***Cl.4.1.9.1.(28)*** **$Tx=F_x(1.5e_x \pm 0.1D_{nx})$ or** **$Tx=F_x(0.5e_x \pm 0.1D_{nx})$**	***Cl.4.1.8.11.(8,9,10)*** **$Tx=F_x(e_x \pm 0.1D_{nx})$** Must determine torsional sensitivity
Irregularities	***Cl.4.1.9.3*** Mainly height restrictions and some specific restrictions on masonry	***Cl.4.1.8.6*** Irregularities better defined with more stringent requirements

3.3 Comparison of the Seismic Design Requirements of the 2004 and 1994 Editions of CSA S304.1

3.3.1 Summary of New Seismic Design Provisions in CSA S304.1-04

The classification of masonry walls has been expanded, and new definitions introduced in NBCC 2005 and CSA S304.1-04, as shown in Table 3.1. These changes provide similar definitions for masonry and concrete walls in the new standards.

NBCC 2005 imposes more height limitations than NBCC 1995. Walls with “limited ductility” are a new classification with the same R_d and R_o values as “conventional construction”. This classification allows design of limited ductility walls in taller buildings, however more stringent detailing is provided.

Moderately ductile squat shear walls are a new classification with an R_d = 2.0. They have less severe restrictions on height to thickness ratios, and require additional checks on horizontal reinforcement.

3.3.2 Comparison of the Seismic Design and Detailing Requirements for Reinforced Masonry Walls in CSA S304.1-04 and CSA S304.1-94

This section compares the seismic design and detailing requirements for classes of walls in the 1994 and 2004 editions of CSA S304.1 standard. The following classes of walls can be compared:

- “Moderately ductile shear walls” (S304.1-04) and “reinforced masonry with nominal ductility” (S304.1-94) – see Table 3-3, and
- “Shear walls with conventional construction” (S304.1-04) and “reinforced masonry” (S304.1-94).

The “limited ductility shear walls” and “moderately ductile squat shear walls”, did not exist in previous editions of CSA S304.1, so a comparison is not possible. For information on the seismic requirements for these wall classes see Table 2-4.

Table 3-3. Comparison of Seismic Design Requirements for Moderately Ductile Shear Walls (S304.1-04) and Reinforced Masonry with Nominal Ductility (S304.1-94)

Provision	**CSA S304.1-94** **Reinforced masonry with nominal ductility**	**CSA S304.1-04** **Moderately ductile shear walls**
Ductility level	R =2.0	R_d =2.0 R_o =1.5
Plastic hinge region	***Clause A5.2*** l_p = greater of l_w or $h_w/6$	***Clause 10.16.5.2.1*** Unchanged
Ductility check	***Clause A.7*** 1. $\varepsilon_m = 0.0025$ *2.* $c/l_w < 0.2$ when $h_w/l_w < 3$	***Clause 10.16.5.2.3*** 1. $\varepsilon_m = 0.0025$ 2. $c/l_w < 0.2$ when $h_w/l_w < 4$ $c/l_w < 0.15$ when $4 < h_w/l_w < 8$
Wall height-to-thickness ratio restrictions	***Clause A5.2*** $h/(t+10) < 14$	***Clause 10.16.5.2.2*** Unchanged
Shear/diagonal tension resistance	***Clause A6.1*** $V_r = 0.5V_m + V_s$ (50% reduction in the masonry shear resistance)	***Clause 10.16.5.3.1*** Unchanged
Sliding shear resistance	***Clause A6.2*** $V_r = \phi_m \mu P_2$ only the reinforcement in the tension zone should be taken into account for P_2 calculation.	***Clause 10.16.5.3.2*** Unchanged
Grouting	***Clause A5.3*** Masonry within the plastic hinge region shall be fully grouted.	***Clause 10.16.4.1.3*** Unchanged
Minimum seismic reinforcement requirements	**Clause 5.2.2** Minimum seismic reinforcement requirements apply	***Clause 10.15.2.2*** Unchanged

Note that shear walls with conventional construction (S304.1-04) and reinforced masonry walls (S304.1-94) do not require the special seismic detailing like limited ductility and moderate ductility walls. These walls need to be designed to resist the effect of factored loads, and to satisfy the minimum seismic reinforcement requirements summarized in Table 3-4. Under the NBCC 2005 Cl.4.1.8.1.1, seismic design requirements need to be considered when $S(0.2) \geq 0.12$. However, it is possible to use unreinforced masonry at sites where $I_E F_a S_a(0.2) < 0.35$ (S304.1-04 Cl.4.5.1).

Table 3-4. Comparison of CSA S304.1-94 and S304.1-04 Seismic Reinforcement Requirements for Shear Walls

	CSA S304.1-94	**CSA S304.1-04**
Applicability of minimum seismic reinforcement requirements	***Clause 6.3.3.1*** In velocity- or acceleration-related seismic zones of 2 and higher, reinforcement conforming to Clause 5.2.2 shall be provided for masonry construction in loadbearing and lateral load-resisting masonry	***Clause 4.6.1*** At sites where the seismic hazard index $I_E F_a S_a(0.2) \geq 0.35$, reinforcement conforming to Clause 10.15.2 shall be provided for masonry construction in loadbearing and lateral load-resisting masonry
Minimum area: vertical & horizontal Reinforcement	***Clause 5.2.2.2*** Loadbearing walls and shear walls shall be reinforced horizontally and vertically with steel having a minimum total area of $0.002A_g$ distributed as follows: $A_v = 0.002A_g\alpha$ $A_h = 0.002A_g(1-\alpha)$ Where A_v = area of vertical steel A_h = area of horizontal steel α = distribution factor between 0.33 and 0.67, at the discretion of the designer.	***Clause 10.15.2.2*** (Same requirements in different terms) Loadbearing walls (including shear walls) shall be reinforced horizontally and vertically with steel having a minimum total area of $A_{stotal} = 0.002A_g$ distributed with a minimum area in one direction of at least $A_{v\min} = 0.00067A_g$ (approximately one-third of the total area)

<table>
<tr><th></th><th>CSA S304.1-94</th><th>CSA S304.1-04</th></tr>
<tr><td rowspan="2">Spacing: vertical reinforcement</td><td>Clause 5.2.2.2</td><td>Clause 10.16.4.3.2</td></tr>
<tr><td>Vertical reinforcement shall be spaced at not more than
a) 6 times the wall thickness or
b) 1200 mm</td><td>Vertical seismic reinforcement shall be uniformly distributed over the length of the wall. Its spacing shall not exceed the <u>lesser of</u>
a) $6(t+10)$ mm
b) 1200 mm
c) $l_w/4$ (for limited ductility or moderately ductile walls only)
but it need not be less than 600 mm</td></tr>
<tr><td rowspan="2">Spacing: horizontal reinforcement</td><td>Clause 5.2.2.2</td><td rowspan="2"><u>Outside plastic hinge regions (Cl.10.15.2.6):</u>
Horizontal seismic reinforcement shall be continuous between lateral supports. Its spacing shall not exceed
a) 400 mm where only joint reinforcement is used;
b) 1200 mm where only bond beams are used; or
c) 2400 mm for bond beams and 400 mm for joint reinforcement where both are used.

<u>Plastic hinge regions (Cl. 10.16.4.3.3):</u>
Reinforcing bars are to be used in the plastic hinge region, at a spacing not more than
a) 1200 mm or
b) $l_w/2$</td></tr>
<tr><td>Horizontal reinforcement shall be spaced at not more than
c) 6 times the wall thickness or
d) 1200 mm
When joint reinforcement is provided, the spacing should not exceed 400 mm (this is not clearly specified by S304.1).</td></tr>
</table>

3.4 Comparison of Masonry Wall Design for Different Design Codes and Site Locations

3.4.1 Building Description

Two typical shear walls, one squat and one flexural (non-squat), are considered for a single-storey reinforced masonry warehouse. The reinforcement required by NBCC 2005 and CSA 304.1-04 is compared to the reinforcement required by NBCC 1995 and CSA 304.1-94. The example warehouse is 64 m long and 27 m wide, with a wall height of 6.6 m. Masonry walls are located around the perimeter, with steel columns in the interior. The roof structure consists of steel beams, open web steel joists, and a composite steel and concrete deck. The design is presented for: Vancouver, BC; Calgary, AB; and Toronto, ON.

3.4.2 Design Criteria

1. Lateral seismic forces are calculated using the NBCC 2005 and NBCC 1995 (wind loads were not considered)
2. Masonry walls are designed to CSA S304.1-94 and CSA S304.1-04 for in-plane seismic loads (slenderness effects not checked in the design)
3. Masonry properties: 190 mm hollow concrete block units, block strength 15 MPa, and Type S mortar
4. Reinforcement properties: Grade 400 steel for vertical reinforcement and horizontal bond beam reinforcement, and ladder-type wire (No.9 ASWG) joint reinforcement

3.4.3 NBCC Seismic Load Calculations

The seismic weight (W) is calculated as 7370 kN, and includes the dead load and 25% of the snow load. For consistency, the same seismic weight has been taken for all locations, despite the difference in actual design snow loads. The upper half of the walls is included in the seismic weight calculation, and they are assumed to be fully grouted (conservative assumption for the weight calculation only). The fundamental period has different values depending on the code: NBCC 2005 gives a period of 0.2 sec, while NBCC 1995 gives 0.07 sec and 0.11 sec for the main directions.

The roof diaphragm is considered to be rigid in the design. The building is symmetrical in plan with regard to both principal axes. The effects of accidental torsion are taken into account by increasing the in-plane seismic force along the sides of the building by 10%.

NBCC 1995 and NBCC 2005 seismic design parameters used for this study are summarized in tables below.

Table 3-5. An Overview of the NBCC 1995 and NBCC 2005 Design Parameters

Code	**NBCC 1995**	**NBCC 2005**
Ductility Level	Reinforced masonry R = 1.5	Shear walls with conventional construction R_d = 1.5 R_o = 1.5
Soil conditions	F= 1.5	Site Class D
Building Importance	Normal importance- all other buildings (Cl.4.1.9.1.10) I = 1.0	Normal importance (Table 4.1.2.1) I_E =1.0

Table 3-6. NBCC 2005 Seismic Design Parameters (Site Class D)

Location	$S_a(0.2)$ (Table C-2, Appendix C)	F_a (Table 4.1.8.4B)	**Seismic hazard index** $I_E F_a S_a(0.2)$
Vancouver	0.96	1.1	1.06 >0.35
Toronto	0.28	1.3	0.36>0.35
Calgary	0.15	1.3	0.20<0.35

Table 3-7. NBCC 1995 Seismic Design Parameters (Foundation factor F=1.5)

Location	Z_a	Z_v	Z_a/Z_v	S	$S \cdot F$	v
Vancouver	4	4	1	3	3	0.2
Toronto	1	0	1	3	3	0.05
Calgary	0	1	<1	2.1	3	0.05

3.4.4 Shear Wall Design

The dimensions of the typical squat and flexural shear walls are shown in Figure 3-1. The dimensions and material properties are the same for all three locations. The axial loads are slightly different (150 kN for the flexural wall and 230 kN for the squat wall). Note that the height/length aspect ratios are equal to 0.83 and 2.20 for the squat and flexural walls respectively.

The following material properties were used in the design:

- 200 mm nominal width concrete masonry units (190 mm actual)
- Masonry compressive strength: f'_m = 9.8 MPa for hollow ungrouted masonry, and f'_m =7.5 MPa for fully grouted masonry (15 MPa block)
- Steel yield strength: f_y = 400 MPa (used both for Grade 400 steel bars and joint reinforcement)

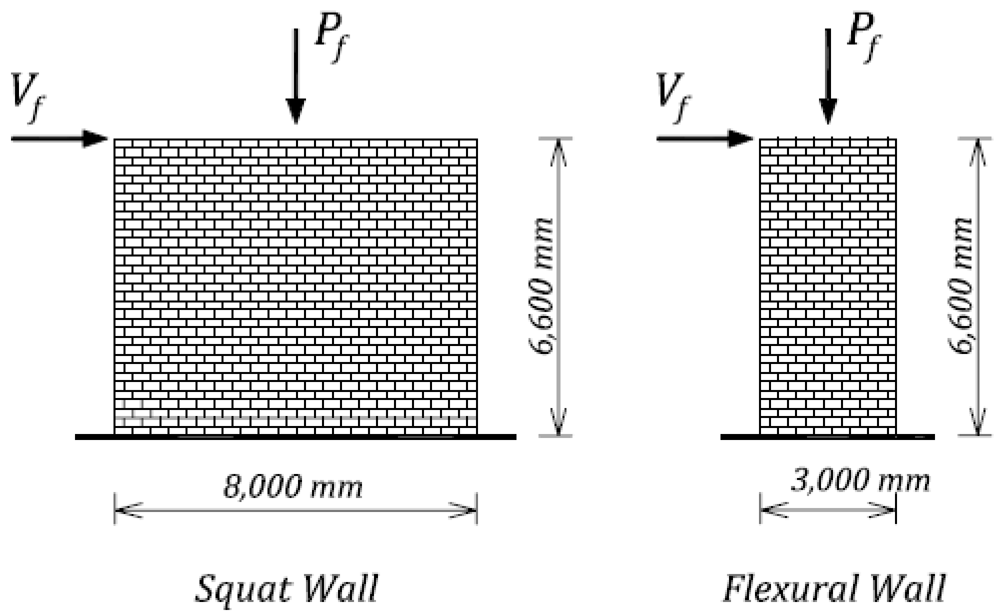

Figure 3-1. Wall dimensions and loading scheme.

The wall design parameters and key results are summarized in the following tables. Note that the vertical reinforcement is specified in terms of the number of bars of a specific size; this is different from a typical design specification, where the same information would be presented in terms of bar size and spacing.

Table 3-8. Design Results – Squat Shear Wall

Location	**Shear Force V_f (kN)**		**Vertical and Horizontal Reinforcement**	
	NBCC 1995	**NBCC 2005**	**NBCC 1995 S304.1-94**	**NBCC 2005 S304.1-04**
Vancouver	531	630	V:14-15M (*) ρ_v =0.18% H:15M@600 ρ_h =0.18%	V:16-15M (*) ρ_v =0.21% H:15M@600 ρ_h =0.18%
Toronto	133	185	V:4-15M (***) ρ_v =0.05% H: none ρ_h =0	V:8-15M (*,**) ρ_v =0.11% H:15M@2400+ ρ_h =0.10% 9 ga. joint reinf @200
Calgary	133	100	V:4-15M (***) ρ_v =0.05% H: none ρ_h =0	V:4-15M (***) ρ_v =0.05% H: none ρ_h =0

Notes:

V – vertical reinforcement ρ_v = vertical reinforcement ratio

H – horizontal reinforcement ρ_h = horizontal reinforcement ratio

*-fully grouted wall based on shear design

** - minimum seismic reinforcement requirements govern, corresponding to ρ_{total} =0.2% (S304.1-04 Cl.10.15.2.2)

***-minimum reinforcement requirements for loadbearing walls govern (S304.1-04 Cl.10.15.1.2)

Table 3-9. Design Results – Flexural Shear Wall

Location	Shear Force V_f (kN)		Vertical and Horizontal Reinforcement	
	NBCC 1995	**NBCC 2005**	**NBCC 1995 S304.1-94**	**NBCC 2005 S304.1-04**
Vancouver	152	180	V: 13-15M (*,**) ρ_v =0.5% H:15M@1200 ρ_h =0.09%	V: 15-15M (*,**) ρ_v =0.5% H: 15M@1200 ρ_h =0.09%
Toronto	38	55	V: 2-15M ρ_v =0.07% H: none ρ_h =0	V: 4-15M ρ_v =0.14% H: 15M@1200 ρ_h =0.09%
Calgary	38	30	V: 2-15M ρ_v =0.07% H: none ρ_h =0	V: 2-15M ρ_v =0.07% H: none ρ_h =0

Notes: V – vertical reinforcement H – horizontal reinforcement

ρ_v = vertical reinforcement ratio ρ_h = horizontal reinforcement ratio

*-fully grouted wall based on shear design

** - minimum seismic reinforcement requirements govern, corresponding to ρ_{total} =0.2% (S304.1-04 Cl.10.15.2.2)

3.4.5 Discussion

3.4.5.1 Design to NBCC 2005 and CSA S304.1-04

CSA S304.1-04 Cl.4.6.1 requires that minimum seismic reinforcement be provided when the seismic hazard index $I_E F_a S_a(0.2) \geq 0.35$ (Cl.10.15.2.2) (see Table 3-4). This applies to the wall designs for Vancouver and Toronto, but not Calgary. However, since these are loadbearing walls, the Calgary design must meet the minimum reinforcement requirements for loadbearing walls (Cl.10.15.1.1). Reinforcement requirements for the walls at the three locations are summarized in Table 3-10.

Table 3-10. CSA S304.1-4 Requirements for Shear Wall Reinforcement

Location	Unreinforced masonry Cl.4.6.1	Minimum reinf. required if walls are loadbearing Cl.10.15.1	Minimum seismic reinf. requirements Cl.10.15.2	Beyond minimum seismic reinf. requirements
Vancouver	Not possible	No, must meet seismic reinforcement requirements	Yes	Depends on the specific design
Toronto	Possible in some locations depending on site soil class	Yes, if reinforcement is required by design	Yes, if $I_E F_a S_a(0.2) \geq 0.35$	Depends on the specific design
Calgary	Possible for most locations	Yes, if reinforcement is required by design	Yes, if $I_E F_a S_a(0.2) \geq 0.35$	Depends on the specific design

3.4.5.2 Design to NBCC 1995 and CSA S304.1-94

CSA S304.1-94 Cl.6.3.3.1 required that minimum seismic reinforcement be provided for velocity- or acceleration-related seismic zones of 2 and higher (Cl.5.2.2) (see Table 3-4). This applies to the Vancouver design, but not to the Calgary or Toronto designs. However, since these shear walls are also loadbearing walls, the Toronto and Calgary designs must meet the minimum reinforcement requirements for loadbearing walls (Cl.5.2.1). It should be noted that S304.1-94 permitted the use of unreinforced masonry for Calgary and Toronto designs, provided that the tensile and compressive stresses were less than the permitted values.

3.4.5.3 Key Differences in the Designs

Squat wall (Table 3-8):

- Minor difference for Vancouver vertical reinforcement (16-15M bars for the NBCC 2005 design versus 14-15M bars for the NBCC 1995 design)
- An increase in vertical reinforcement for Toronto (8-15M bars for NBCC 2005 design versus 4-15M bars for NBCC 1995 design), plus the need to provide horizontal reinforcement to meet minimum S304.1-04 seismic reinforcement requirements (15M@2400 mm bond beam reinforcement and joint reinforcement at 200 mm spacing)
- No difference for Calgary

Flexural (non-slender) shear wall (Table 3-9):

- No difference for Vancouver
- An increase in vertical reinforcement in Toronto (4-15M bars for the NBCC 2005 design versus 2-15M bars for the NBCC 1995 design), plus the need to provide horizontal reinforcement to meet minimum S304.1-04 seismic reinforcement requirements (15M@1200 mm bond beam reinforcement versus 2-15M@2400 mm (note that S304.1-04 limits horizontal reinforcement spacing to maximum 1200 mm in the plastic hinge region)
- No difference for Calgary

3.4.5.4 Influence of Site Class and Building Importance

CSA S304.1-04 minimum seismic reinforcement requirements must be satisfied at locations where the seismic hazard index $I_E F_a S_a(0.2) \geq 0.35$ (Cl.4.6.1). The provision of minimum seismic reinforcement at a particular location is governed by the site class and the building importance (expressed through seismic importance factor I_E). Site classes B to E are considered as the most relevant for design purposes. Note that the fundamental period (T) is taken equal to 0.2 sec, which is typical for low-rise masonry buildings. The results for the three locations are summarized in Tables 3-11 to 3-13.

Note that the shaded cells indicate designs for which the S304.1-04 minimum seismic reinforcement requirements apply.

The following observations relate to the seismic hazard index values and the resulting seismic reinforcement requirements for parameters considered in this study:

- Vancouver site requires minimum S304.1-04 seismic reinforcement for all site classes and building importance levels
- Toronto site chosen for this study requires minimum S304.1-04 seismic reinforcement for many cases; note that the Toronto site chosen for this study has higher seismicity ($S_a(0.2)$ of 0.28) compared to some other sites in the Metro Toronto region (see Table 3-6), and that the results might be different for sites characterized by lower seismicity (more similar to Calgary)
- Calgary site does not require minimum seismic reinforcement for most cases (except for the site class E for higher importance buildings)

*Table 3-11. **Vancouver:** Seismic Hazard Index $I_E F_a S_a(0.2)$ for Different Site Classes and Building Importance Factors ($S_a(0.2)$ = 0.96)*

Site Class	F_a	Seismic Hazard Index		
		I_E=1.0	**I_E=1.3**	**I_E=1.5**
B	1.0	0.96	1.25	1.44
C	1.0	0.96	1.25	1.44
D	1.1	1.06	1.38	1.59
E	0.9	0.86	1.12	1.29

*Table 3-12. **Toronto:** Seismic Hazard Index $I_E F_a S_a(0.2)$ for Different Site Classes and Building Importance Factors ($S_a(0.2)$ = 0.28)*

Site Class	F_a	Seismic Hazard Index		
		I_E=1.0	**I_E=1.3**	**I_E=1.5**
B	0.8	0.22	0.29	0.34< 0.35
C	1.0	0.28	0.36	0.42
D	1.3	0.36	0.47	0.54
E	2.0	0.56	0.73	0.84

*Table 3-13. **Calgary:** Seismic Hazard Index $I_E F_a S_a(0.2)$ for Different Site Classes and Building Importance Factors ($S_a(0.2)$ = 0.15)*

Site Class	F_a	Seismic Hazard Index		
		I_E=1.0	I_E=1.3	I_E=1.5
B	0.8	0.12	0.16	0.18
C	1.0	0.15	0.20	0.23
D	1.3	0.20	0.26	0.30
E	2.1	0.32<0.35	0.42	0.48