NRC·CNRC

Construction

NRC's Seismic Evaluation and Upgrading Guidelines for Existing Buildings in Canada

Webinar Series

Application of Tier 1 and Tier 2 Evaluation & Deficiency-Based Upgrading Procedures

By Seismic Resilience Team

January 21, 2026

National Research Council Canada
Conseil national de recherches Canada

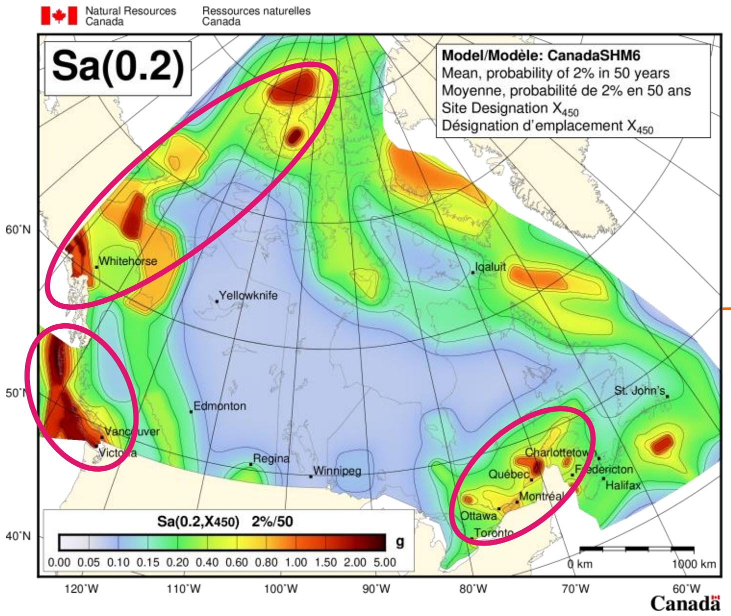
Canada

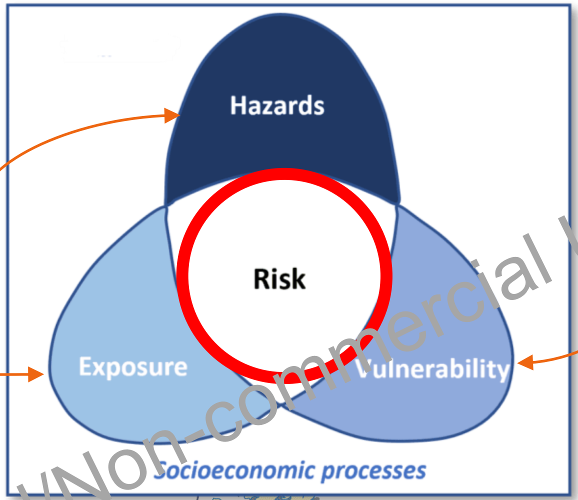
Outline

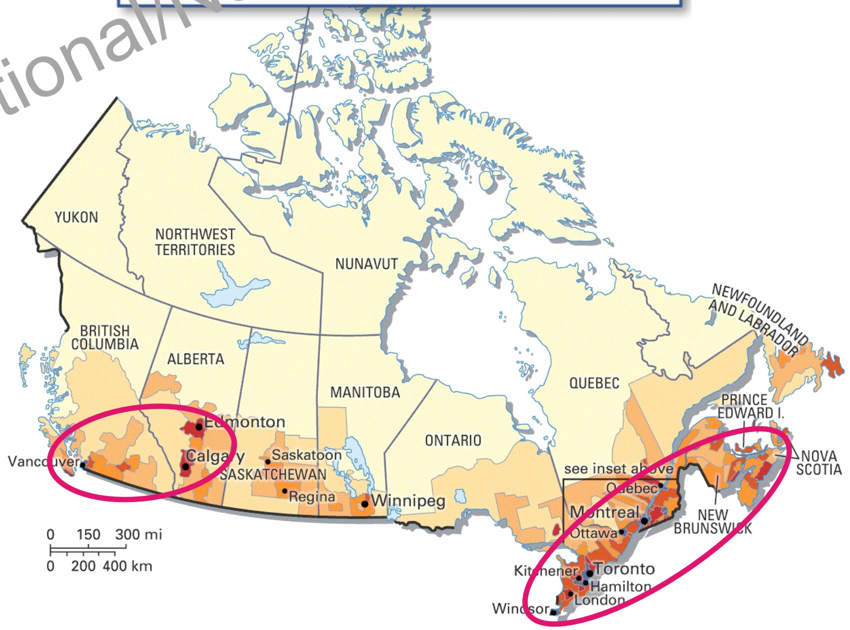
- Introduction
- Tier 1 Quick Evaluation
- Tier 2 Deficiency-Based Evaluation
- Deficiency-Based Upgrading
- Summary

Introduction

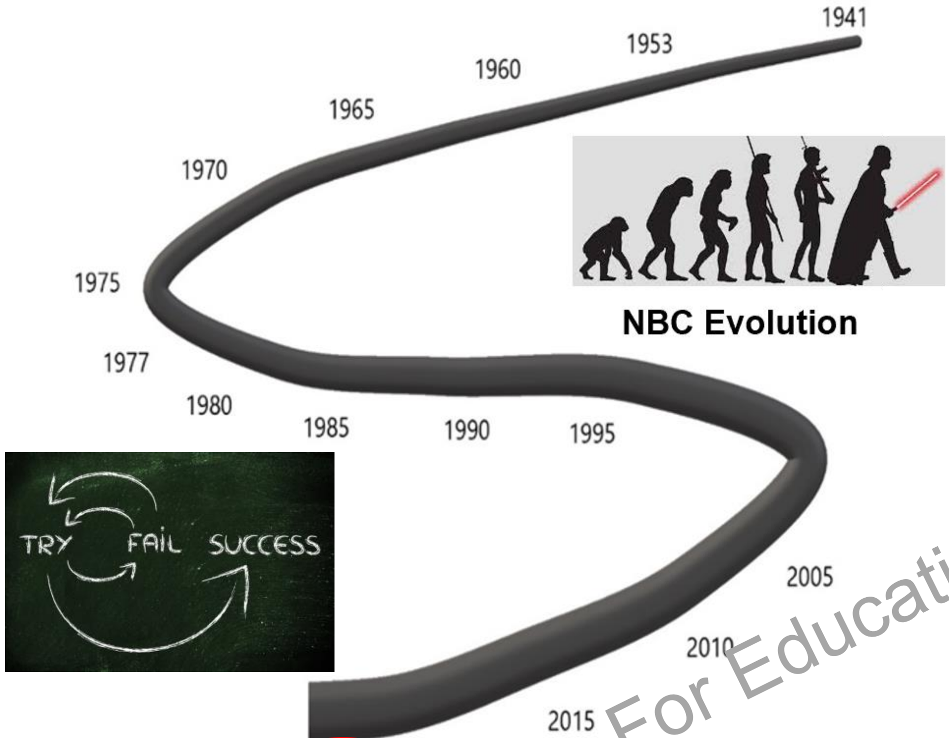
Earthquake Risk in Canada



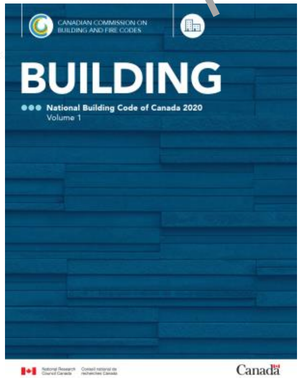




Seismic Risk Management of Existing Buildings



NBC Evolution



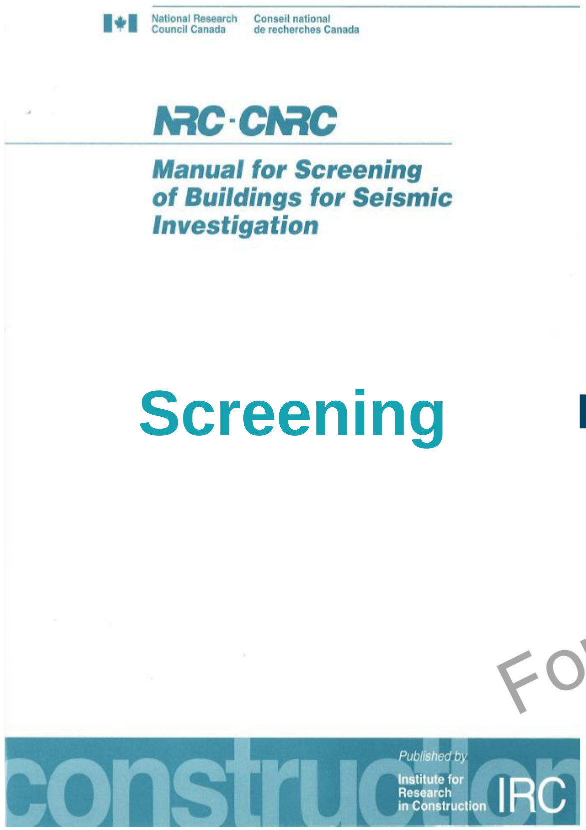
Large Building Inventory

Is Seismic Risk Acceptable?

How to Find the Answer?

Economy | Accuracy | Time

Existing NRC's Seismic Guidelines



Screening →

Evaluation →

Upgrading

Compatible with **NBC 1990**

NBC 2015/2020 Commentary L

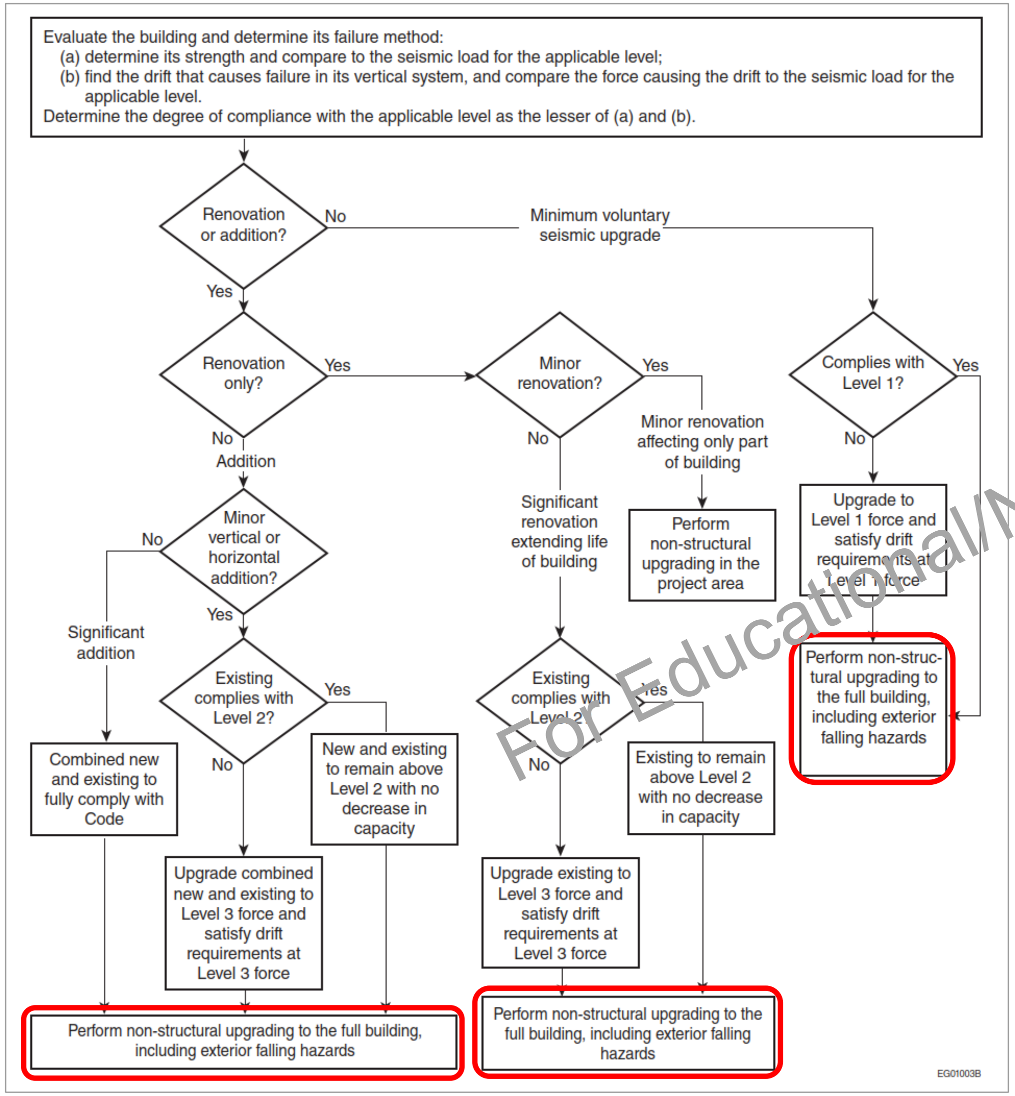


Figure L-1
Flow chart for the seismic assessment and upgrading of existing buildings

Inconsistent seismic upgrading levels for structural and non-structural components

Three seismic assessment/upgrading levels

- Level 1: 0.5 × 5% in 50 years
- Level 2: 10% in 50 years (475-year return period)
- Level 3: 5% in 50 years (975-year return period)

EGBC Seismic Retrofit Guidelines (SRG)

New features/ updates have been incorporated

Scope

- Life safety objective
- Low-rise school buildings
- Certain types of low-rise buildings

May apply with AHJ approval

Methodology

- Performance-based approach using inelastic deformations
- Probability of drift exceedance as acceptance criteria
- Web-based Seismic Performance Analyzer

Evolution of SRG

- Bridging Guidelines (2006)
- SRG-1 (May 2011)
- SRG-2 (November 2013)
- SRG-3 (June 2017)
- SRG 2020 (November 2022)
- SRG 2023 (March 2024)

NRC's Seismic Risk Management Framework

Structural

Non-Structural

Seismic Risk Management Framework

Protect

Level 1
Preliminary Screening

Level 2
Detailed Screening

Level 3
Seismic Evaluation

Risk Mitigation
(e.g., Seismic Upgrading)

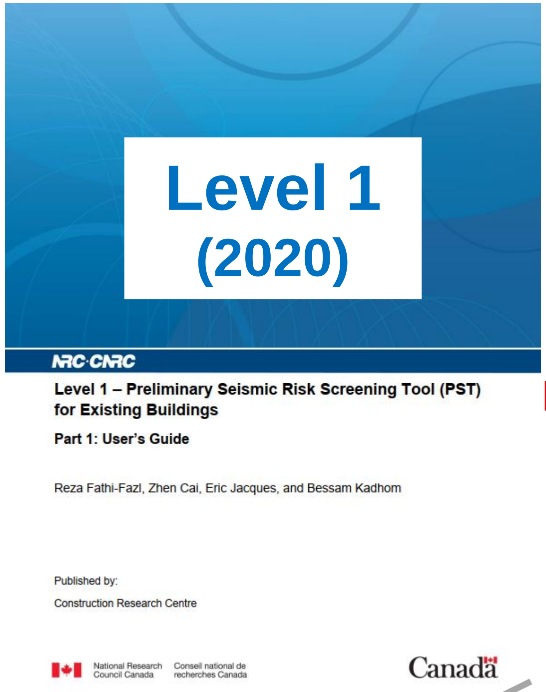
- Death
- Dollar
- Downtime

Safety ★★★★★

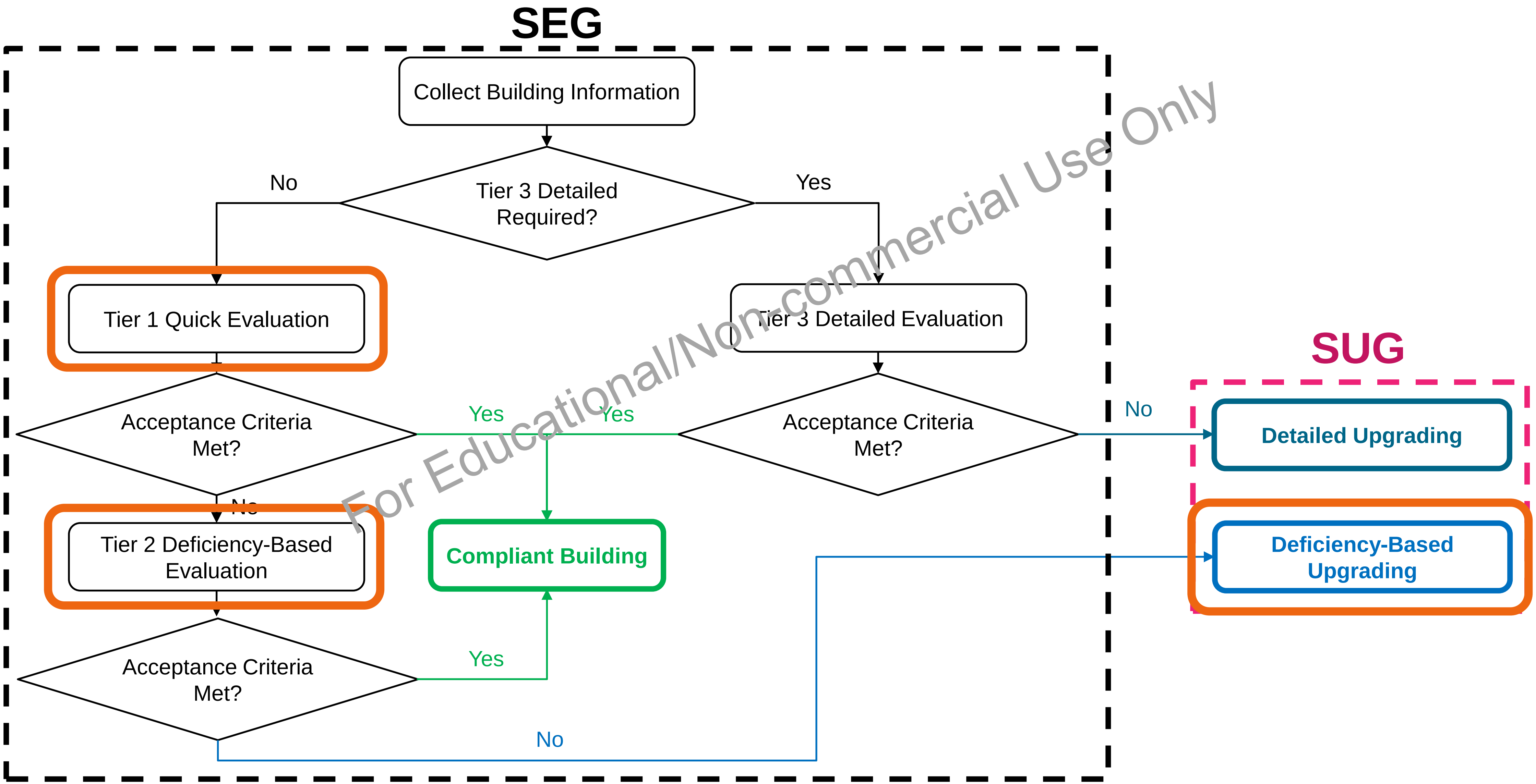
Repair ★★★★★

Recovery ★★★★★

NRC's Updated Seismic Tools/ Guidelines



Seismic Evaluation & Upgrading Process



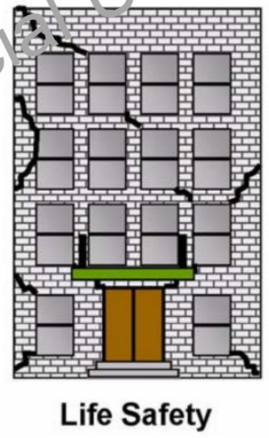
Tier 1 Quick Evaluation

Tier 1 Quick Evaluation

Intent and Scope

Tier 1 evaluation

- A set of <u>checklists</u> to uncover potential <u>major seismic deficiencies</u>
- Does <u>not require structural modelling/ analysis</u>
- Deals with <u>life safety</u> and does not address more stringent objectives



Evaluating engineers must receive proper <u>training</u>

The completed report must be <u>reviewed</u>

Tier 1 Quick Evaluation Checklists

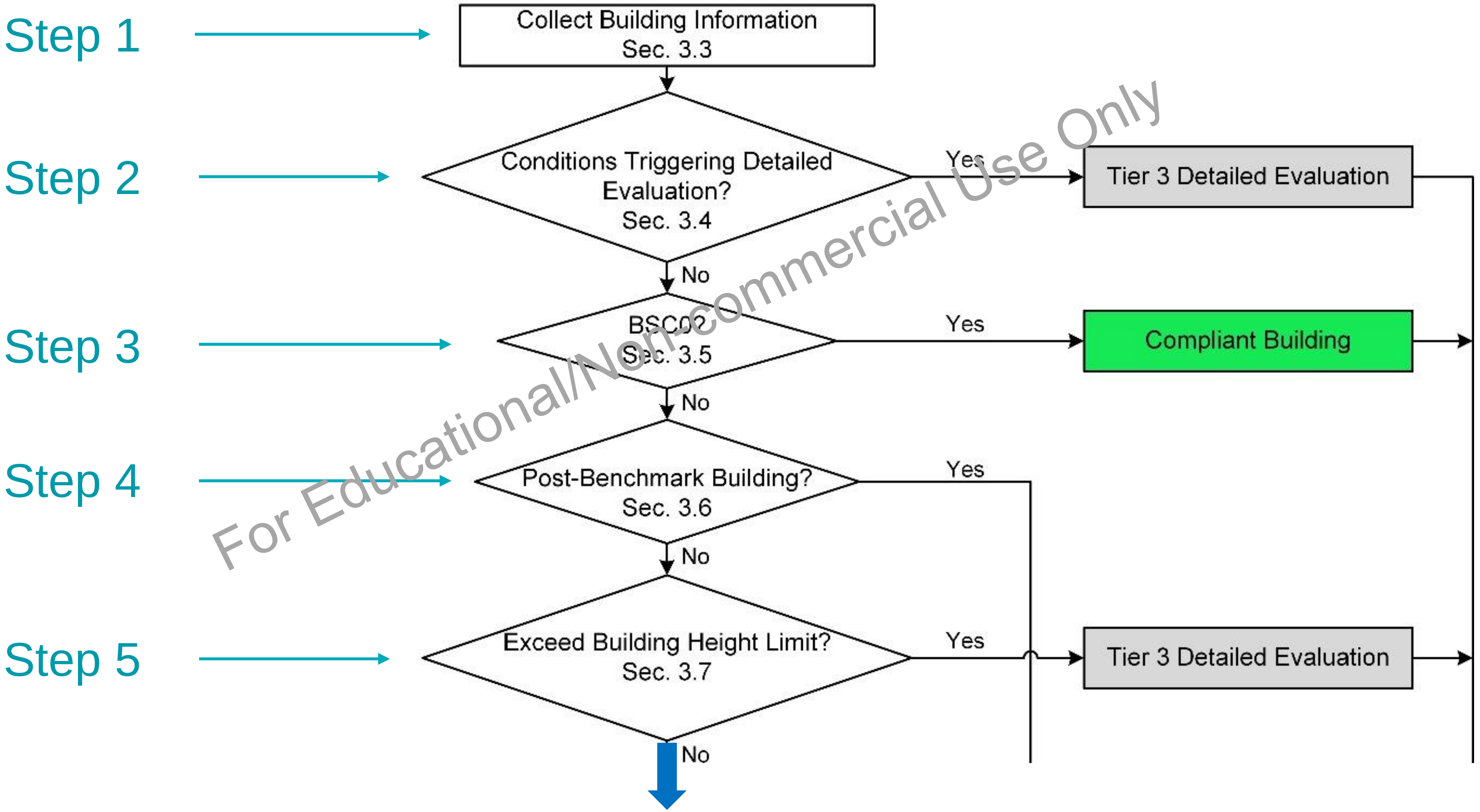
Tier 1 evaluation procedure contains a set of checklists

- Low Seismicity Checklist
- Basic Configuration Checklist
- Structural Checklists
- Non-structural Checklist

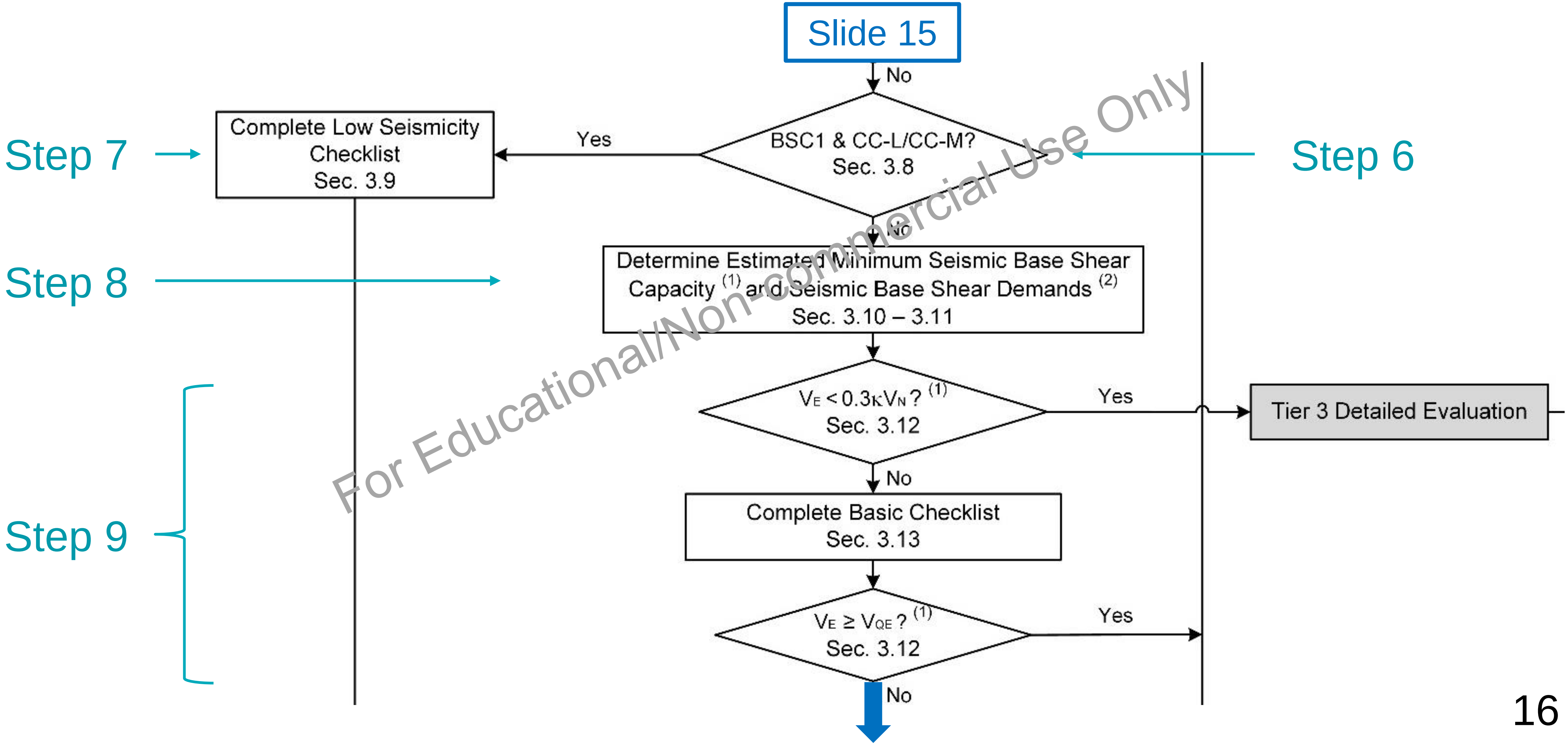
Appendix B Tier 1 Quick Evaluation Checklists

This appendix provides a set of blank Tier 1 *Quick Evaluation* checklists that assist *evaluating engineers* in identifying potential major seismic deficiencies in *existing buildings*. These checklists are organized as follows:

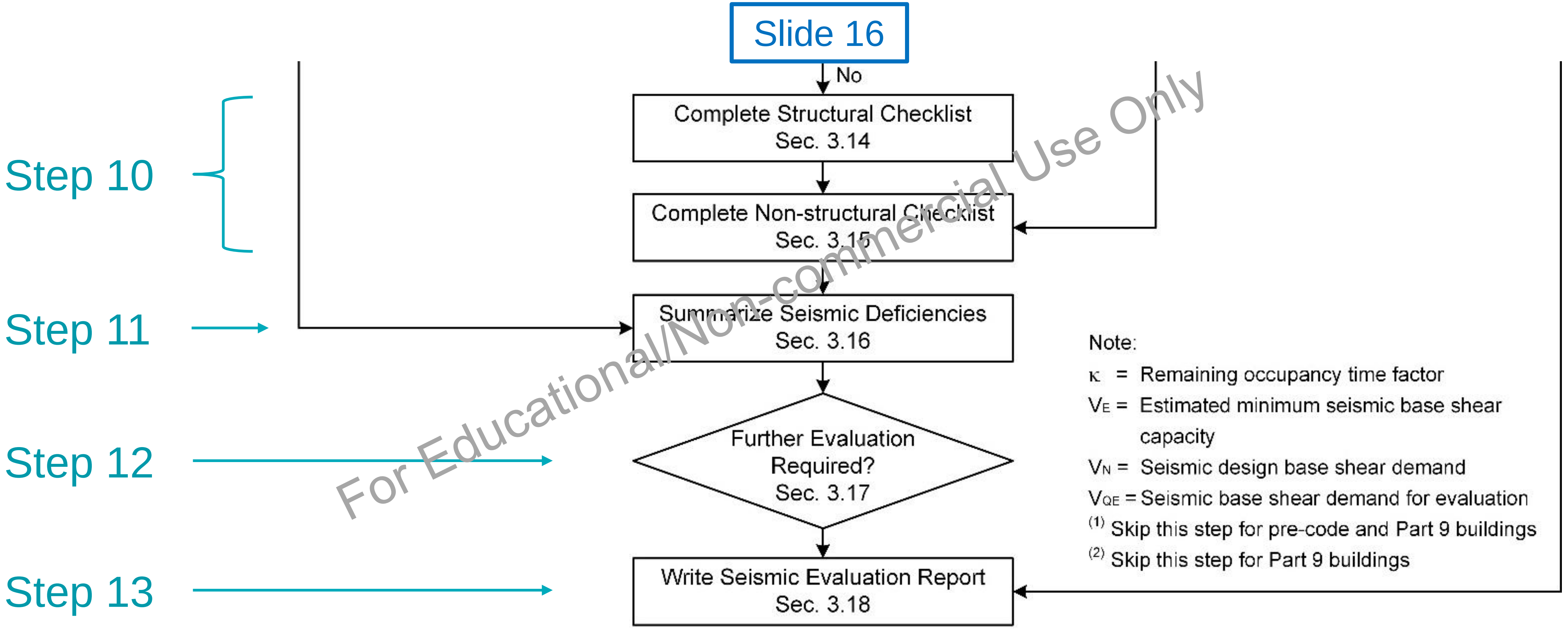
Quick Evaluation Process (Step-by-Step)



Quick Evaluation Process



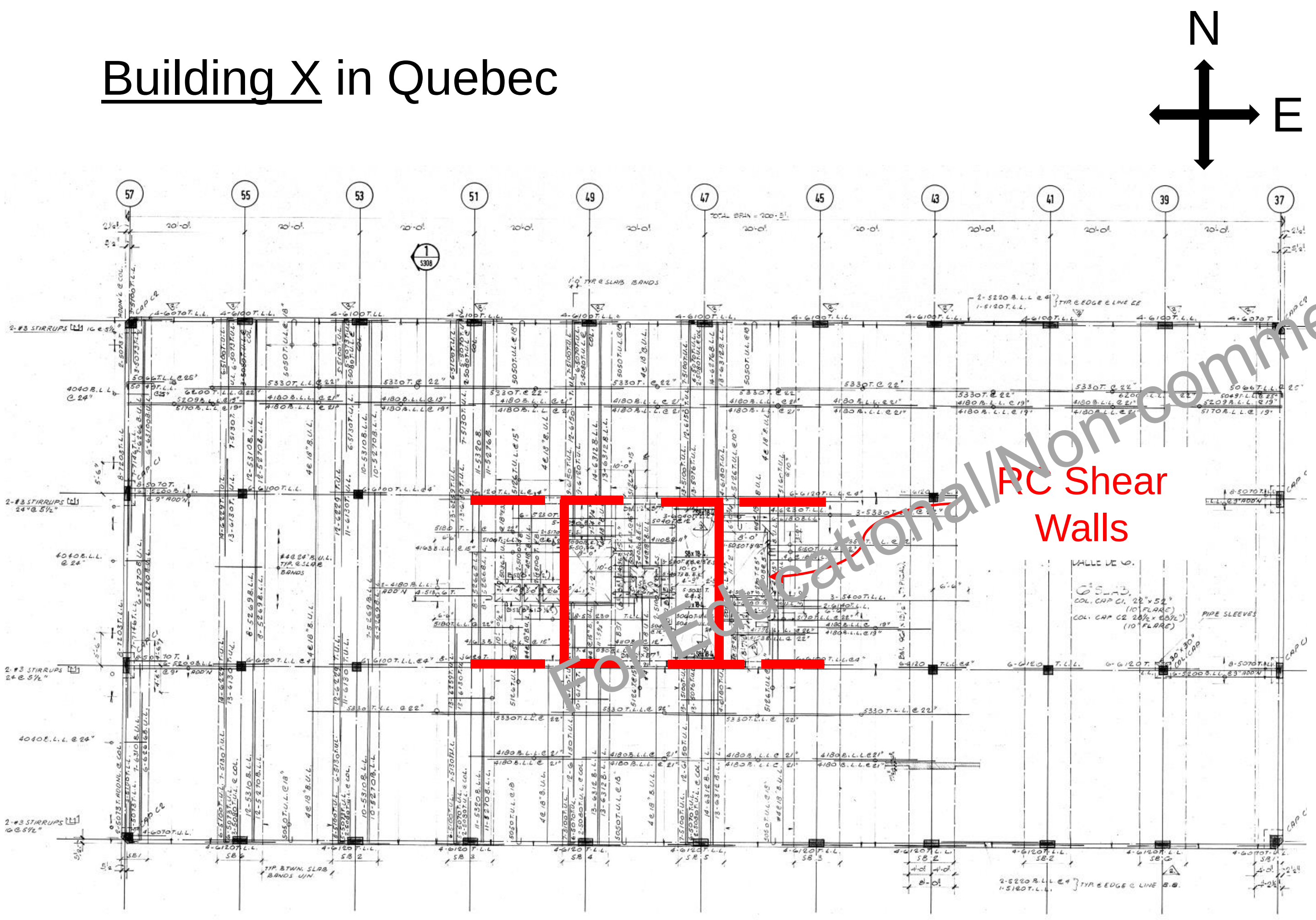
Quick Evaluation Process



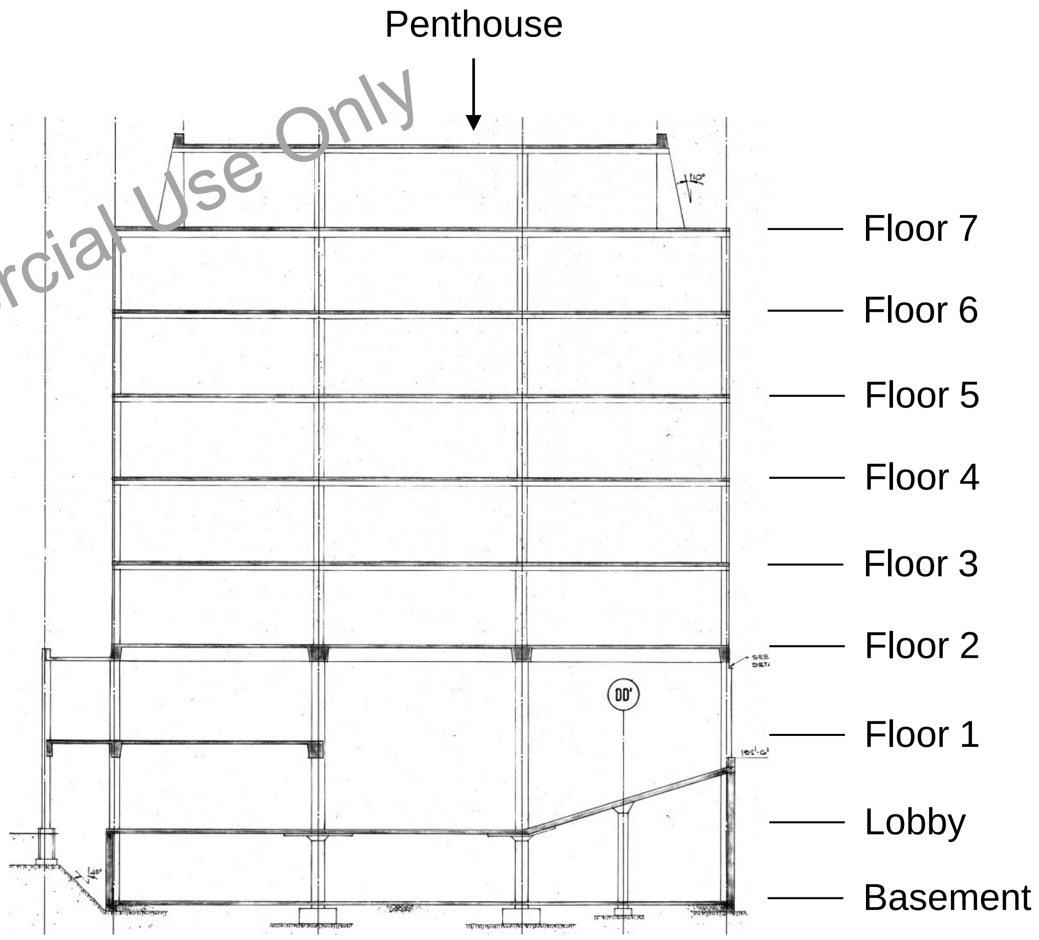
Step 1: Gather building information

Refer to Section 2.2 of Level 3 – SEG for instructions

Building X in Quebec



Typical Floor Plan



Building Elevation

Step 1: Gather building information

Building Information	
No. of storeys	8 (7 + penthouse)
Total floor area	14,700 m^2
Building use and occupancy	Office
Building height above grade	30.8 m
Year built	1977
Original design NBC	1975
SFRS	RC shear walls
Gravity-load-carrying system	RC shear walls and frames
Model building type	CSW
Site class	A
Original building importance	Normal
Building deterioration	No
Seismic upgrading	No
Geological hazard	No
Remaining occupancy time	> 10 years

Seismic Data (Site Class A)	
$S_a(0.2)$	0.436 g
$S_a(0.5)$	0.235 g
$S_a(1.0)$	0.117 g
$S_a(2.0)$	0.056 g
$S_a(5.0)$	0.015 g
PGA	0.279 g

CMF is not considered for simplicity and practicality purposes

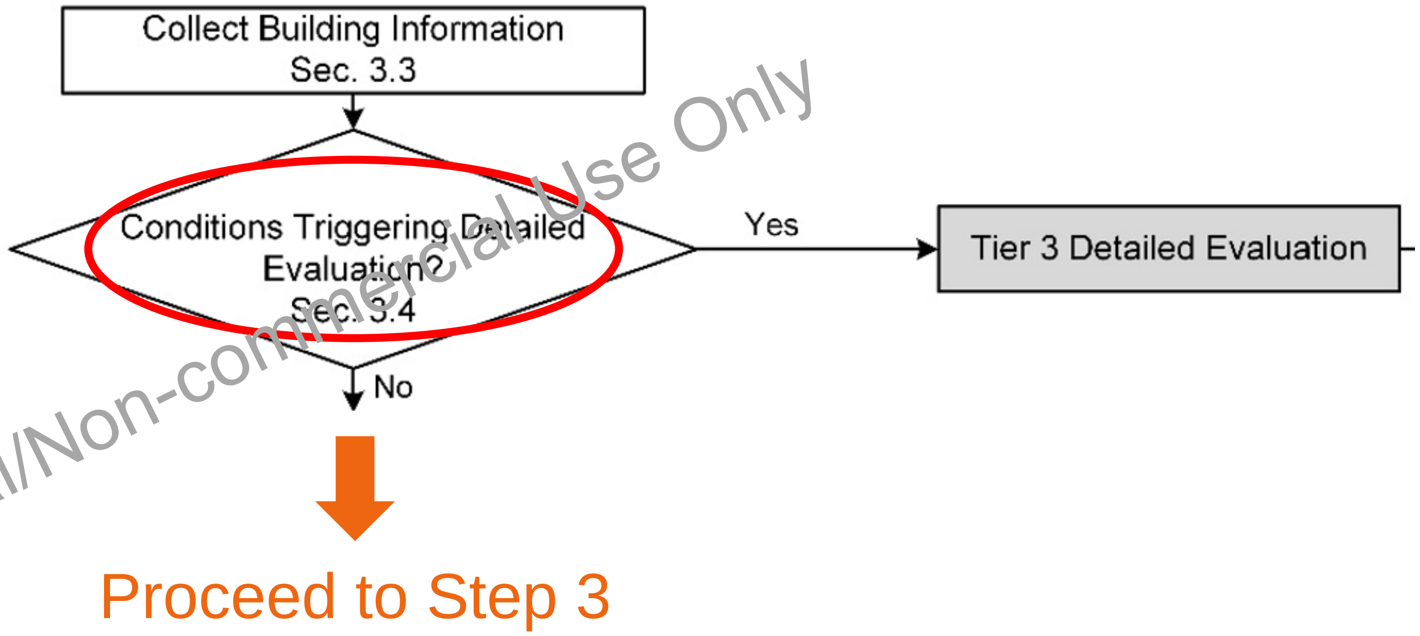
Material Properties	
Specified compressive strength of concrete (MPa)	
Footing	20.7
Slab on grade	20.7
Foundation wall	20.7
Shear wall	34.5
Slab and beam	27.6
Other	27.6
Specified yield strength of steel (MPa)	
Reinforcement steel	415

Proceed to Step 2

Step 2: Identify the presence of conditions triggering Tier 3 evaluation

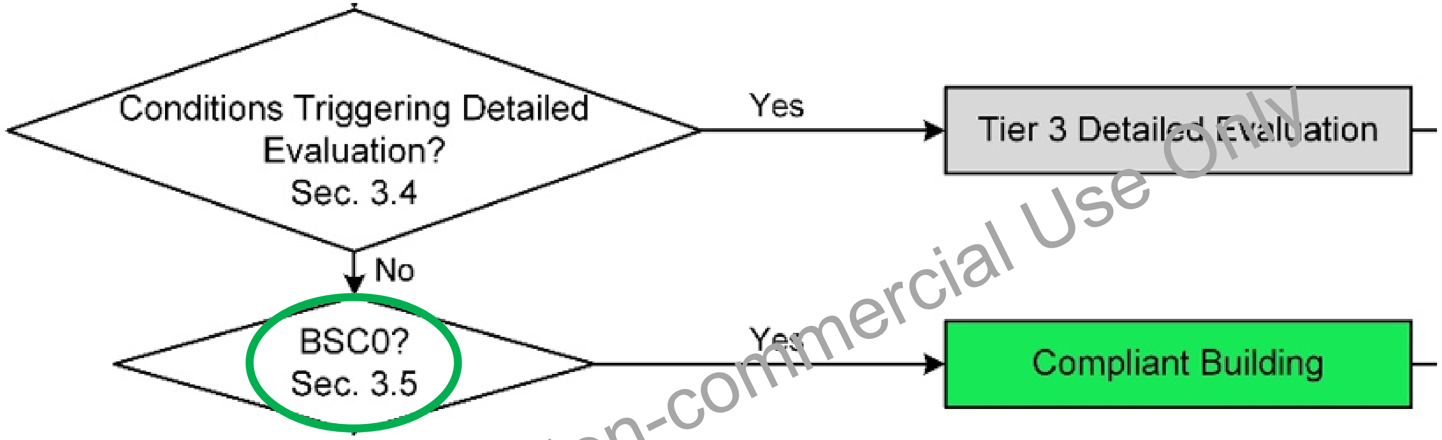
Conditions triggering Tier 3 evaluation

- Building deterioration or damage
- Unknow model building type
- Seismic isolation/supplemental energy dissipation
- Site designation F (X_F)
- Presence of any geologic hazard (e.g. landslide)



None of above conditions apply to Building X

Step 3: Determine whether seismic evaluation is required



Definitions Building Seismic Categories (BSC) in Level 3 – SEG

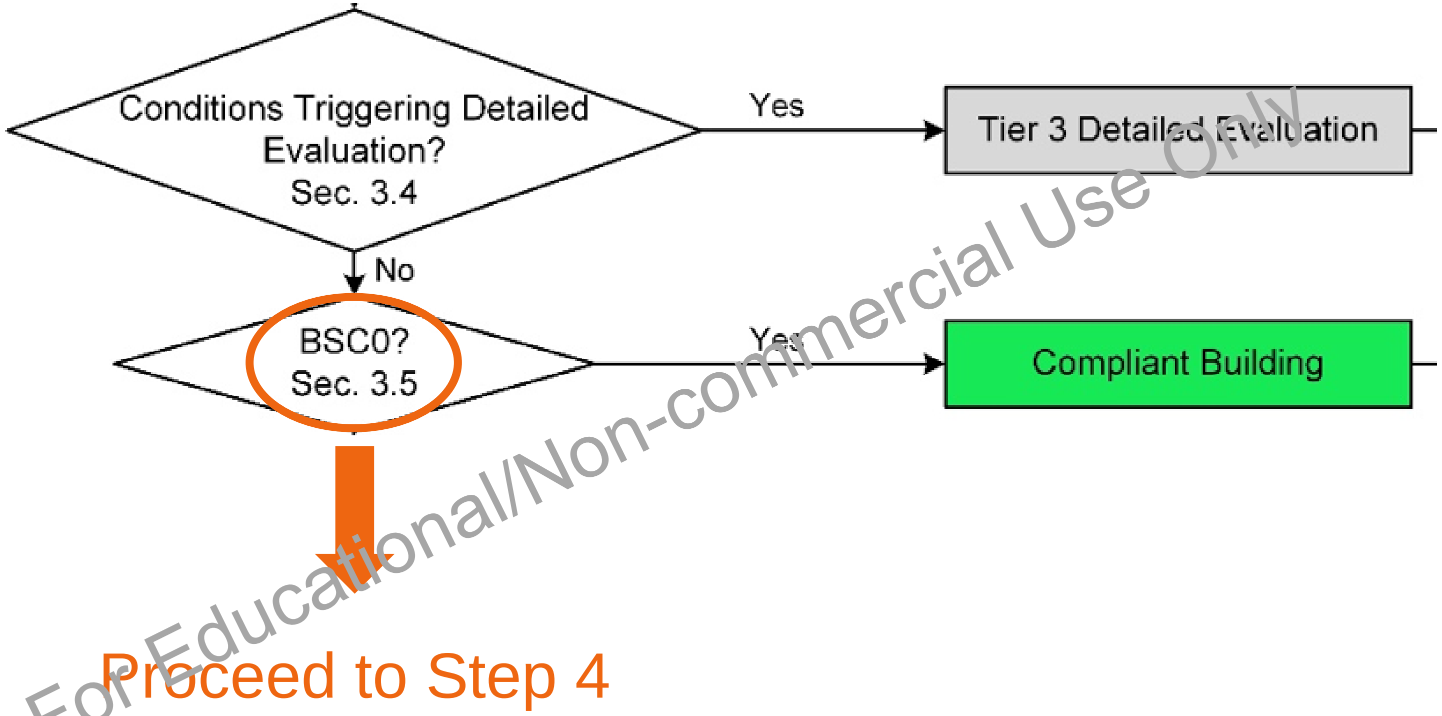
Building Seismic Category (BSC)		$I_E S(0.2)$		$I_E S(1.0)$	
		$\geq$	$<$	$\geq$	$<$
BSC0	Very Low Seismicity		0.10g		0.05g
BSC1	Low Seismicity	0.10g	0.20g	0.05g	0.10g
BSC2	Moderate Seismicity	0.20g	0.35g	0.10g	0.20g
BSC3	Moderately High Seismicity	0.35g	0.75g	0.20g	0.30g
BSC4	High Seismicity	0.75g	1.15g	0.30g	0.5g
BSC5	Very High Seismicity	1.15g		0.5g	

Step 3: Determine whether seismic evaluation is required

Building X

$I_E S(0.2) = 0.5$ g

$I_E S(0.2) = 0.2$ g

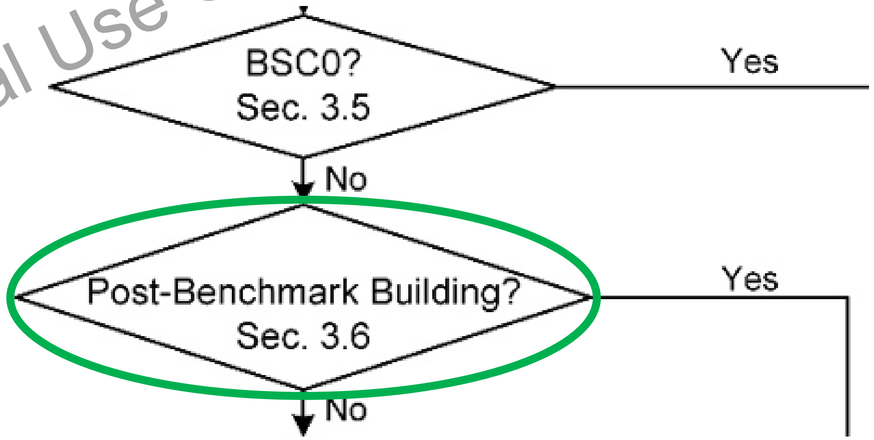


BSC3	Moderately High Seismicity	0.35g	0.75g	0.20g	0.30g
BSC4	High Seismicity	0.75g	1.15g	0.30g	0.5g
BSC5	Very High Seismicity	1.15g		0.5g	

Step 4: Determine whether structural seismic evaluation is required

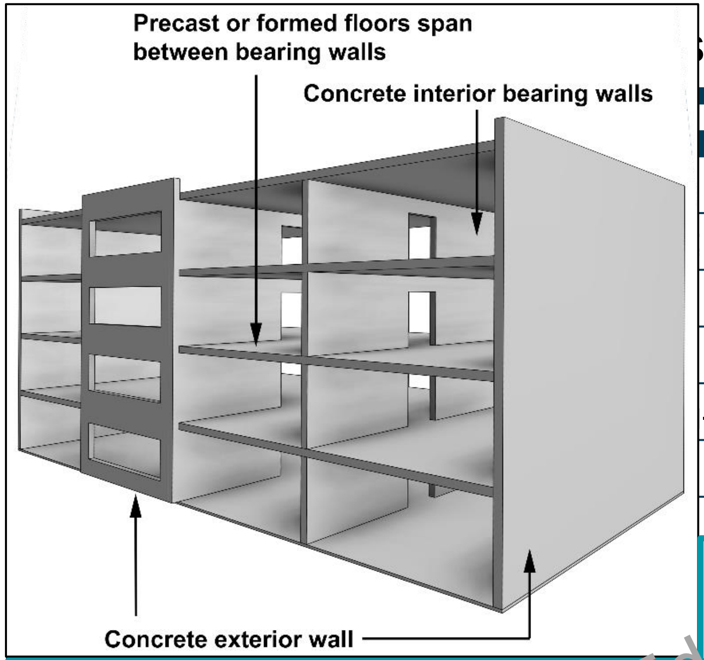
Benchmark NBC Editions of Model Building Types

Model building type	Benchmark NBC edition
WLF-P9	2010
WLF	2005 (≤ 4 storeys); 2015 (4 <storeys ≤ 6)
WPB	2005
SMF	2005
SBF	2010 (buckling-restrained braced frames); 2005 (other)
SLF	2005
SCW	2005
SIW	2005
CMF	2015 (two-way slabs without beams); 2005 (other)
CSW	2005
CIW	2005
PCW	2015
PCF (PCF1 and PCF2)	2005
RML	2005
RMC	2005
URM	2005
CFS (CFS1 and CFS2)	2010



Post-benchmark buildings are exempt from structural seismic evaluation

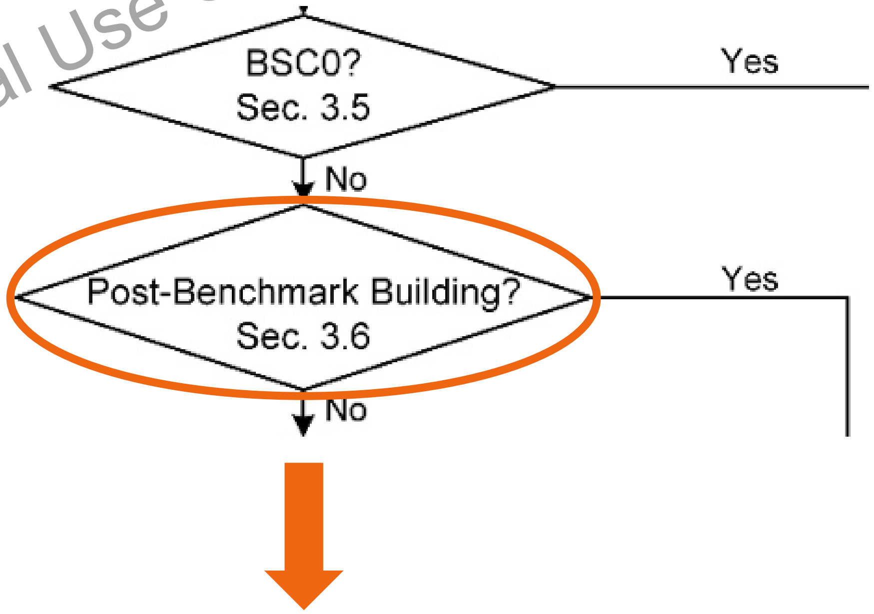
Step 4: Determine whether structural seismic evaluation is required



of Model Building Types

	Benchmark NBC edition
	2010
	4 storeys); 2015 (4 <storeys ≤ 6)
	2005
	2005
	-restrained braced frames); 2005 (other)
	2005
	2005
CSW	2005
CIW	2005
PCW	2015
PCF (PCF1 and PCF2)	2005
RML	2005
RMC	2005
URM	2005
CFS (CFS1 and CFS2)	2010

Original design code of building X
NBC 1975



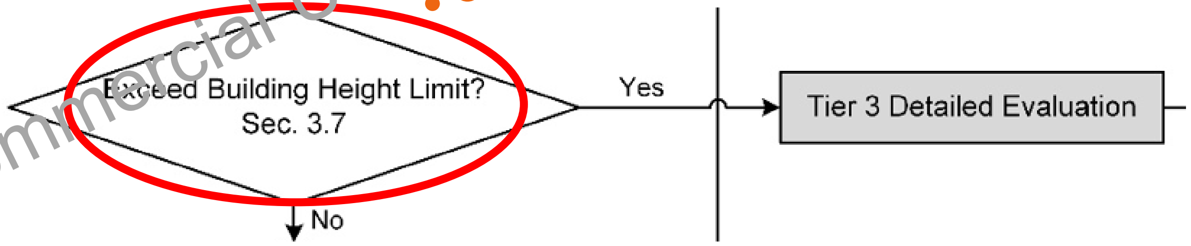
Proceed to Step 5

Step 5: Determine the conformity with building height limit

Model Building Type	Building Height Limit (m) [1]							
	BSC1		BSC2		BSC3		BSC4-5	
	CC-L or CC-M	CC-H	CC-L or CC-M	CC-H	CC-L or CC-M	CC-H	CC-L or CC-M	CC-H
WLF-P9	NL	NL	NL	NL	NL	NL	NL	10
WLF	NL	NL	NL	20	20	20	20	10
WPB	NL	NL	NL	15	15	15	15	10
SMF	NL	NL	NL	15	15	15	15	10
SBF	NL	NL	NL	15	15	15	15	10
SIW	15	15	15	15	NP	NP	NP	NP
SCW	15	15	15	15	NP	NP	NP	NP
SLF	15	15	15	15	NP	NP	NP	NP
CMF	NL	NL	NL	20	20	15	15	10
CSW	NL	NL	NL	40	40	30	30	20
CIW	15	15	15	15	NP	NP	NP	NP
PCF	25	20	20	15	NP	NP	NP	NP
PCW	25	15	10	10	NP	NP	NP	NP
RML/RMC	NL	30	30	20	NP	NP	NP	NP
URM	30	15	15	10	NP	NP	NP	NP
CFS	15	15	15	10	NP	NP	NP	NP

[1] NL = No building height limit; NP = Tier 1 and Tier 2 evaluation are not permitted.

Tier 1 evaluation is not permitted for buildings exceeding height limits



Building height limit for Building X

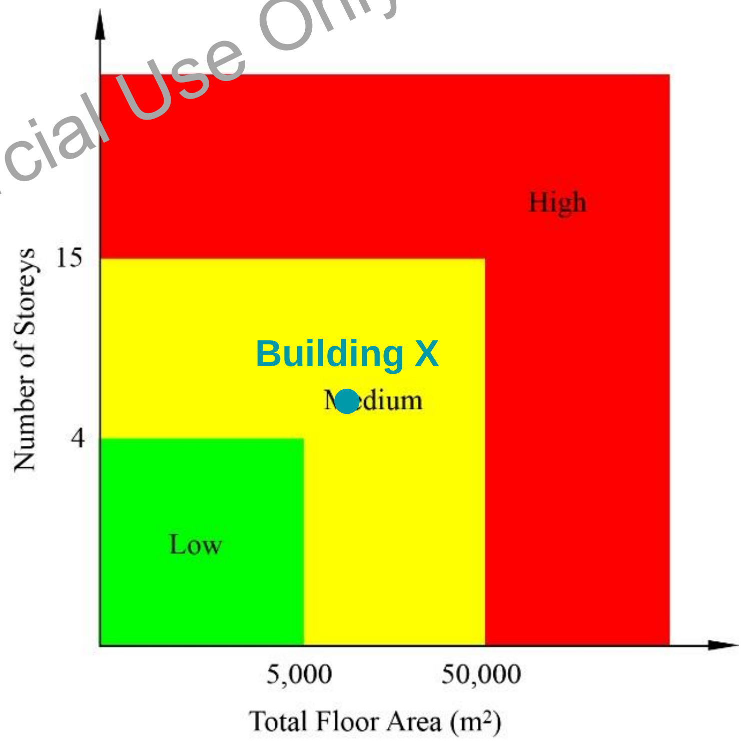
- Model building type → CSW
- Seismicity → BSC3
- Consequence class → ?

Step 5: Determine the conformity with building height limit

Model Building Type	Building Height Limit (m) [1]							
	BSC1		BSC2		BSC3		BSC4-5	
	CC-L or CC-M	CC-H	CC-L or CC-M	CC-H	CC-L or CC-M	CC-H	CC-L or CC-M	CC-H
WLF-P9	NL	NL	NL	NL	NL	NL	NL	10
WLF	NL	NL	NL	20	20	20	20	10
WPB	NL	NL	NL	15	15	15	15	10
SMF	NL	NL	NL	15	15	15	15	10
SBF	NL	NL	NL	15	15	15	15	10
SIW	15	15	15	15	NP	NP	NP	NP
SCW	15	15	15	15	NP	NP	NP	NP
SLF	15	15	15	15	NP	NP	NP	NP
CMF	NL	NL	NL	20	20	15	15	10
CSW	NL	NL	NL	40	40	30	30	20
CIW	15	15	15	15	NP	NP	NP	NP
PCF	25	20	20	15	NP	NP	NP	NP
PCW	25	15	10	10	NP	NP	NP	NP
RML/RMC	NL	30	30	20	NP	NP	NP	NP
URM	30	15	15	10	NP	NP	NP	NP
CFS	15	15	15	10	NP	NP	NP	NP

[1] NL = No building height limit; NP = Tier 1 and Tier 2 evaluation are not permitted.

Consequences of Failure of Office Buildings



CC-M

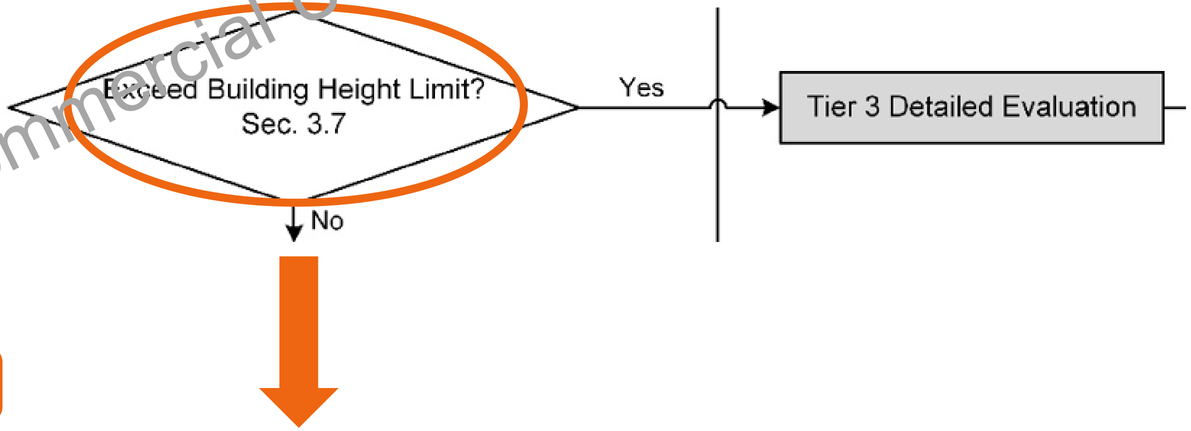
No. of storeys	8 (7 + penthouse)
Total floor area	14,700 m^2

Step 5: Determine the conformity with building height limit

Model Building Type	Building Height Limit (m) [1]							
	BSC1		BSC2		BSC3		BSC4-5	
	CC-L or CC-M	CC-H	CC-L or CC-M	CC-H	CC-L or CC-M	CC-H	CC-L or CC-M	CC-H
WLF-P9	NL	NL	NL	NL	NL	NL	NL	10
WLF	NL	NL	NL	20	20	20	20	10
WPB	NL	NL	NL	15	15	15	15	10
SMF	NL	NL	NL	15	15	15	15	10
SBF	NL	NL	NL	15	15	15	15	10
SIW	[illegible]	[illegible]	[illegible]	15	NP	NP	NP	NP
SCW	[illegible]	[illegible]	[illegible]	15	NP	NP	NP	NP
SLF	15	15	15	15	NP	NP	NP	NP
CMF	NL	NL	NL	20	[illegible]	15	15	10
CSW	NL	NL	NL	40	40	30	30	20
CIW	15	15	15	15	NP	NP	NP	NP
PCF	25	20	20	15	NP	NP	NP	NP
PCW	25	15	10	10	NP	NP	NP	NP
RML/RMC	NL	30	30	20	NP	NP	NP	NP
URM	30	15	15	10	NP	NP	NP	NP
CFS	15	15	15	10	NP	NP	NP	NP

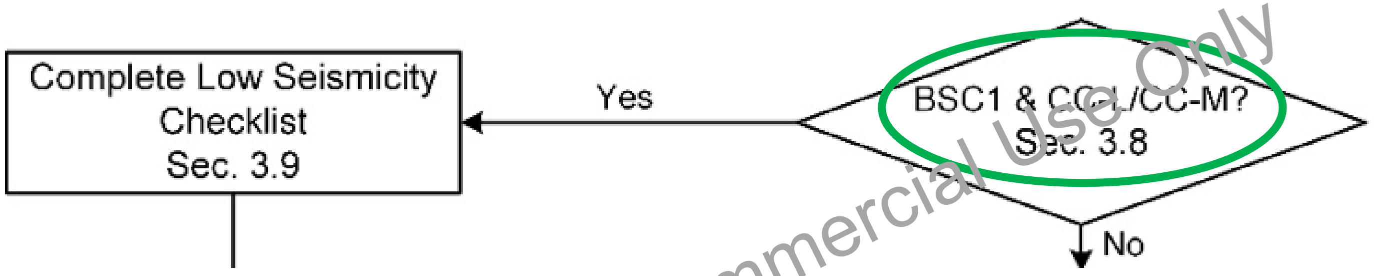
[1] NL = No building height limit; NP = Tier 1 and Tier 2 evaluation are not permitted.

Building height = 30.8 m



Proceed to Step 6

Step 6: Determine the applicability of Low Seismicity Checklist



Definitions Building Seismic Categories (BSC) in Level 3 – SEG

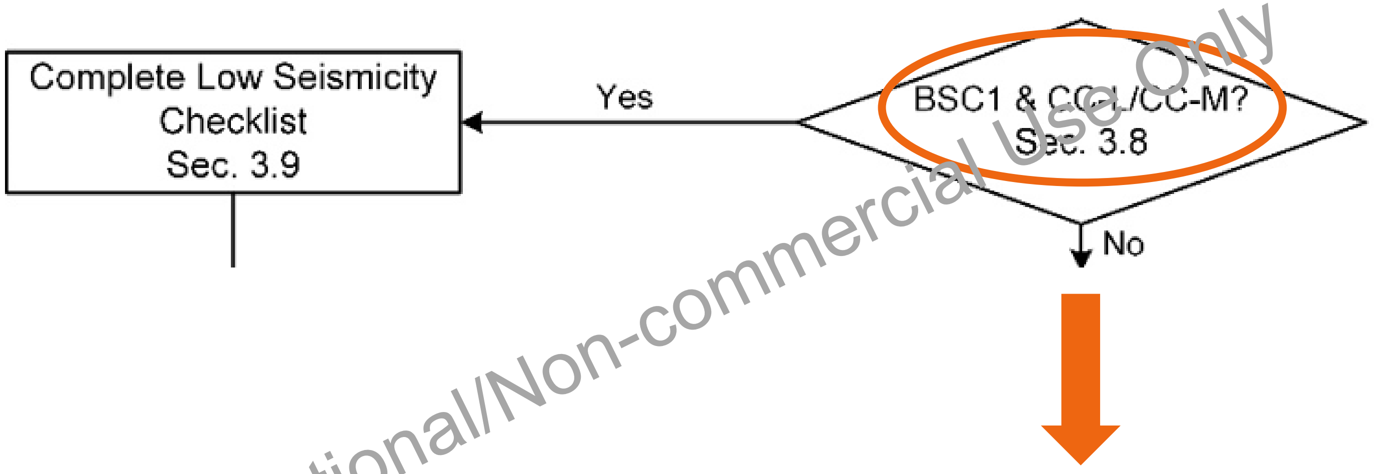
Building Seismic Category (BSC)		$I_E S(0.2)$		$I_E S(1.0)$	
		>	≤	>	≤
BSC0	Very Low Seismicity		0.10g		0.05g
BSC1	Low Seismicity	0.10g	0.20g	0.05g	0.10g
BSC2	Moderate Seismicity	0.20g	0.35g	0.10g	0.20g
BSC3	Moderately High Seismicity	0.35g	0.75g	0.20g	0.30g
BSC4	High Seismicity	0.75g	1.15g	0.30g	0.5g
BSC5	Very High Seismicity	1.15g		0.5g	

Step 6: Determine the applicability of Low Seismicity Checklist

Building X

$I_E S(0.2) = 0.5$ g

$I_E S(0.2) = 0.2$ g



Proceed to Step 8

(Step 7 is not applicable)

BSC3	Moderately High Seismicity	0.35g	0.75g	0.20g	0.30g
BSC4	High Seismicity	0.75g	1.15g	0.30g	0.5g
BSC5	Very High Seismicity	1.15g		0.5g	

Step 8: Calculate Estimated Minimum Seismic Base Shear Capacity and Seismic Base Shear Demands

Estimated Minimum Seismic Base Shear Capacity (V_E)

$$V_E = \alpha_Q V_D$$

Table 3.2: Adjusted earthquake load factor (α_Q)

NBC edition	α_Q
1941 – 1960	1.0
1965 – 1970	1.35
1975 – 1985	1.35 (Ultimate strength design);
	1.05 (Limit states design or lack of information)
1990 – present	1.0

Building X

Step 8: Calculate Estimated Minimum Seismic Base Shear Capacity and Seismic Base Shear Demands

Estimated Minimum Seismic Base Shear Capacity (V_E)

$$V_E = \alpha_Q V_D$$

→ Minimum seismic design base shear demand per original design NBC

- V_D = seismic design base shear capacity on existing documentation (if information is available)
- Otherwise, calculate V_D according to Appendix D of Level 3 – SEG

Appendix D Guidance for Calculating the Minimum Seismic Design Base Shear Demands

This appendix provides guidance for calculating the minimum seismic design base shear demand (V_D) in accordance with the applicable NBC edition that was used to design or upgrade the building under evaluation. The calculated V_D value needs to be multiplied by an adjusted earthquake load factor (α_D) to obtain the estimated minimum seismic base shear *capacity* (V_E).

Step 8: Calculate Estimated Minimum Seismic Base Shear Capacity and Seismic Base Shear Demands

V_D in East-West (E-W) direction of Building X

$$V_{D1} = 4{,}243 \text{ kN}$$

Information is available from drawings

V_D in North-South (N-S) direction of Building X

$$V_{D2} = 4{,}199 \text{ kN}$$

Step 8: Calculate Estimated Minimum Seismic Base Shear Capacity and Seismic Base Shear Demands

Estimated Seismic Base Shear Capacity (V_E) of Building X

$$V_E = \alpha_Q V_D$$

V_E in East-West (E-W) direction

$$V_{E1} = 1.05 \times 4{,}243 = 4{,}456 \text{ kN}$$

V_E in North-South (N-S) direction

$$V_{E2} = 1.05 \times 4{,}199 = 4{,}409 \text{ kN}$$

Step 8: Calculate Estimated Minimum Seismic Base Shear Capacity and Seismic Base Shear Demands

Seismic Base Shear Demand for Evaluation (V_{QE})

$$V_{QE} = \kappa \alpha_{QE} V_N$$

Remaining occupancy time (in years)

Remaining occupancy time does not apply to post-disaster buildings

$\kappa = 0.31$ for $n \leq 5$ years

$\kappa = 0.46$ for $n \leq 10$ years

$\kappa = 1.0$ for $n > 10$ years

Step 8: Calculate Estimated Minimum Seismic Base Shear Capacity and Seismic Base Shear Demands

Seismic Base Shear Demand for Evaluation (V_{QE}) of Building X

$$V_{QE} = \kappa \alpha_{QE} V_N$$

$\kappa = 1.0$, n > 10 years

Step 8: Calculate Estimated Minimum Seismic Base Shear Capacity and Seismic Base Shear Demands

Seismic Base Shear Demand for Evaluation (V_{QE})

$$V_{QE} = \kappa \alpha_{QE} V_N$$

Consequence Class – High

Inspection Quality \ Redundancy Degree	Low	Medium	High
High	0.80	0.65	0.55
Medium	0.90	0.75	0.60
Low	1.00	0.80	0.65

Consequence Class – Medium

Inspection Quality \ Redundancy Degree	Low	Medium	High
High	0.65	0.55	0.45
Medium	0.75	0.60	0.50
Low	0.80	0.65	0.55

Consequence Class – Low

Inspection Quality \ Redundancy Degree	Low	Medium	High
High	0.55	0.45	0.35
Medium	0.60	0.50	0.40
Low	0.65	0.55	0.45

Step 8: Calculate Estimated Minimum Seismic Base Shear Capacity and Seismic Base Shear Demands

Seismic Base Shear Demand for Evaluation (V_{QE}) of Building X

$$V_{QE} = \kappa \alpha_{QE} V_N$$

?

Inspection Quality \ Redundancy Degree	Low	Medium	High
High	0.80	0.65	0.55
Medium	0.90	0.75	0.60
Low	1.00	0.80	0.65

Consequence Class – High

?

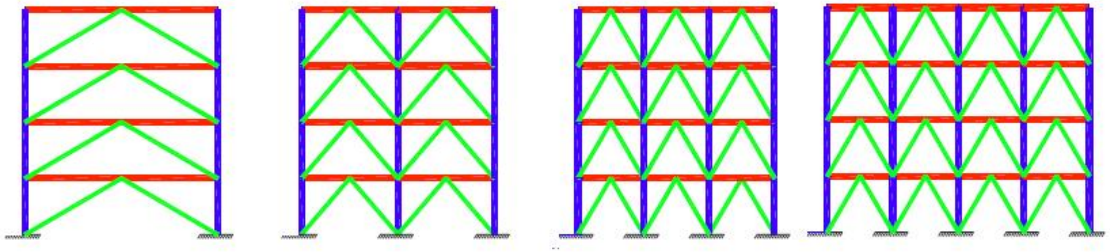
Inspection Quality \ Redundancy Degree	Low	Medium	High
High	0.65	0.55	0.45
Medium	0.75	0.60	0.50
Low	0.80	0.65	0.55

Consequence Class – Medium

Inspection Quality \ Redundancy Degree	Low	Medium	High
High	0.55	0.45	0.35
Medium	0.60	0.50	0.40
Low	0.65	0.55	0.45

Consequence Class – Low

Redundancy Degree



Redundancy Degree Classification

- Structural system
  - Number of lines of SFRS
  - Number of bays of SFRS in each line/
    Sum of length of shear walls in each line

Refer to Section 2.5 of Level 3 – SEG for instructions

Structural System	Description	Low	Medium	High
Shear wall (SW)	Number of lines of shear walls in each direction and		≥ 2 (1)	
	Ratio (r) of the sum of lengths of shear walls in each line to the storey height (2)	r < 2	2 ≤ r < 3	r ≥ 3
Moment-resisting frame (MRF)	Number of lines of moment-resisting frames in each direction and		≥ 2 (1)	
	Number of bays of moment-resisting frames in each line	1	2	≥ 3
Braced frame (BF)	Number of lines of braced frames in each direction and		≥ 2 (1)	
	Number of braced bays in each line	1	2	≥ 3
Strap-braced wall (SBW)	Number of lines of walls in each direction and		≥ 2 (1)	
	Ratio (r) of the sum of lengths of strap-braced walls in each line to the storey height (2)	r < 2	2 ≤ r < 3	r ≥ 3

(1) In cases where there is only one line of SFRS in either direction, the redundancy degree should be identified as low regardless of the number of bays or the r value. In cases where there are at least four lines of SFRS in both directions, the redundancy degree of the building can be identified as High if any of following criteria are met: (i) minimum two bays in each line of frame, or (ii) r ≥ 2.0 for each line of wall.

(2) The second largest r value should be used when determine the redundancy degree in the direction under consideration.

Redundancy Degree of Building X

Lengths of shear walls are obtained from structural drawings

Redundancy degree in E-W direction

- High

Redundancy degree in N-S direction

- Medium

Redundancy degree of building X

- Medium

Structural System	Description	Low	Medium	High
Shear wall (SW)	Number of lines of shear walls in each direction and		≥ 2 [1]	
	Ratio (r) of the sum of lengths of shear walls in each line to the storey height [2]	r < 2	2 ≤ r < 3	r ≥ 3
Moment-resisting frame (MRF)	Number of lines of moment-resisting frames in each direction and		≥ 2 [1]	
	Number of bays of moment-resisting frames in each line	1	2	≥ 3
Braced frame (BF)	Number of lines of braced frames in each direction and		≥ 2 [1]	
	Number of braced bays in each line	1	2	≥ 3
Strap-braced wall (SBW)	Number of lines of walls in each direction and		≥ 2 [1]	
	Ratio (r) of the sum of lengths of strap-braced walls in each line to the storey height [2]	r < 2	2 ≤ r < 3	r ≥ 3

[1] In cases where there is only one line of SFRS in either direction, the redundancy degree should be identified as low regardless of the number of bays or the r value. In cases where there are at least four lines of SFRS in both directions, the redundancy degree of the building can be identified as High if any of following criteria are met: (i) minimum two bays in each line of frame, or (ii) r ≥ 2.0 for each line of wall.

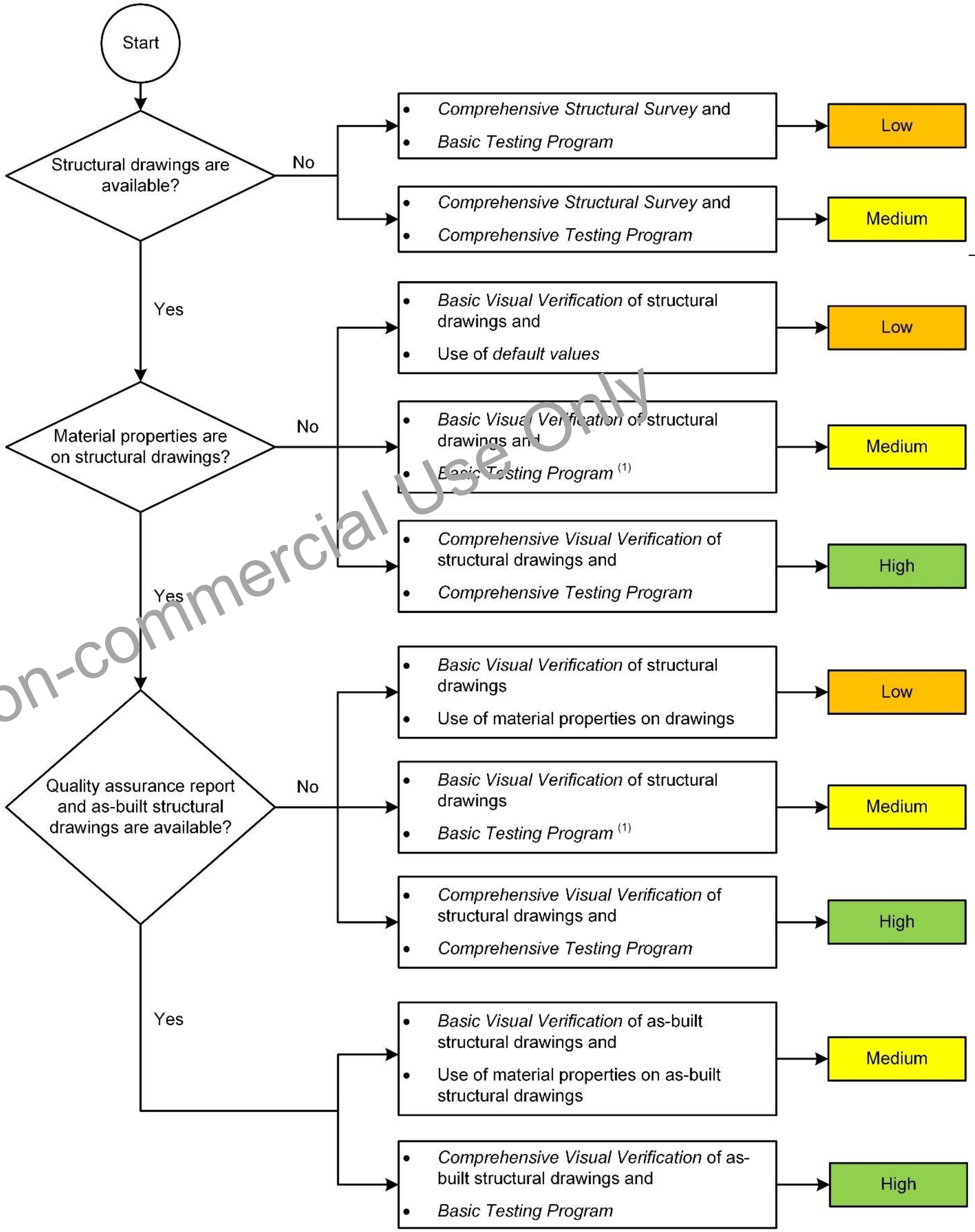
[2] The second largest r value should be used when determine the redundancy degree in the direction under consideration.

Inspection Quality

Inspection Quality Classification

- Existing construction documentation
- Visual verification/ Structural survey
- Material testing

Refer to Section 2.6 of Level 3 – SEG for instructions



(1) Default values of material properties may be used for wood or masonry structures. If that is the case, a bounding analysis must be carried out according to Section 5.3.5.

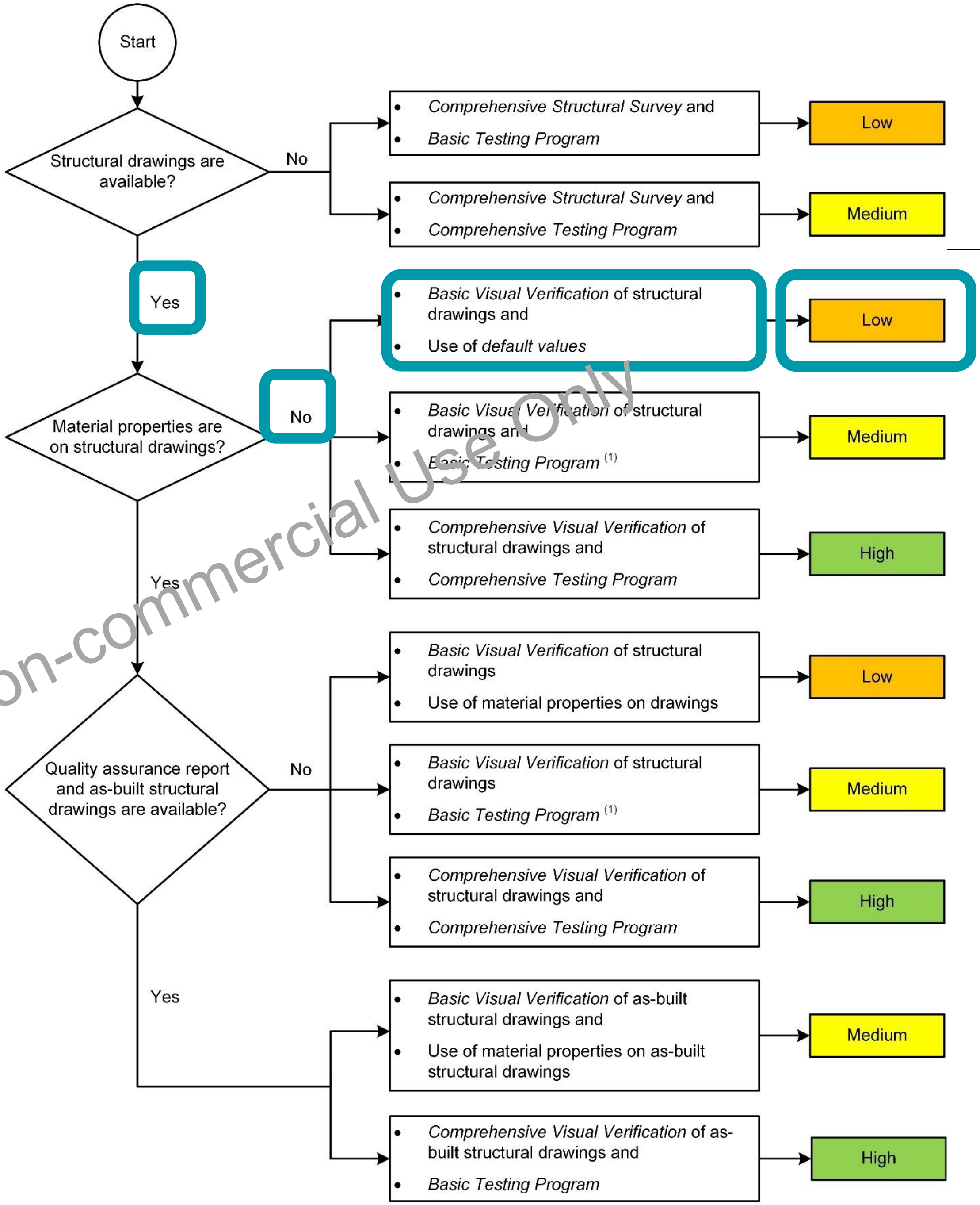
Inspection Quality of Building X

Building X

- Availability of structural drawings = Yes
- Availability of material properties = No
- Visual verification = Basic
- Material testing = No

Inspection quality of building X

- Low



(1) Default values of material properties may be used for wood or masonry structures. If that is the case, a bounding analysis must be carried out according to Section 5.3.5.

Step 8: Calculate Estimated Minimum Seismic Base Shear Capacity and Seismic Base Shear Demands

Seismic Base Shear Demand for Evaluation (V_{QE}) for Building X

$$V_{QE} = \kappa \alpha_{QE} V_N$$

Consequence Class – High

Inspection Quality \ Redundancy Degree	Low	Medium	High
High	0.80	0.65	0.55
Medium	0.90	0.75	0.60
Low	1.00	0.80	0.65

Consequence Class – Medium

Inspection Quality \ Redundancy Degree	Low	Medium	High
High	0.65	0.55	0.45
Medium	0.75	0.60	0.50
Low	0.80	0.65	0.55

Consequence Class – Low

Inspection Quality \ Redundancy Degree	Low	Medium	High
High	0.55	0.45	0.35
Medium	0.60	0.50	0.40
Low	0.65	0.55	0.45

Step 8: Calculate Estimated Minimum Seismic Base Shear Capacity and Seismic Base Shear Demands

Seismic Base Shear Demand for Evaluation (V_{QE}) for Building X

$$V_{QE} = 1.0 \times 0.65 \times V_N$$

$$V_N = \frac{S(T_a) M_V I_E W}{R_d R_o}$$

Parameter	Value
$T_a = 0.05\ h^{3/4}$	0.703
$S(T_a)$	0.188
M_V	1.0
I_E	1.0
W	156,000 kN
R_d	**?**
R_o	**?**

Accurate weight calculation is important for reliable evaluation

Step 8: Calculate Estimated Minimum Seismic Base Shear Capacity and Seismic Base Shear Demands

Values of equivalent R_d and R_o for Building X

NBC edition	R_d	R_o
Pre – 1965	1.0	1.0
1965	$\dfrac{\text{Min}\left(\frac{1}{C}, 1.35\right)}{1.35}$	1.0
1970	$\dfrac{\text{Min}\left(\frac{6.8}{K}, 1.35R_d\right)}{1.35}$	1.0
1975 – 1985	$\dfrac{\text{Min}\left(\frac{6.8}{K}, 1.5R_d\right)}{1.5}$	1.0
1990 and 1995	Min(R, R_d)	1.0
2005 – present	R_d	R_o

K = 0.8 for ductile dual system per NBC 1975

R_d = 1.5 for conventional construction

Step 8: Calculate Estimated Minimum Seismic Base Shear Capacity and Seismic Base Shear Demands

Seismic Base Shear Demand for Evaluation (V_{QE}) of Building X

$$V_{QE} = 1.0 \times 0.65 \times V_N$$

Parameter	Value
$T_a = 0.05\ h^{3/4}$	0.703
$S(T_a)$	0.188
M_V	1.0
I_E	1.0
W	156,000 kN
R_d	1.5
R_o	1.0

$$V_N = \frac{S(T_a)M_V I_E W}{R_d R_o} = 19{,}552 \text{ kN}$$

$$V_{N,min} = \frac{S(4.0)\ M_V I_E W}{R_d R_o} = 2{,}985 \text{ kN}$$

$$V_{N,max} = \text{Max}\left(\frac{\frac{2}{3}S(0.2)I_E W}{R_d R_o}, \frac{S(0.5)I_E W}{R_d R_o}\right) = 30{,}229 \text{ kN}$$

Step 8: Calculate Estimated Minimum Seismic Base Shear Capacity and Seismic Base Shear Demands

Seismic Base Shear Demand for Evaluation (V_{QE}) of Building X

$$V_{QE} = 1.0 \times 0.65 \times V_N$$

$$= 1.0 \times 0.65 \times 19{,}552 = 12{,}709 \text{ kN}$$

↓

Proceed to Step 9

Step 9: Select Appropriate Quick Evaluation Checklists

Criteria for Selecting Appropriate Quick Evaluation Checklists

$V_E \geq V_{QE}$ ➡ Basic Configuration + Non-structural

$0.3\kappa V_N \leq V_E < V_{QE}$ ➡ Basic Configuration + Structural + Non-structural

$V_E < 0.3\kappa V_N$ ➡ Skip Checklists & → Tier 3 Detailed Evaluation

Building X

$V_{E1} = 4{,}456$ kN

$V_{E2} = 4{,}409$ kN

< $0.3\kappa V_N = 5{,}866$ kN

Step 9: Select Appropriate Quick Evaluation Checklists

Criteria for Selecting Appropriate Quick Evaluation Checklists

For illustrative purposes

$V_E \geq V_{QE}$	→	Basic Configuration + Non-structural
$0.3\kappa V_N \leq V_E < V_{QE}$	→	Basic Configuration + Structural + Non-structural
$V_E < 0.3\kappa V_N$	→	Skip Checklists & → Tier 3 Detailed Evaluation

→ Proceed to Step 10

Step 10: Completion of Quick Evaluation Checklists

Basic Configuration & Structural Checklists for Building X

BSC where the building is located	Evaluation statements for CC-L/ CC-M buildings	Additional evaluation statements for CC-H buildings
BSC1 (Low Seismicity)	N/A [1]	BSC2
BSC2 (Moderate Seismicity)	BSC2	BSC3
BSC3 (Moderately High Seismicity)	BSC2-3	BSC4
BSC4 (High Seismicity)	BSC2-4	BSC5
BSC5 (Very High Seismicity)	BSC2-5	N/A

[1] Basic Configuration Checklist and Structural Checklists do not apply to CC-L or CC-M buildings in BSC1. Instead, the Low Seismicity Checklist should be selected and completed according to Section 3.9.

Table above does not apply to the Non-structural Checklist

Step 10: Completion of Basic Configuration Checklist

Load Path

There are clearly defined load paths that transfer inertial forces to foundation and supporting ground.

Table B.2: Basic Configuration Checklist for CC-L or CC-M buildings

Status	Evaluation Statement	Tier 2 Evaluation Reference	Commentary Reference
Moderate Seismicity (BSC2)			
Building System Characteristics			
☒ C ☐ NC ☐ N/A ☐ U	LOAD PATH: The structure has a clearly defined load path (or paths), including structural elements and connections, that transfers the inertial forces generated by the earthquake to the foundations and supporting ground.	Sec. 4.4.1	Sec. C.2.1
☐ C ☐ NC ☐ N/A ☐ U	REDUNDANCY: The building has a required degree of redundancy as per Table 3.5.	Sec. 4.4.1	Sec. C.2.1
☐ C ☐ NC ☐ N/A ☐ U	ADJACENT BUILDINGS: The clear distance between the building under evaluation and any adjacent building is greater than 0.1% of the height of the shorter building in Low Seismicity (BSC1), 0.2% in Moderate Seismicity (BSC2), 0.4% in Moderately High Seismicity (BSC3), and 1.2% in High and Very High Seismicity (BSC4-5).	Sec. 4.4.1	Sec. C.2.1
☐ C ☐ NC ☐ N/A ☐ U	MEZZANINES: Interior mezzanine levels have independent SFRS from the main structure or are anchored to the SFRS of the main structure.	Sec. 4.4.1	Sec. C.2.1

Step 10: Completion of Basic Configuration Checklist

Table 3.5: Required minimum redundancy degree for conducting a Tier 1 evaluation

Model building type	Structural system (1) & redundancy degree	BSC1		BSC2		BSC3		BSC4-5	
		CC-L& CC-M	CC-H	CC-L& CC-M	CC-H	CC-L& CC-M	CC-H	CC-L& CC-M	CC-H
WLF-P9, WLF, WPB SCW, SIW, CSW, CIW, PCW, PCF1, RML, RMC, URM, CFS1	SW (Low)	N/A	✓	✓					
	SW (Med.)				✓	✓		✓	
	SW (High)						✓		✓

Redundancy

The redundance degree of the building is Medium, which complies with Table 3.5.

☒ C ☐ NC ☐ N/A ☐ U	LOAD PATH: The structure has a clearly defined load path (or paths), including structural elements and connections, that transfers the inertial forces generated by the earthquake to the foundations and supporting ground.	Sec. 4.4.1	Sec. C.2.1
☒ C ☐ NC ☐ N/A ☐ U	REDUNDANCY: The building has a required degree of redundancy as per Table 3.5.	Sec. 4.4.1	Sec. C.2.1

Step 10: Completion of Basic Configuration Checklist

Adjacent Buildings

Building X is well separated from adjacent buildings.

☒ C ☐ NC ☐ N/A ☐ U	ADJACENT BUILDINGS: The clear distance between the building under evaluation and any adjacent building is greater than 0.1% of the height of the shorter building in Low Seismicity (BSC1), 0.2% in Moderate Seismicity (BSC2), 0.4% in Moderately High Seismicity (BSC3), and 1.2% in High and Very High Seismicity (BSC4-5).	Sec. 4.4.1	Sec. C.2.1
☐ C ☐ NC ☒ N/A ☐ U	MEZZANINES: Interior mezzanine levels have independent SFRS from the main structure or are anchored to the SFRS of the main structure.	Sec. 4.4.1	Sec. C.2.1

Step 10: Completion of Basic Configuration Checklist

Discontinuity in Capacity

Concrete shear walls are continuous from the roof to foundation.

Vertical Stiffness Irregularity

Wall dimensions and thicknesses are consistent from the roof to foundation.

Building Irregularities			
☒ C ☐ NC ☐ N/A ☐ U	DISCONTINUITY IN CAPACITY – WEAK STOREY: The storey shear capacity is not less than that in the storey above. The storey shear capacity is the total capacity of all seismic-resisting elements of the SFRS sharing the storey shear for the direction under consideration.	Sec. 4.4.2	Sec. C.2.2
☒ C ☐ NC ☐ N/A ☐ U	VERTICAL STIFFNESS IRREGULARITY: The lateral stiffness of the SFRS in a storey is not less than 70% of the stiffness of any adjacent storey, or not less than 80% of the average stiffness of the three storeys above or below.	Sec. 4.4.2	Sec. C.2.2

<u>Step 10</u>: Completion of Basic Configuration Checklist

Vertical Geometric Irregularity

Wall dimensions are consistent along building height.

Vertical Irregularities

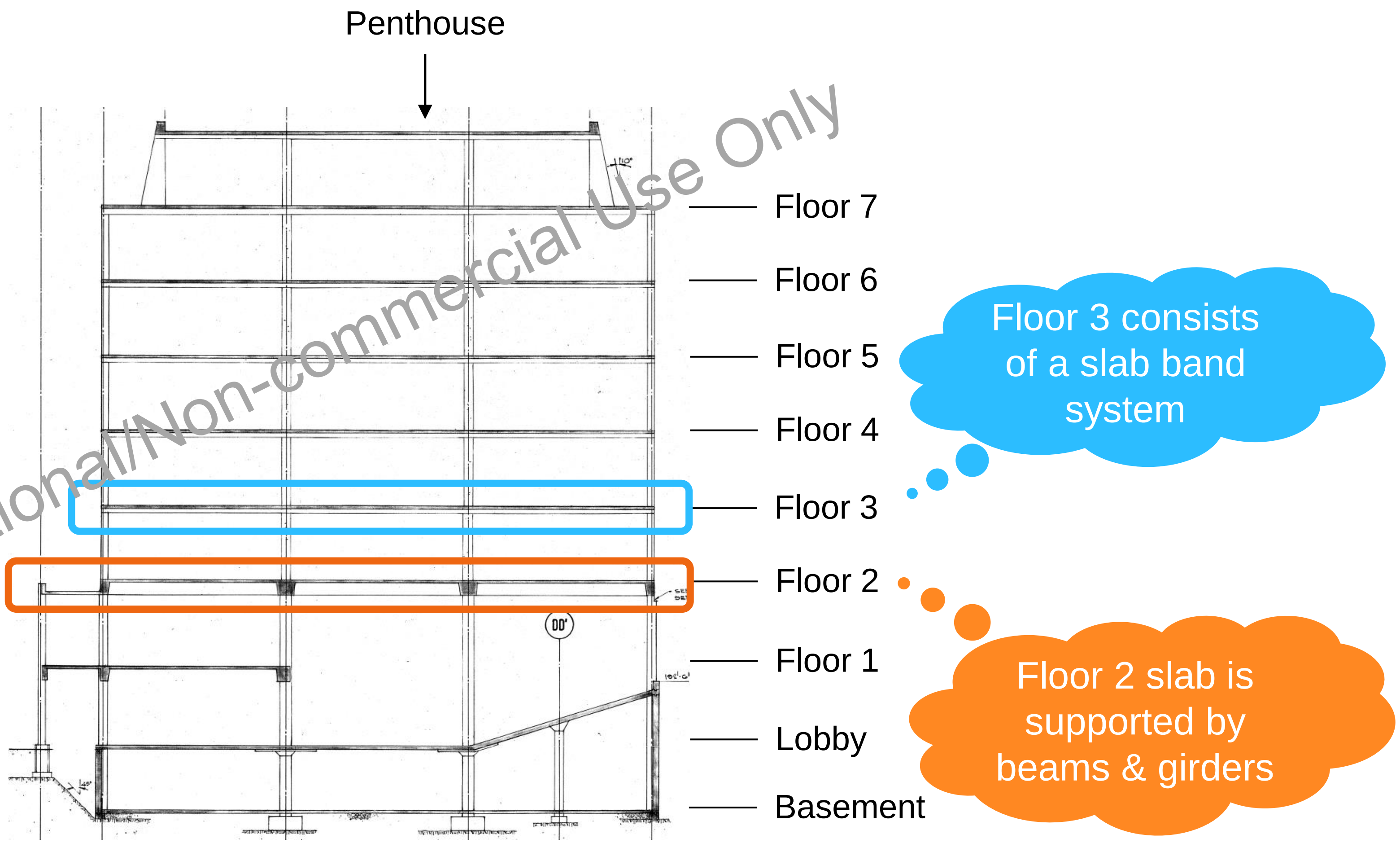
All vertical elements in the SFRS are continuous to the foundation.

Status	Evaluation Statement	Tier 2 Evaluation Reference	Commentary Reference
☒ C ☐ NC ☐ N/A ☐ U	VERTICAL GEOMETRIC IRREGULARITY: The horizontal dimension of the SFRS in any storey is not more than 130% of that in an adjacent storey, excluding one-storey penthouses and mezzanines.	Sec. 4.4.2	Sec. C.2.2
☐ C ☐ NC ☐ N/A ☐ U	WEIGHT (MASS) IRREGULARITY: The weight of any storey is not more than 150% of the weight of an adjacent storey. Roofs that are lighter than the floors below, penthouses, and mezzanines need not be considered.	Sec. 4.4.2	Sec. C.2.2
☒ C ☐ NC ☐ N/A ☐ U	VERTICAL DISCONTINUITIES: All vertical elements in the seismic-force-resisting system are continuous to the foundation.	Sec. 4.4.2	Sec. C.2.2

Step 10: Completion of Basic Configuration Checklist

Weight (Mass) Irregularity

The calculated weight of Floor 2 is greater than 150% of the weight of Floor 3.



Building Elevation

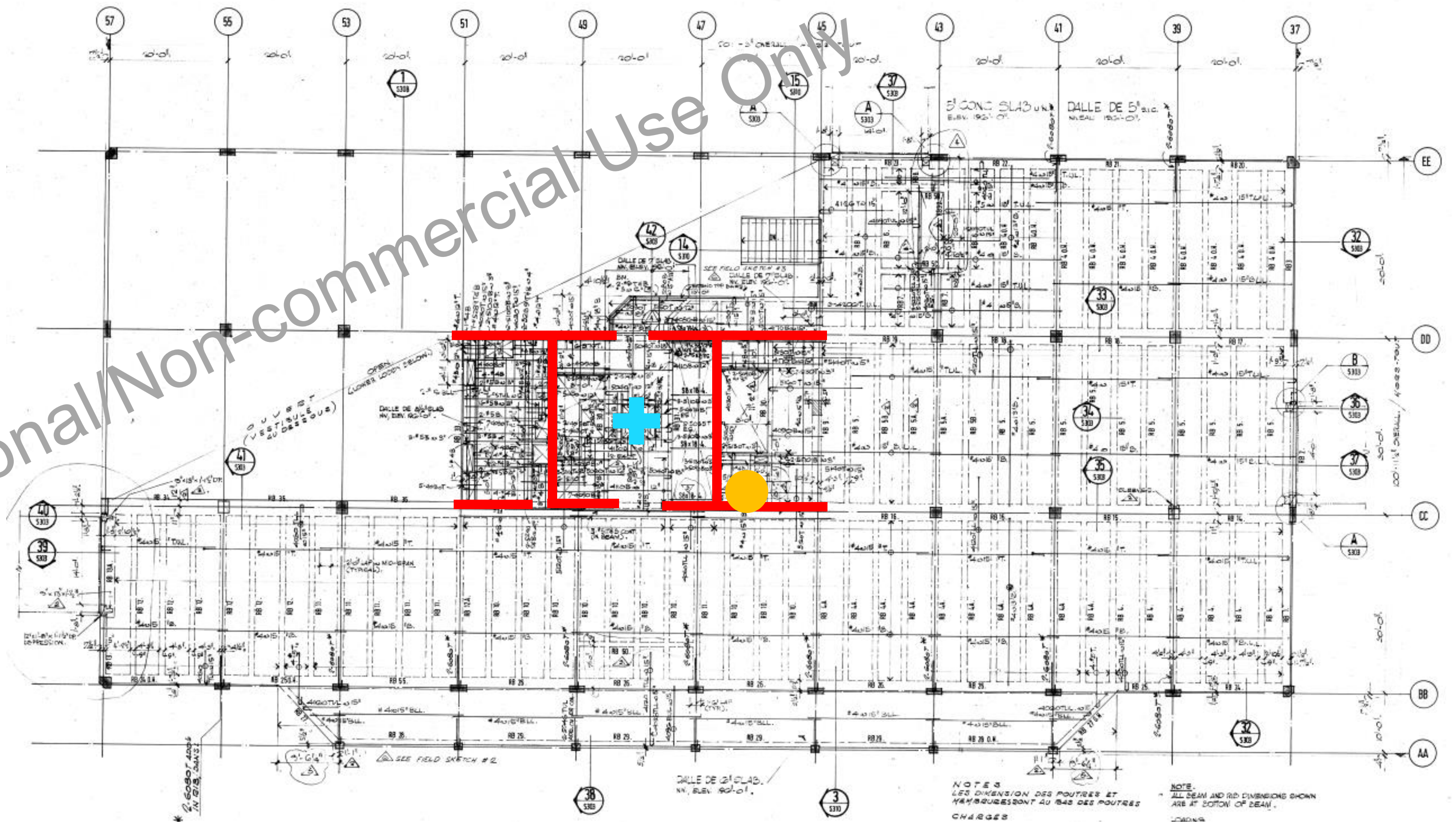
Step 10: Completion of Basic Configuration Checklist

N
E

Floor 1 Plan

Torsional Irregularity

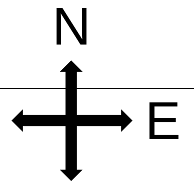
The largest distance between CR and CM occurs at Floor 1 where some slabs are missing.



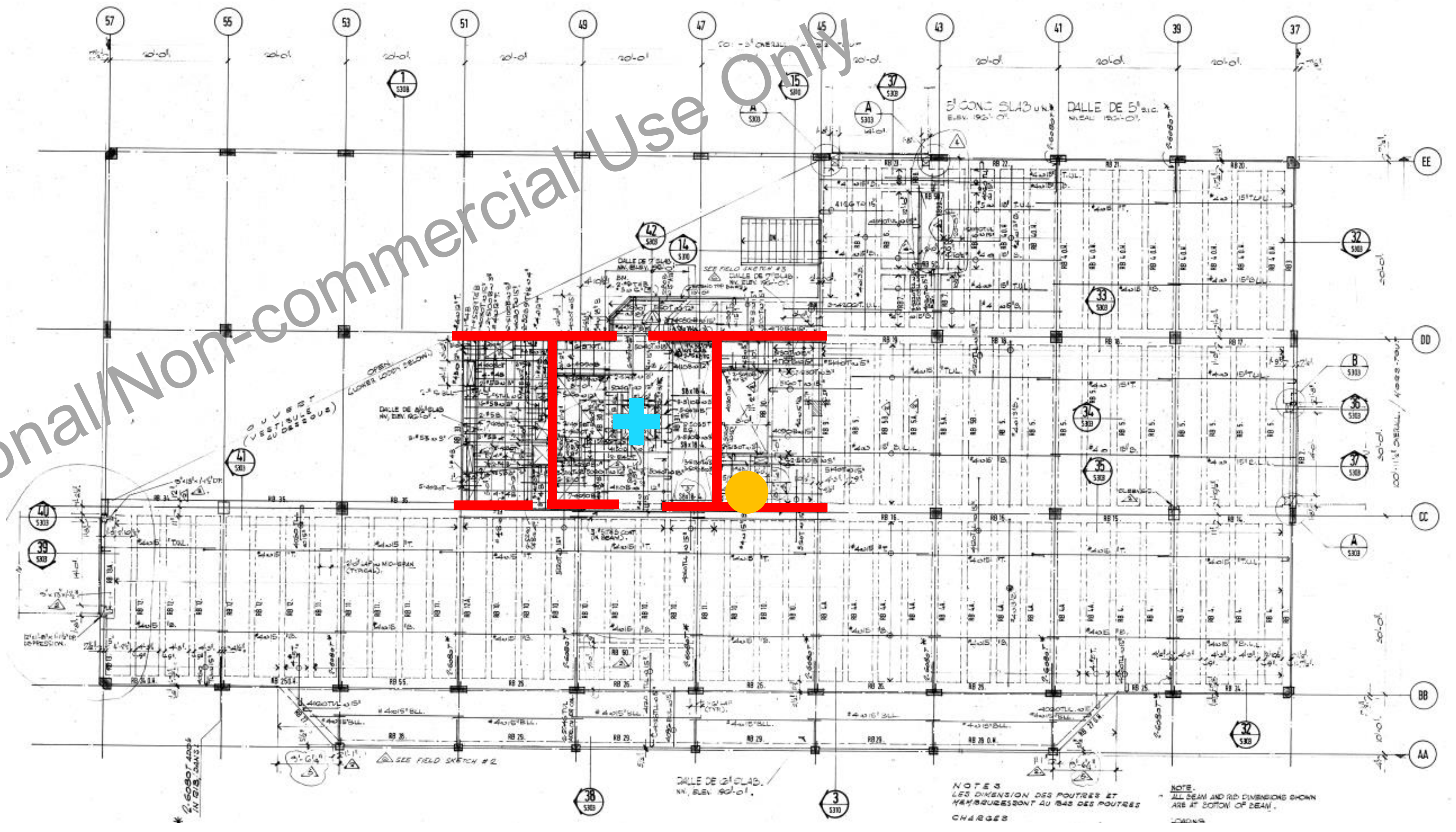
Centre of rigidity

Centre of mass

Step 10: Completion of Basic Configuration Checklist



Floor 1 Plan



Centre of rigidity
Centre of mass

Torsional Irregularity

The largest distance between CR and CM occurs at Floor 1 where some slabs are missing. The calculated relative distance is **15%** in E-W direction and **12%** in N-S direction. Both values are smaller than the 20% threshold.

Step 10: Completion of Basic Configuration Checklist

Liquefaction

The building is located on hard rock (Site Class A).

Moderately High Seismicity (BSC3) (Complete the Following Items in Addition to the Items for Moderate Seismicity)			
Foundation Configuration			
☐ C ☐ NC ☒ N/A ☐ U	TIES BETWEEN FOUNDATION ELEMENTS: Individual piles or pile caps, drilled piers, and caissons are interconnected by continuous ties in not less than two directions, or are located on soils classified as X_A, X_B, or X_C.	Sec. 4.5.1	Sec. C.3.1
Geologic Hazards			
☒ C ☐ NC ☐ N/A ☐ U	LIQUEFACTION: Liquefaction-susceptible, saturated, loose granular soils that could jeopardize the building's seismic performance do not exist in the foundation soils at depths within 15 m under the building.	Sec. 4.5.2	Sec. C.3.2

Step 10: Completion of Basic Configuration Checklist

Status	Evaluation Statement	Tier 2 Evaluation Reference	Commentary Reference
☒ C ☐ NC ☐ N/A ☐ U	SLOPE FAILURE: The building is not located on or adjacent to slopes susceptible to slides or rockfalls.	Sec. 4.5.2	Sec. C.3.2
☒ C ☐ NC ☐ N/A ☐ U	SURFACE FAULT RUPTURE: Surface fault rupture and surface displacement at the building site are not anticipated.	Sec. 4.5.2	Sec. C.3.2

Slope Failure

No slope is present in the proximity of the building

Surface Fault Rupture

No surface fault rupture or surface displacement are anticipated.

Geotechnical investigation recommended to confirm

Step 10: Completion of Structural Checklist

Complete Frames

Concrete frames form a complete gravity-load-carrying system.

Reinforcing Steel

The calculated ratio of reinforcing steel is equal to 0.0021 in both horizontal and vertical directions.

Table B.11: Structural Checklist for CC-L or CC-M CSW buildings

Status	Evaluation Statement	Tier 2 Evaluation Reference	Commentary Reference
Moderate Seismicity (BSC2) and			
Moderately High Seismicity (BSC3)			
Seismic-Force-Resisting System			
☒ C ☐ NC ☐ N/A ☐ U	COMPLETE FRAMES: Steel or concrete frames that are not considered to be part of the SFRS form a complete gravity-load-resisting system.	Sec. 4.6.1.5	Sec. C.4.1.5
☐ C ☐ NC ☐ N/A ☐ U	SHEAR STRESS CHECK: The shear stress in the concrete shear walls, calculated by Eq. (3.8) in Section 3.14.2.2.2, is less than the greater of 0.52 MPa or $0.18\phi_c\sqrt{f_c'}$.	Sec. 4.6.2.1	Sec. C.4.2.1
☒ C ☐ NC ☐ N/A ☐ U	REINFORCING STEEL: The ratio of reinforcing steel area to gross concrete area is not less than 0.0015 in the vertical direction and 0.002 in the horizontal direction.	Sec. 4.6.2.1	Sec. C.4.2.1

Step 10: Completion of Structural Checklist

Shear Stress Check

The calculated average shear stresses exceed the threshold in the majority of shear walls .

$$v_j^{avg} = \frac{V_j}{A_w}$$

$$V_j = \sum_{x=j}^{n_s} F_x$$

$$F_x = (V_{QE} - F_t)W_x h_x / (\sum_{i=1}^{n_s} W_i h_i)$$

$$F_t = 0.07 T_a V_{QE}$$

Table B.11: Structural Checklist for CC-L or CC-M CSW buildings

Status	**Evaluation Statement**	**Tier 2 Evaluation Reference**	**Commentary Reference**
Moderate Seismicity (BSC2) and			
Moderately High Seismicity (BSC3)			
Seismic-Force-Resisting System			
☒ C ☐ NC ☐ N/A ☐ U	COMPLETE FRAMES: Steel or concrete frames that are not considered to be part of the SFRS form a complete gravity-load-resisting system.	Sec. 4.6.1.5	Sec. C.4.1.5
☐ C ☒ NC ☐ N/A ☐ U	SHEAR STRESS CHECK: The shear stress in the concrete shear walls, calculated by Eq. (3.8) in Section 3.14.2.2.2, is less than the greater of 0.52 MPa or $0.18\phi_c\sqrt{f_c'}$.	Sec. 4.6.2.1	Sec. C.4.2.1
☐ C ☐ NC ☐ N/A ☐ U	REINFORCING STEEL: The ratio of reinforcing steel area to gross concrete area is not less than 0.0015 in the vertical direction and 0.002 in the horizontal direction.	Sec. 4.6.2.1	Sec. C.4.2.1

Step 10: Completion of Structural Checklist

Transfer to Shear Walls

The building was constructed using cast-in-place concrete. There is no gap between the slab and shear walls.

Foundation Dowels

The reinforcing steel in concrete shear walls is directly doweled into the foundation with equal size and spacing.

Connections			
☐ C ☐ NC ☒ N/A ☐ U	WALL ANCHORAGE AT FLEXIBLE DIAPHRAGMS: Exterior concrete or masonry walls that are dependent on flexible diaphragms for lateral support are anchored for out-of-plane forces at each diaphragm level with steel anchors, reinforcing dowels, or straps that are developed into the diaphragm. Connections have capacity to resist the connection force calculated by Eq. (3.1) in Section 3.9.	Sec. 4.8.1	Sec. C.6.1
☒ C ☐ NC ☐ N/A ☐ U	TRANSFER TO SHEAR WALLS: Diaphragms are connected for transfer of seismic forces to the shear walls.	Sec. 4.8.2	Sec. C.6.2
☒ C ☐ NC ☐ N/A ☐ U	FOUNDATION DOWELS: Wall reinforcement is doweled into the foundation with vertical bars equal in size and spacing to the vertical wall reinforcing directly above the foundation.	Sec. 4.8.3	Sec. C.6.3

Step 10: Completion of Non-structural Checklist

Evaluation statements apply to Building X

- URM partitions
- Concrete parapets
- Cladding

N/A should be selected for non-applicable statements

Step 10: Completion of Non-structural Checklist

Unreinforced Masonry Partitions

No lateral support is present at the top of the partition. The height-to-thickness ratio (4.34/0.2=21.7) exceeds the threshold of 14.

Heavy Partitions Supported by Ceilings

The tops of masonry partitions are not laterally supported by ceiling.

Table B.20: Non-structural Checklist

Status	Evaluation Statement (1) (2)	Tier 2 Evaluation Reference	Commentary Reference
Architectural Components			
Exterior and interior walls (Category 1 in NBC); and Cantilever parapets and other cantilever walls except retaining walls (Category 2 in NBC)			
Areas other than means of egress ☐ C ☒ NC ☐ N/A ☐ U Means of egress ☐ C ☒ NC ☐ N/A ☐ U	**CC-L/CC-M: BSC2 to 5; CC-H: BSC1 to 5** UNREINFORCED MASONRY PARTITIONS: Unreinforced masonry partitions are braced so that the height-to-thickness and length-to-thickness ratios are not greater than the following values. • 20 for CC-H in BSC1 • 14 for CC-L, CC-M, and CC-H in BSC2 and BSC3 • 9 for CC-L, CC-M, and CC-H in BSC4 and BSC5	Sec. 6.3-6.4	Sec. C.7.1
Areas other than means of egress ☒ C ☐ NC ☐ N/A ☐ U Means of egress ☒ C ☐ NC ☐ N/A ☐ U	**CC-L/CC-M: BSC2 to 5; CC-H: BSC2 to 5** HEAVY PARTITIONS SUPPORTED BY CEILINGS: The tops of masonry partitions are not laterally supported by an integrated ceiling system.	Sec. 6.3-6.4	Sec. C.7.1

Step 10: Completion of Non-structural Checklist

Concrete Parapets

Concrete parapets are not required to be checked except for those around means of egress. The vertical reinforcement information is not available.

?

Further inspection/ scanning recommended

Status	Evaluation Statement [(1) (2)]	Tier 2 Evaluation Reference	Commentary Reference
Areas other than means of egress ☐ C ☐ NC ☒ N/A ☐ U Means of egress ☐ C ☐ NC ☒ N/A ☐ U	**CC-L/CC-M: BSC3 to 5; CC-H: BSC3 to 5** REINFORCED MASONRY PARAPETS OR CORNICES: Reinforced masonry parapets or cornices are less than 1.2 m in height and are anchored to the structural system at a spacing equal to or less than 1.8 m.	Sec. 6.3	Sec. C.7.1
Areas other than means of egress ☒ C ☐ NC ☐ N/A ☐ U Means of egress ☐ C ☐ NC ☐ N/A ☒ U	**CC-L/CC-M: BSC4 to 5; CC-H: BSC3 to 5** CONCRETE PARAPETS: Concrete parapets have vertical reinforcement when their height-to-thickness ratio is greater than the following values. • 2.5 for CC-L and CC-M in BSC4 and BSC5 • 2.5 for CC-H in BSC3 • 1.5 for CC-H in BSC4 to BSC5	Sec. 6.3	Sec. C.7.1

Step 10: Completion of Non-structural Checklist

?

Cladding panels and their anchors were not inspected during the site visit.

Further intrusive inspection recommended

Areas other than means of egress ☐ C ☐ NC ☐ N/A ☒ U Means of egress ☐ C ☐ NC ☐ N/A ☒ U	**CC-L/CC-M: BSC3 to 5; CC-H: BSC3 to 5** CLADDING ANCHORS: Cladding components weighing more than 0.5 kN/m^2 are mechanically anchored to the structure to resist earthquake loads at a spacing equal to or less than the following. • 1.8 m for CC-L, CC-M, and CC-H in BSC3 • 1.2 m for CC-L, CC-M, and CC-H in BSC4 and BSC5	Sec. 6.3	Sec. C.7.1
Areas other than means of egress ☐ C ☐ NC ☐ N/A ☒ U Means of egress ☐ C ☐ NC ☐ N/A ☒ U	**CC-L/CC-M: BSC3 to 5; CC-H: BSC3 to 5** MULTI-STOREY CLADDING PANELS: For multi-storey panels attached at more than one floor level, panel connections are detailed to accommodate the following interstorey drifts. • 0.01 for CC-L, CC-M, and CC-H in BSC3 • 0.025 for CC-L, CC-M, and CC-H in BSC4 and BSC5 In addition, connection rods have a length-to-diameter ratio of 4 or less.	Sec. 6.3-6.4	Sec. C.7.1

Step 10: Completion of Non-structural Checklist

Cladding panels and their anchors were not inspected during the site visit.

Further intrusive inspection recommended

Areas other than means of egress ☐ C ☐ NC ☐ N/A ☒ U Means of egress ☐ C ☐ NC ☐ N/A ☒ U	**CC-L/CC-M: BSC3 to 5; CC-H: BSC3 to 5** CLADDING PANEL CONNECTIONS FOR OUT-OF-PLANE FORCES: Cladding panels are connected out of plane with a minimum number of connections, as follows. • Two connections for CC-L, CC-M, and CC-H in BSC3 • Four connections for CC-L, CC-M, and CC-H in BSC4 and BSC5	Sec. 6.3	Sec. C.7.1
Areas other than means of egress ☐ C ☐ NC ☐ N/A ☒ U Means of egress ☐ C ☐ NC ☐ N/A ☒ U	**CC-L/CC-M: BSC3 to 5; CC-H: BSC3 to 5** BEARING CONNECTIONS FOR CLADDING PANELS: Where bearing connections are used, there is a minimum of two bearing connections for each panel.	Sec. 6.3	Sec. C.7.1
Areas other than means of egress ☐ C ☐ NC ☐ N/A ☒ U Means of egress ☐ C ☐ NC ☐ N/A ☒ U	**CC-L/CC-M: BSC3 to 5; CC-H: BSC3 to 5** INSERTS IN CONCRETE CLADDING: Where concrete cladding components use inserts, the inserts have positive anchorage or are anchored to the reinforcing steel.	Sec. 6.3	Sec. C.7.1

Step 10: Completion of Non-structural Checklist

Cladding panels and their anchors were not inspected during the site visit.

Further intrusive inspection recommended

Areas other than means of egress ☐ C ☐ NC ☐ N/A ☒ U Means of egress ☐ C ☐ NC ☐ N/A ☒ U	**CC-L/CC-M: not req.; CC-H: BSC3 to 5** CLADDING ISOLATION: For steel or concrete moment-resisting frame buildings, panel connections are detailed using rods attached to framing with oversize holes or slotted holes to accommodate the following interstorey drift ratios. • 0.01 for CC-H in BSC3 • 0.025 for CC-H in BSC4 and BSC5 In addition, connection rods have a length-to-diameter ratio of 4 or less.	Sec. 6.3-6.4	Sec. C.7.1
Areas other than means of egress ☐ C ☐ NC ☐ N/A ☒ U Means of egress ☐ C ☐ NC ☐ N/A ☒ U	**CC-L/CC-M: not req.; CC-H: BSC3 to 5** THREADED RODS FOR CLADDING CONNECTIONS: Threaded rods for panel connections detailed to accommodate interstorey drift by bending rod have a length-to-diameter ratio greater than the following. • 2.4 times the storey height in metres for CC-H in BSC3 • 6 times the storey height in metres for CC-H in BSC4 and BSC5	Sec. 6.3-6.4	Sec. C.7.1

Step 11: Summarize Potential Seismic Deficiencies

Potential Structural Seismic Deficiencies

- Weight (Mass) irregularity (Non-compliant)
- Inadequate shear resistance in concrete shear walls (Non-compliant)

Potential Non-structural Seismic Deficiencies

- Unbraced unreinforced masonry partitions (Non-compliant)
- Cladding panels and their connections (Unknown)

Step 12: Determine the Need of Tier 2 Deficiency-Based Evaluation

Potential Structural Seismic Deficiencies

- Weight (Mass) irregularity (Non-compliant)
- Inadequate shear resistance in concrete shear walls (Non-compliant)

Potential Non-structural Seismic Deficiencies

- Unbraced unreinforced masonry partitions (Non-compliant)
- Cladding panels and their connections (Unknown)

→ Tier 2 Deficiency-Based Evaluation is required

Step 13: Prepare Seismic Report

The seismic evaluation report should include, at a minimum, the following items

- Scope and intent
- Building description (building location, federal heritage designation, number of storeys, building dimensions, building use and occupancy, etc.)
- General information (seismic data, consequences of failure, SFRS, model building type, gravity-load carrying system, foundation system, year built, original design NBC, original building importance, Site Class, material conditions, separation distance, seismic upgrading, geologic hazards, non-structural hazards, lateral supports and connections of non-structural components to the building structure, etc.)

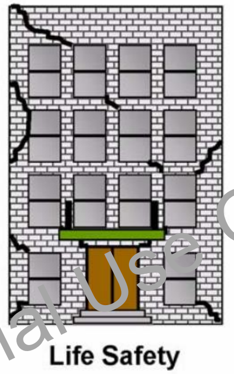
Step 13: Prepare Seismic Report

The seismic evaluation report should include, at a minimum, the following items

- List of existing documentation reviewed and photos taken during the follow-up site visit
- Material conditions and material testing results (if applicable)
- List of assumptions (material properties, site conditions, structural modelling, etc.)
- Rationales for assessing each potential seismic deficiency
- Findings (demand-to-capacity ratios, confirmed seismic deficiencies, etc.)
- Recommendations for further actions (i.e., no action, risk mitigation or Tier 3 Detailed Evaluation)

Tier 2 Deficiency-Based Evaluation

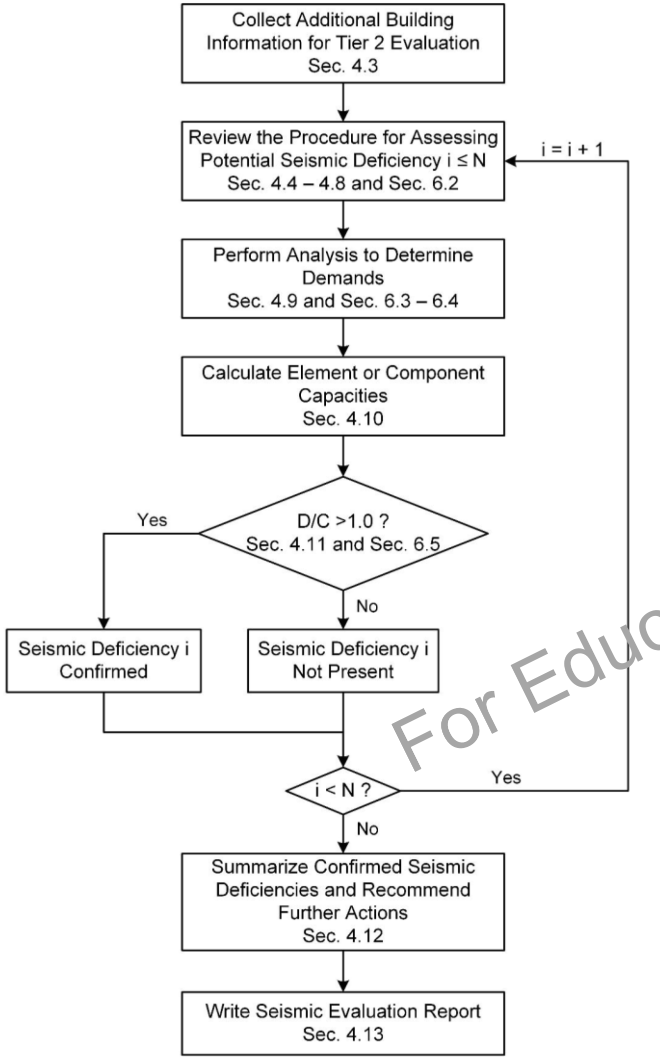
Tier 2 Deficiency-Based Evaluation



Intent and Scope

- Is <u>not a stand-alone</u> procedure
- Is <u>not required</u> when building <u>not found deficient</u> or <u>flagged for a Tier 3 evaluation</u>, after Tier 1 evaluation
- Deals with <u>life safety</u> and does not address more stringent objectives
- Modelling may be required, but the <u>analysis</u> only <u>focuses on identified potential seismic deficiencies</u>

Tier 2 Evaluation Process



N: The total number of identified potential seismic deficiencies during Tier 1 Quick Evaluation
D: The total demand applied on the element or component
C: Element or component capacity

1. Collect building information
2. Review identified potential major seismic deficiencies and their corresponding evaluation procedures
3. Perform analysis to determine the demands
4. Calculate element/component capacities
5. Check the acceptance criteria
6. Summarize seismic deficiencies & recommend further actions
7. Prepare seismic evaluation report

Step 2: Review Potential Seismic Deficiencies

Step 1 is skipped as building info has been collected in Tier 1

Potential Structural Seismic Deficiencies

- Weight (Mass) irregularity (Non-compliant)
- Inadequate shear resistance in concrete shear walls (Non-compliant)

Potential Non-structural Seismic Deficiencies

- Unbraced unreinforced masonry partitions (Non-compliant)
- Cladding panels and their connections (Unknown)

Step 2: Review Potential Seismic Deficiencies

Potential Structural Seismic Deficiencies

- Weight (Mass) irregularity (Non-compliant)
- Inadequate shear resistance in concrete shear walls (Non-compliant)

Tier 2 Evaluation focuses on potential structural deficiencies

Potential Non-structural Seismic Deficiencies

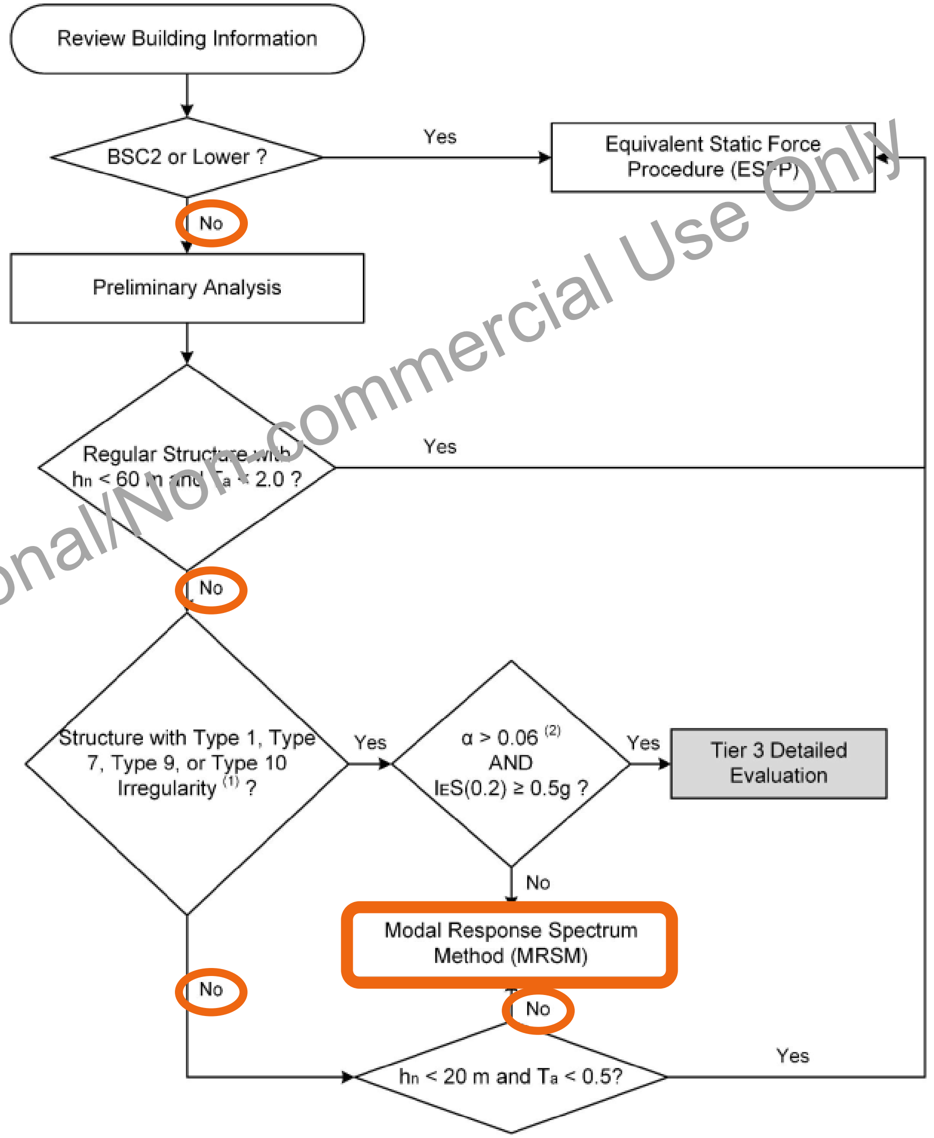
- Unbraced unreinforced masonry partitions (Non-compliant) → Add lateral bracing
- Cladding panels and their connections (Unknown)

Further inspection is recommended

Step 3: Perform Analysis to Determine the Demands

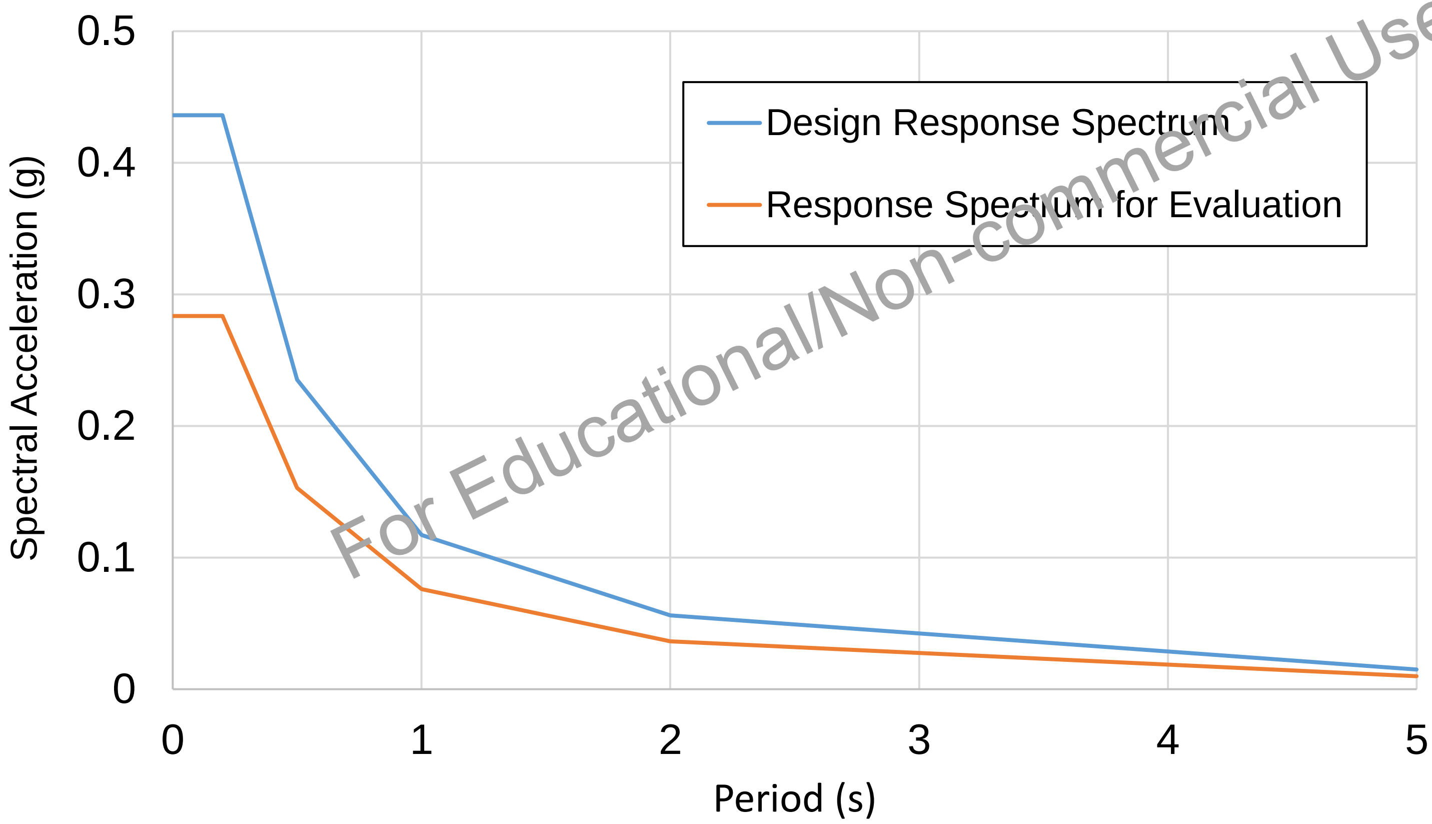
Analysis Procedure Selection

Modal Response Spectrum Method (MRSM)



Step 3: Perform Analysis to Determine the Demands

5%-damped Response Spectra for Building X



From Tier 1 Quick Evaluation

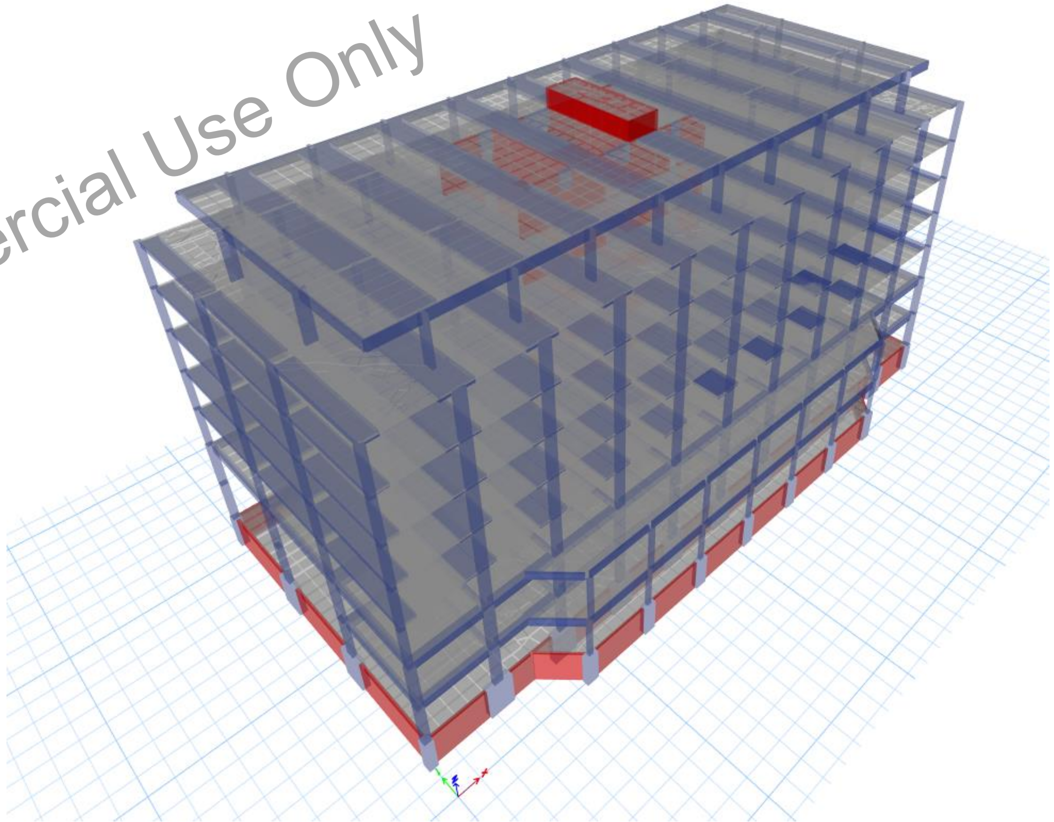
$\kappa = 1.0$

$\alpha_{QE} = 0.65$

Step 3: Perform Analysis to Determine the Demands

Two mathematical models are created to assess the contribution of CMF

- Model A: RC shear walls and coupled shear walls are the sole contributors to seismic resistance.
- Model B: A hybrid SFRS with contributions from both RC shear walls and concrete moment-resisting frames.



Step 3: Perform Analysis to Determine the Demands

Modelling assumptions for Model A (CSW only)

- Release bending at both ends of all columns throughout the building, and release torsion at one end of each column.
- Release bending & torsion at all beams or slab bands framing into the concrete core walls. To prevent joint instabilities, the beam bending & torsion frame releases were not modified at column locations.
- Out-of-plane slab stiffness was reduced to 0.05 to prevent any accidental frame action between the slabs and the concrete core.
- Diaphragm changed from semi-rigid to rigid to significantly expedite the model run-time, which would have negligible effect on the force distribution amongst walls due to their layout.

Step 3: Perform Analysis to Determine the Demands

Modelling assumptions for Model B (CSW + CMF)

- Bending & torsional fixity was utilized at all connections between columns, beams and slab bands
- Bending & torsional fixity was utilized at the connections of all beams or slab bands framing into the central concrete core walls.
- Shear walls were modeled using single shell elements. Coupling beams were modeled as frames with rigid offsets to correctly model the clear spans.
- Floor diaphragms were modeled as semi-rigid to account for the partial flexibility from in-plane bending and shear deformations.
- The base elevation for the model was set at the basement floor elevation. Soil-structure interaction was ignored in the model. All foundations were assumed to be fixed.

Step 3: Perform Analysis to Determine the Demands

Conventional construction is assumed

R_d	1.5
R_o	1.3

Stiffness Property Modifiers for Model A (CSW Only)

Shell Element	F11	F22	F12	M11, V13	M22, V23	M12
Walls	1.00	0.825	0.825	0.50	0.50	0.50
Slabs	0.50	0.50	0.50	0.05	0.05	0.05

Frame Element	A	Av2	Av3	T	M2	M3
Coupling Beams	1.00	0.15	0.50	0.50	0.50	0.40
Beams	N/A	N/A	N/A	N/A	N/A	N/A
Columns	N/A	N/A	N/A	N/A	N/A	N/A

Step 3: Perform Analysis to Determine the Demands

Conventional construction is assumed

R_d	1.5
R_o	1.3

Stiffness Property Modifiers for Model B (CSW + CMF)

Shell Element	F11	F22	F12	M11, V13	M22, V23	M12
Walls	1.00	0.825	0.825	0.50	0.50	0.50
Slabs	0.50	0.50	0.50	0.20	0.20	0.20

Frame Element	A	Av2	Av3	T	M2	M3
Coupling Beams	1.00	0.15	0.50	0.50	0.50	0.40
Beams	1.00	0.50	0.50	0.50	0.50	0.40
Columns	1.00	0.70	0.70	0.70	0.80	0.80

Step 3: Perform Analysis to Determine the Demands

Seismic Base Shear Demand for Evaluation (V_{QE}) of Building X

$$V_{QE} = \kappa \alpha_{QE} V_N$$

Building Periods and Seismic Base Shear Demands from Two Models

Parameter	**Value (Model A)**	**Value (Model B)**
Period – X Direction (E-W)	0.83 s	Negligible difference from Model A
Response Spectrum Scale Factor	1.27	1.27
Base Shear – X Direction (E-W)	8,300 kN	Negligible difference from Model A
Period – Y Direction (N-S)	0.85 s	0.82 s
Response Spectrum Scale Factor	1.19	1.19
Base Shear – Y Direction (N-S)	8,400 kN	8,700 kN

Approx. 5% increase in seismic base shear

Steps 4: Calculate Element Capacities and Interstorey Drifts

Calculation of Structural Capacities

- Wall piers
- Beams and columns
- Strip foundations

+ Structural engineering software

Calculation of Interstorey Drifts

Step 5: Check Acceptance Criteria – Capacity Check

- Acceptance criteria for capacity check

$$D/C \leq 1.0 \quad \text{OR} \quad C/D \geq 1.0$$

Capacity-to-Demand Ratios of Typical SFRS Elements (Worst-Case)

SFRS Element	Capacity to Demand Ratio (Model A)	Capacity to Demand Ratio (Model B)
Wall Piers Flexure	25 to 50%	25 to 50%
Wall Pier Shear	25 to 50%	25 to 50%
Concrete Moment Frames	Not Applicable	75% to 100%
Members Not Part of the SFRS	50% to 75%	Not Applicable
Foundations	50%	50%

Step 5: Check Acceptance Criteria – Drift Check

- Acceptance criteria for drift check

$\delta \leq 0.025$ for Normal Importance Category

The calculated interstorey drifts do not exceed the code limit

Step 6: Summary Deficiencies and Recommend Further Actions

Structural Seismic Deficiencies

- Inadequate flexural and shear resistance in shear walls
- Inadequate flexural and shear capacity in columns
- Inadequate flexural resistance in coupling beams above Floor 5
- Inadequate flexural and shear resistance in foundations

➡ Deficiency-Based Upgrading is recommended

Step 7: Prepare Seismic Evaluation Report

The seismic evaluation report should include, at a minimum, the following items

- Scope and intent
- Building description
- General information
- List of existing documentation reviewed and photos taken during the follow-up site visit
- Material conditions and material testing results (if applicable)
- List of assumptions (material properties, site conditions, structural modelling, etc.)
- Rationales for assessing each potential seismic deficiency
- Findings (demand-to-capacity ratios, confirmed seismic deficiencies, etc.)
- Recommendations for further actions (i.e., no action or Deficiency-Based Upgrading)

Deficiency-Based Upgrading

Structural Upgrading Techniques in SUG

Classes of Upgrading Techniques

1. Add new elements
2. Enhance the performance of existing elements
3. Improve connections between components
4. Reduce seismic demand

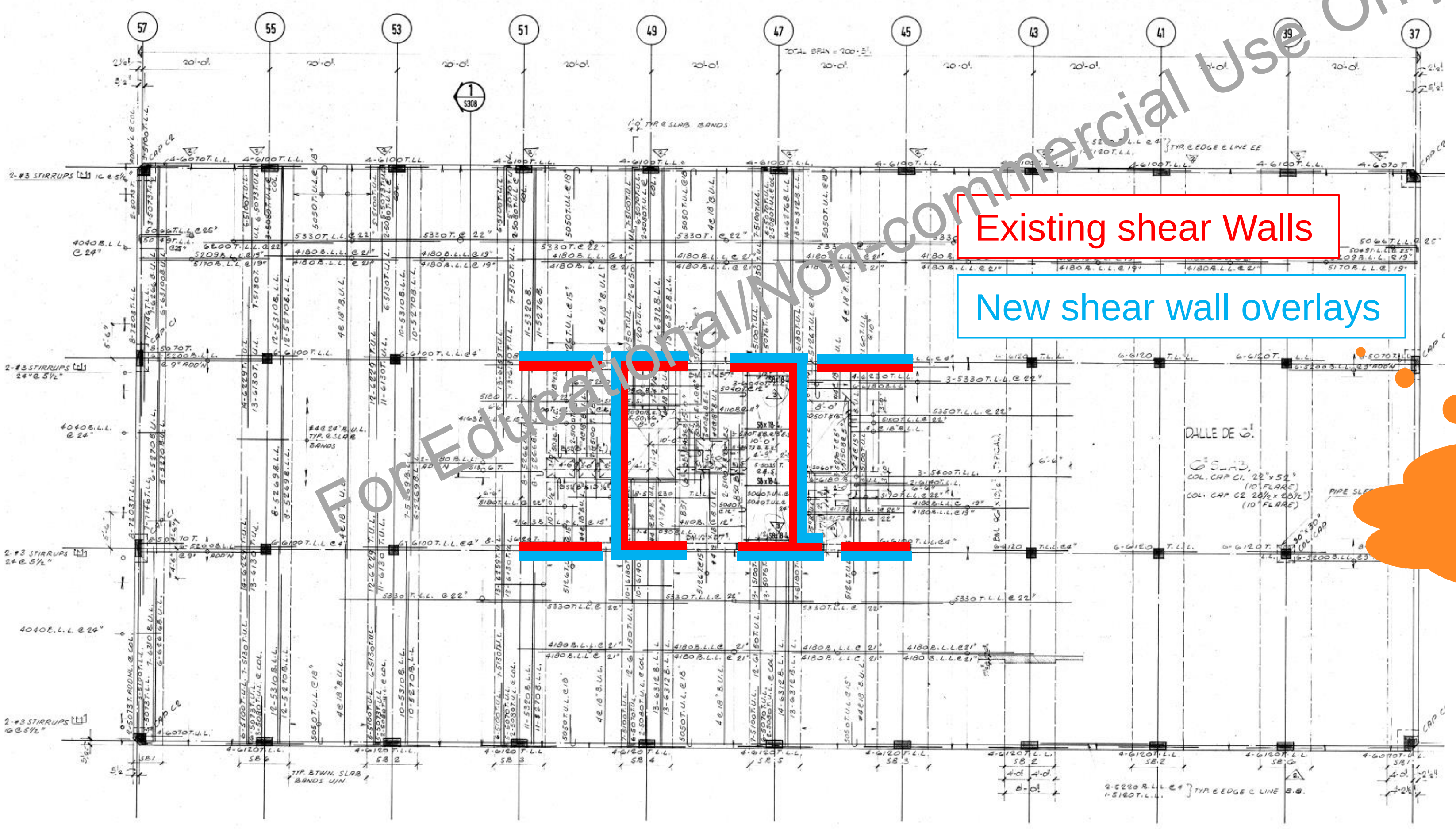
Items 1–3 → Conventional Upgrading Techniques

Item 4 → Innovative Upgrading Technique

This example primarily focuses on selecting upgrading options rather than designing the seismic upgrade or comparing cost of each option

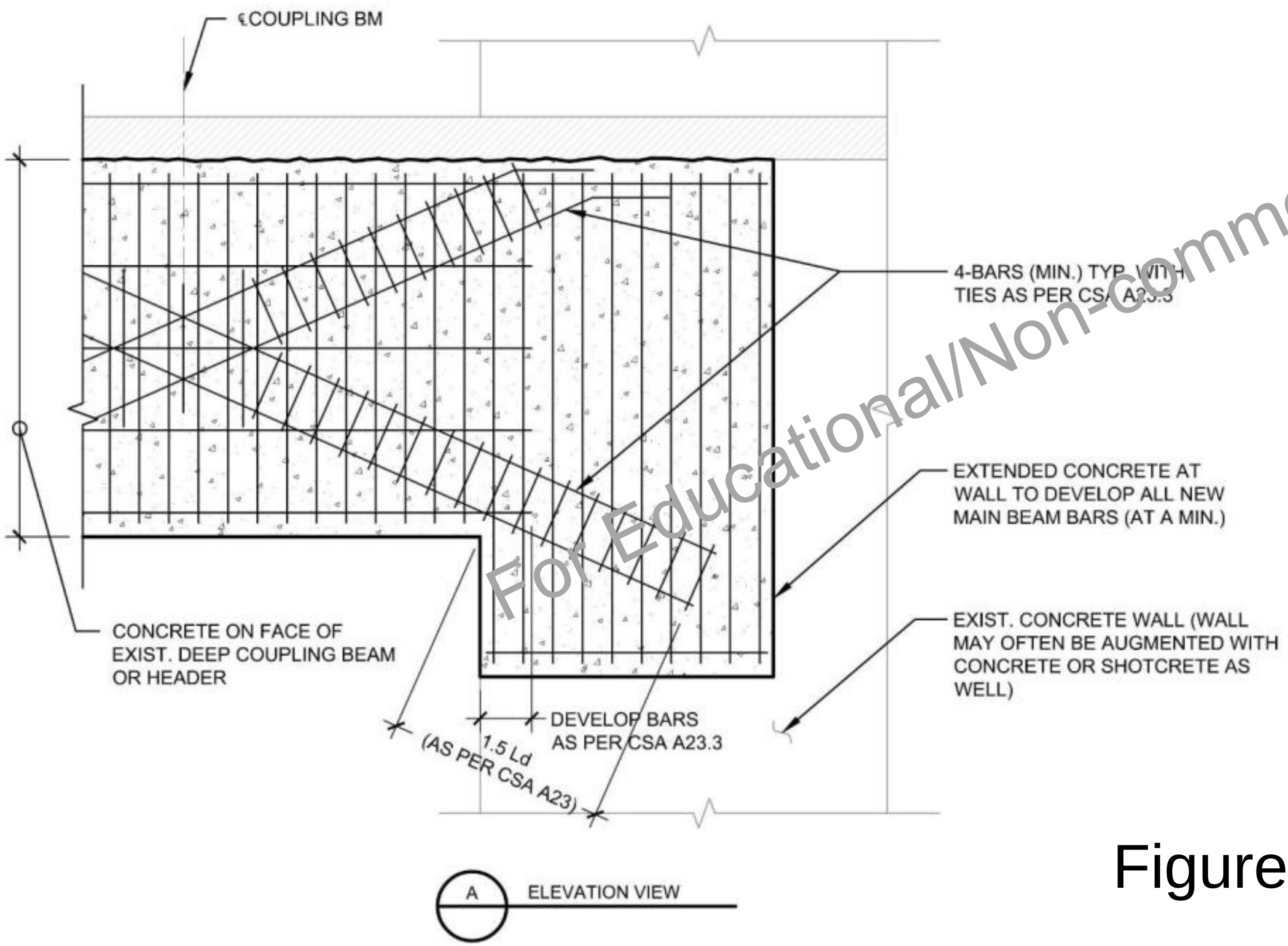
Conventional Upgrading

Option 1: Add new shear wall overlays to existing shear walls



Conventional Upgrading

<u>Option 1:</u> Add new coupling beam overlays



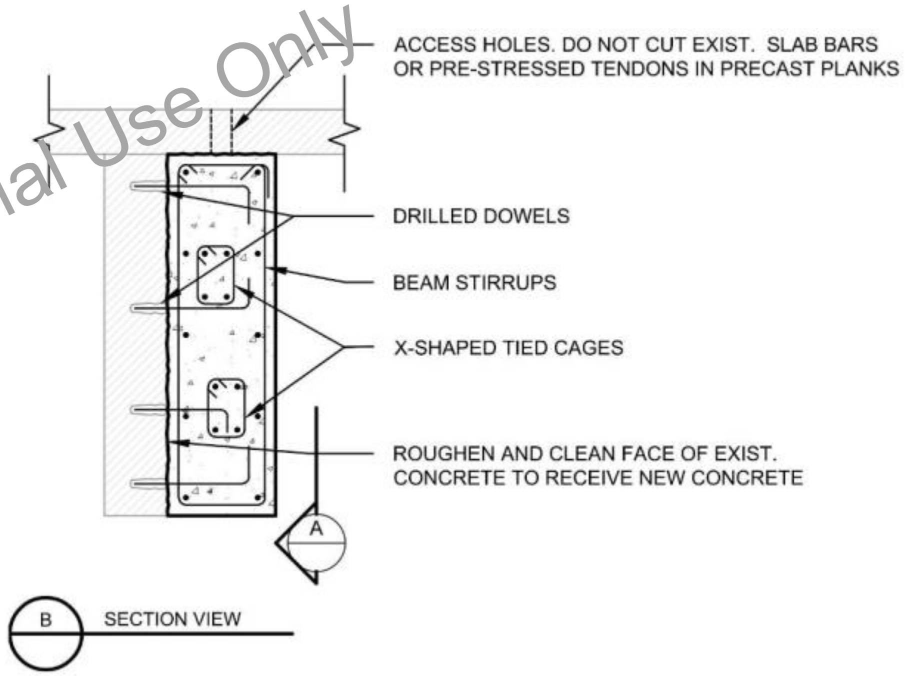
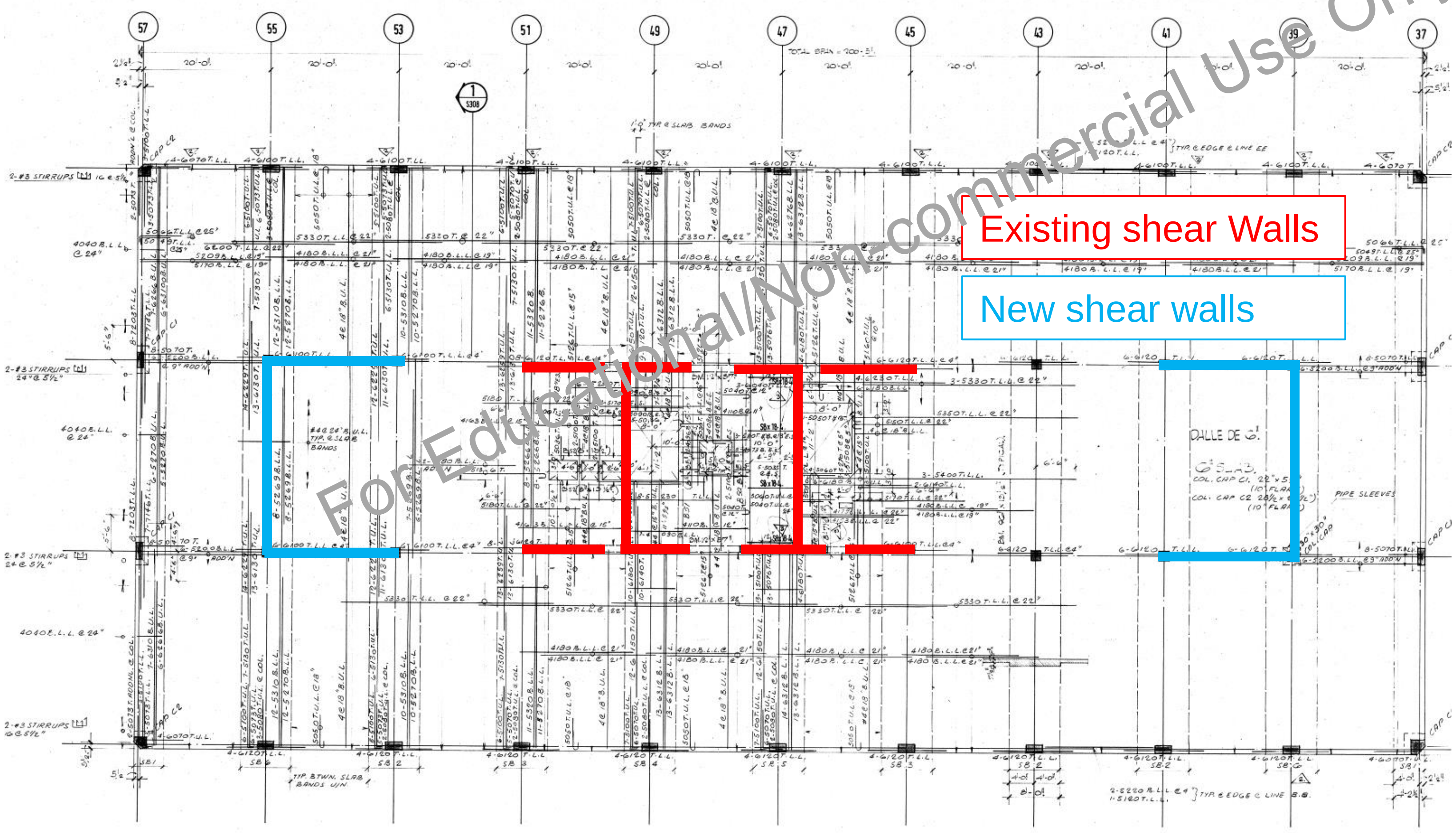


Figure 5.6 of SUG

Conventional Upgrading

Option 2: Add new shear walls to existing building



Conventional Upgrading

Option 2: Connection of new shear walls to existing concrete slab

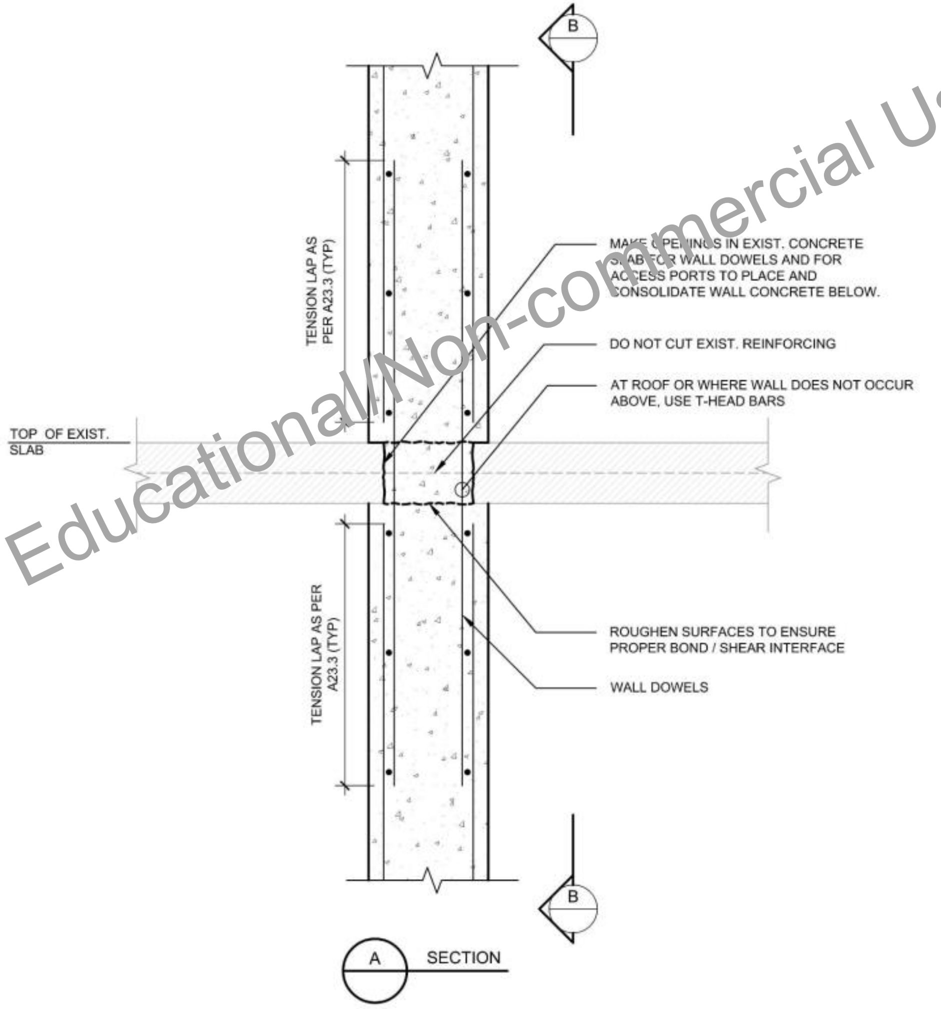
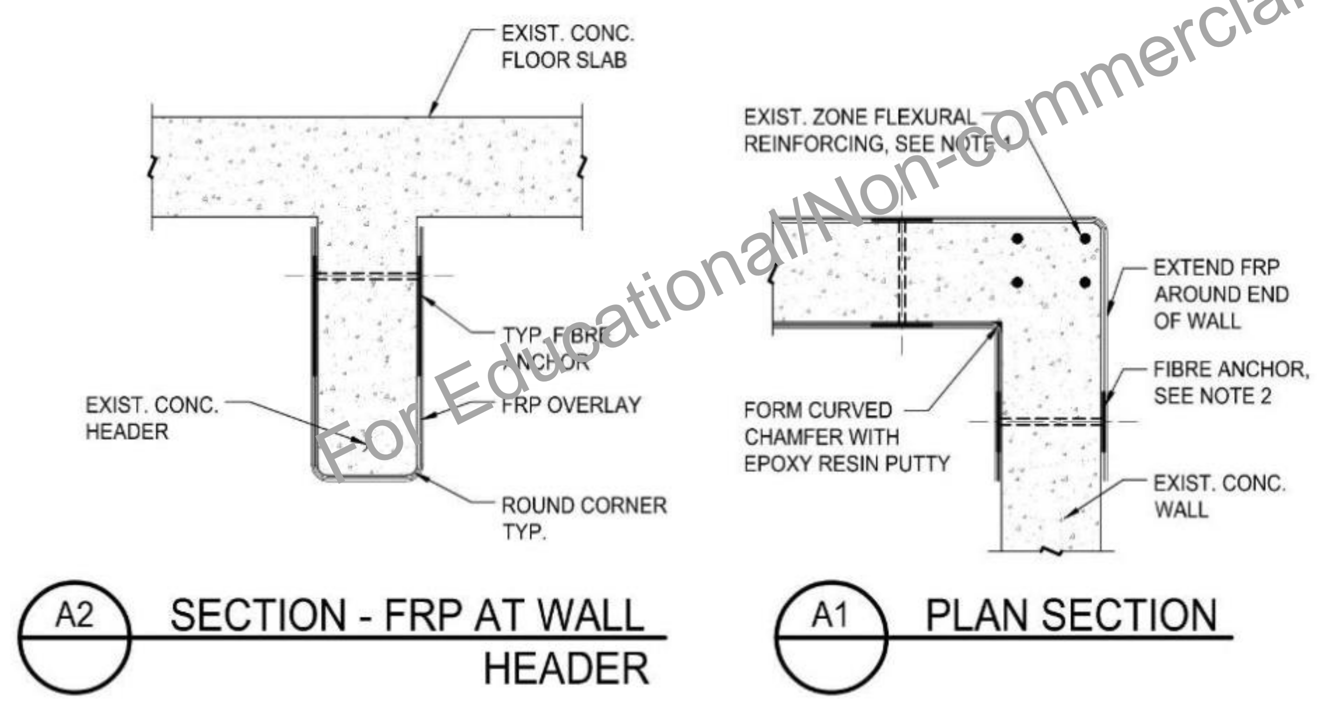


Figure 5.8 of SUG

Conventional Upgrading

Option 3: Add FRP overlay to existing shear walls



NOTES:
1. FLEXURAL RESISTANCE OF SHOWN SHEAR WALL MEETS STRENGTH AND DUCTILITY REQUIREMENTS (i.e. PLASTIC HINGE AT BASE), BUT SHEAR RESISTANCE NEEDS TO BE INCREASED. HORIZONTAL FRP ARE ADDED TO WALL TO INCREASE SHEAR RESISTANCE WITHOUT CHANGING THE FLEXURAL BEHAVIOUR.
2. FIBRE ANCHORS ARE USED TO DEVELOP THE ENDS OF THE HORIZONTAL FRP OVERLAYS FOR THE SHEAR WALL BETWEEN ZONE REINFORCING. SCAN BOTH SIDES OF WALL TO LOCATE EMBEDDED BARS, DO NOT CUT EXISTING REINFORCING BARS.
3. THE HEADER ABOVE THE OPENING RECEIVES SHEAR STRENGTHENING TO AVOID A WEAK JOINT ADJACENT TO THE SHEAR WALL. CARRY THE BOTTOM HORIZONTAL OVERLAY ACROSS THE CONCRETE HEADER.

Figure 5.3 of SUG

Conventional Upgrading

Option 3: Add FRP overlay to existing shear walls

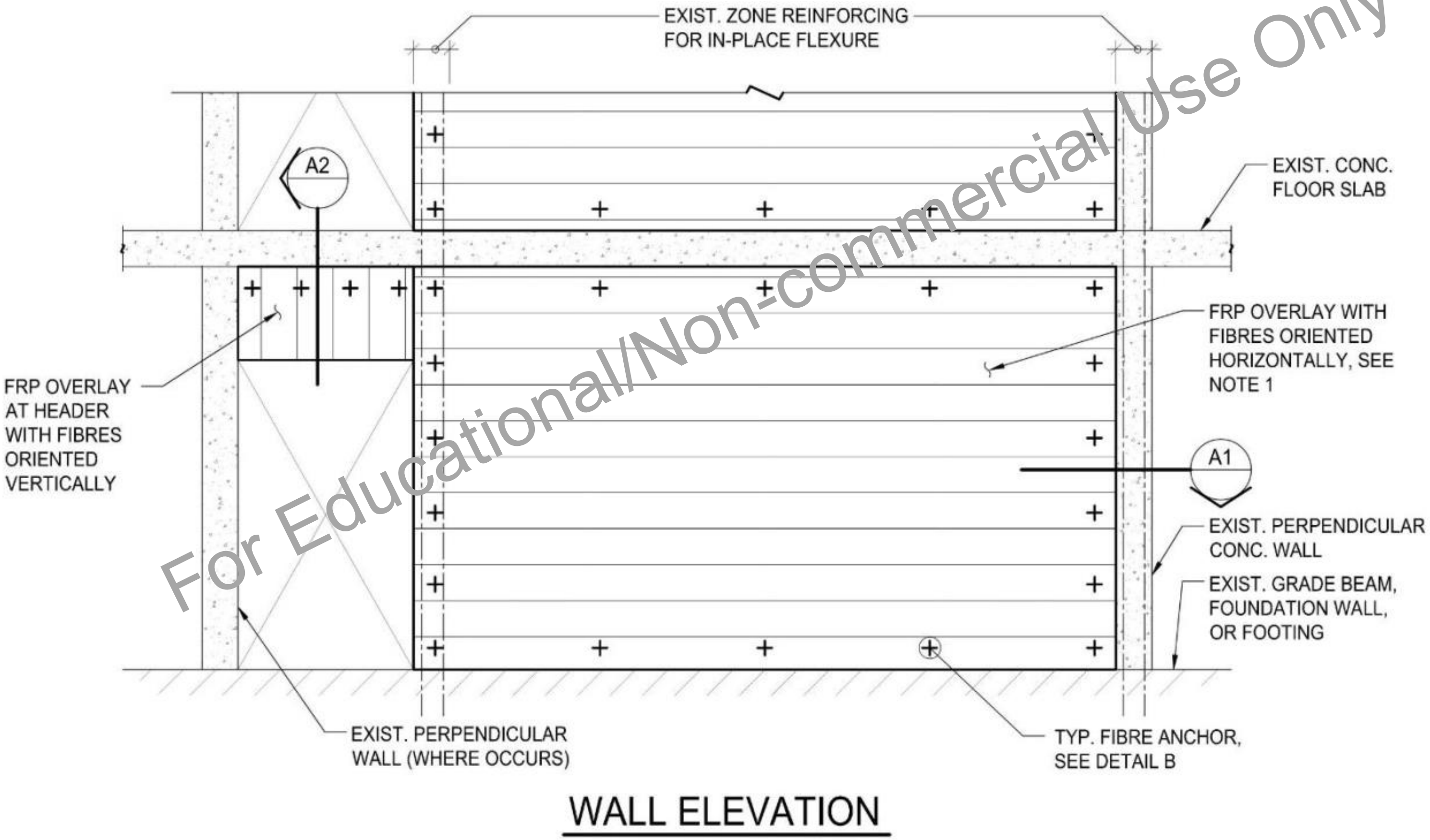


Figure 5.3 of SUG

Conventional Upgrading

Option 3: Add FRP overlay to existing shear walls

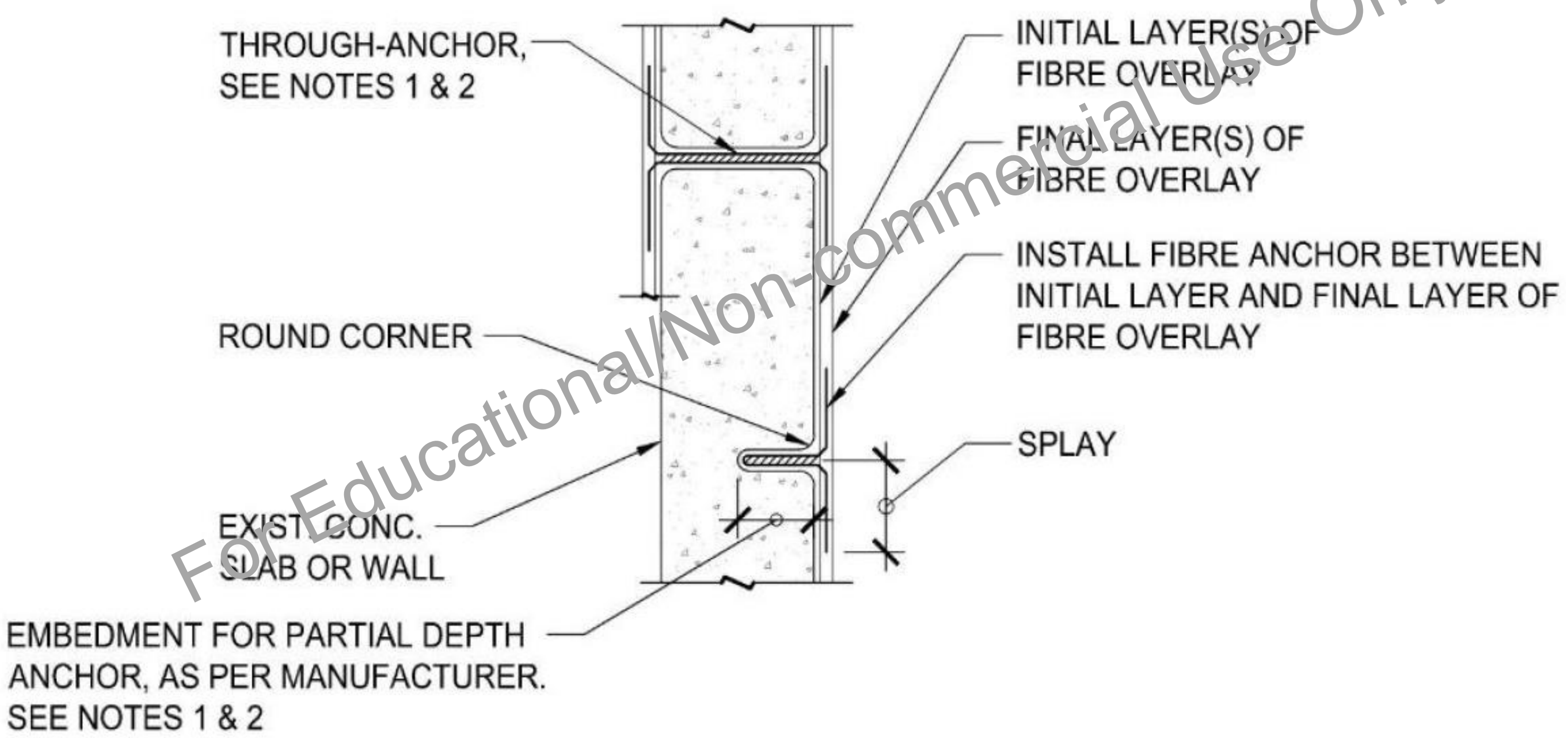
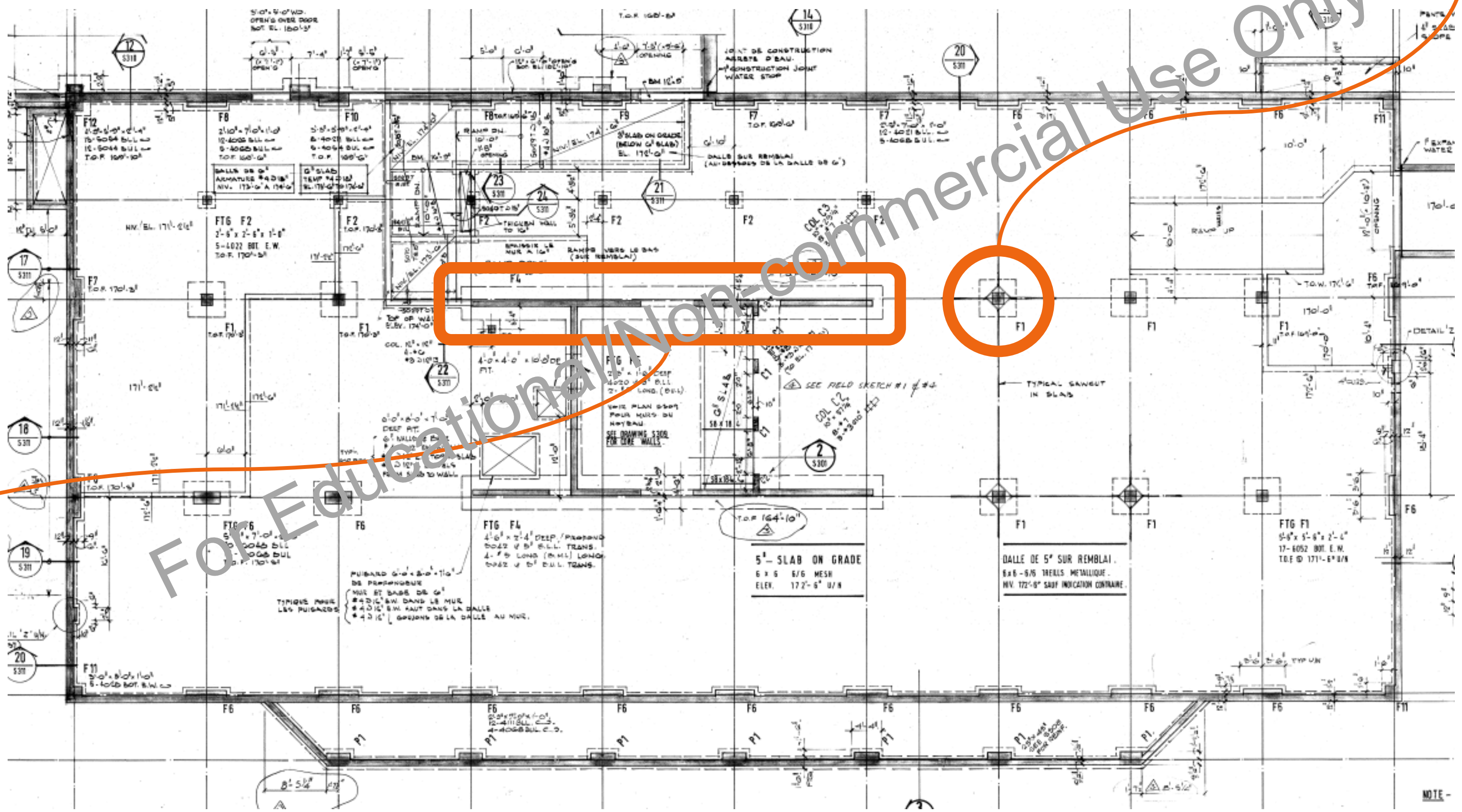


Figure 5.4: FRP anchor details

Upgrading of Foundations

Existing foundations



Spread footing

Strip footing

Basement Floor Plan

Upgrading of Foundations

Enlarge existing strip foundations

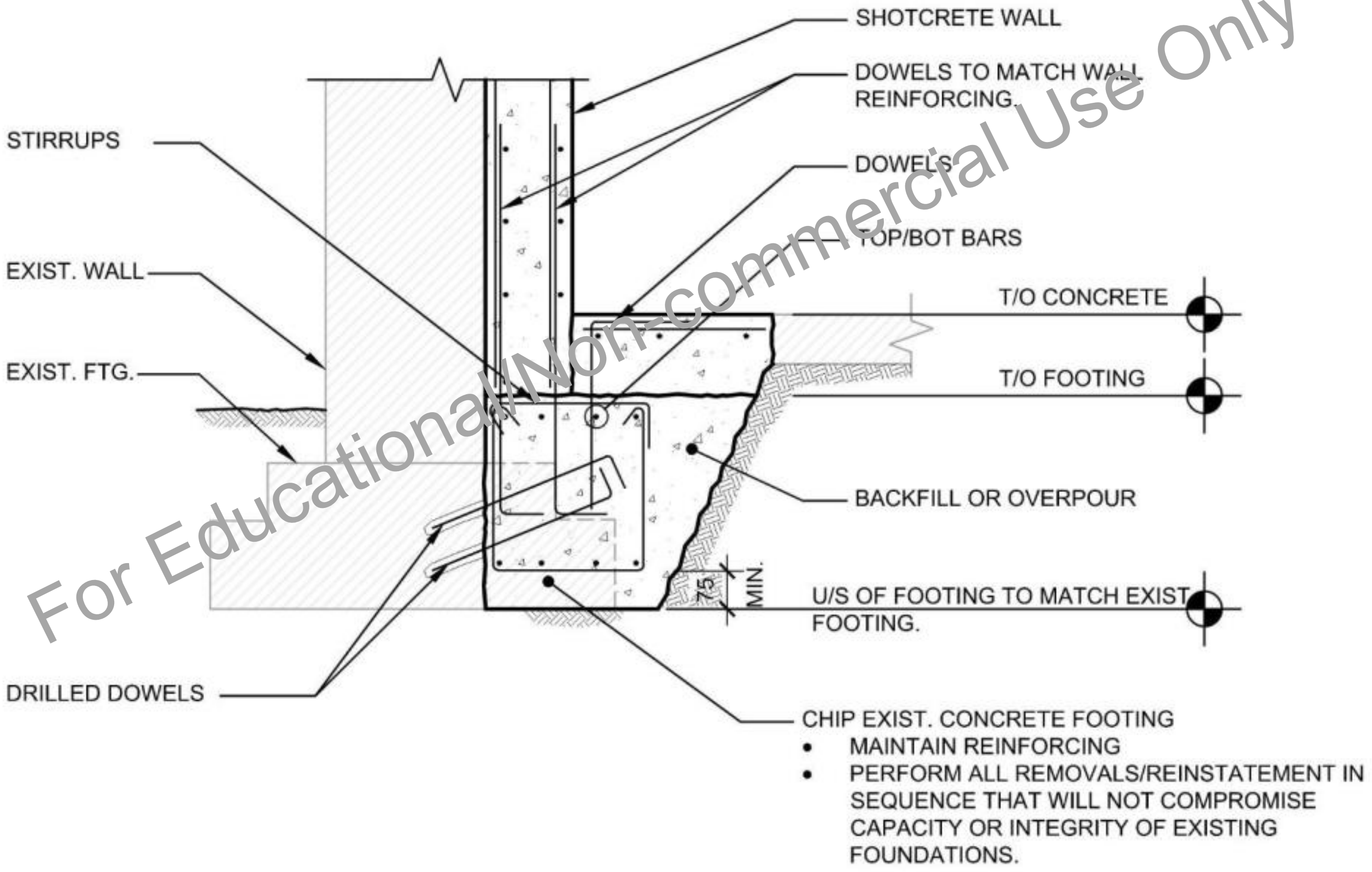


Figure 5.154 of SUG

Upgrading of URM Partitions

Add Lateral Bracing to Existing URM Partitions

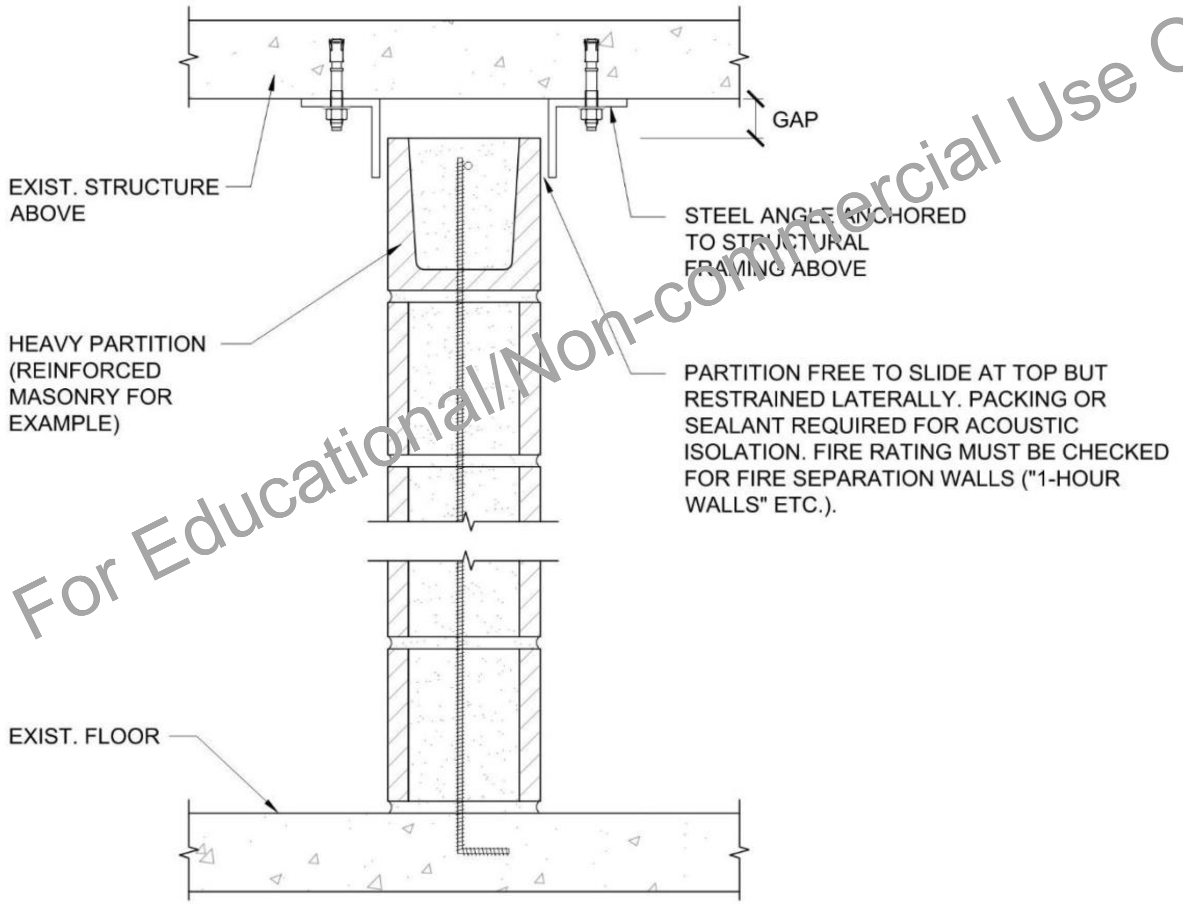
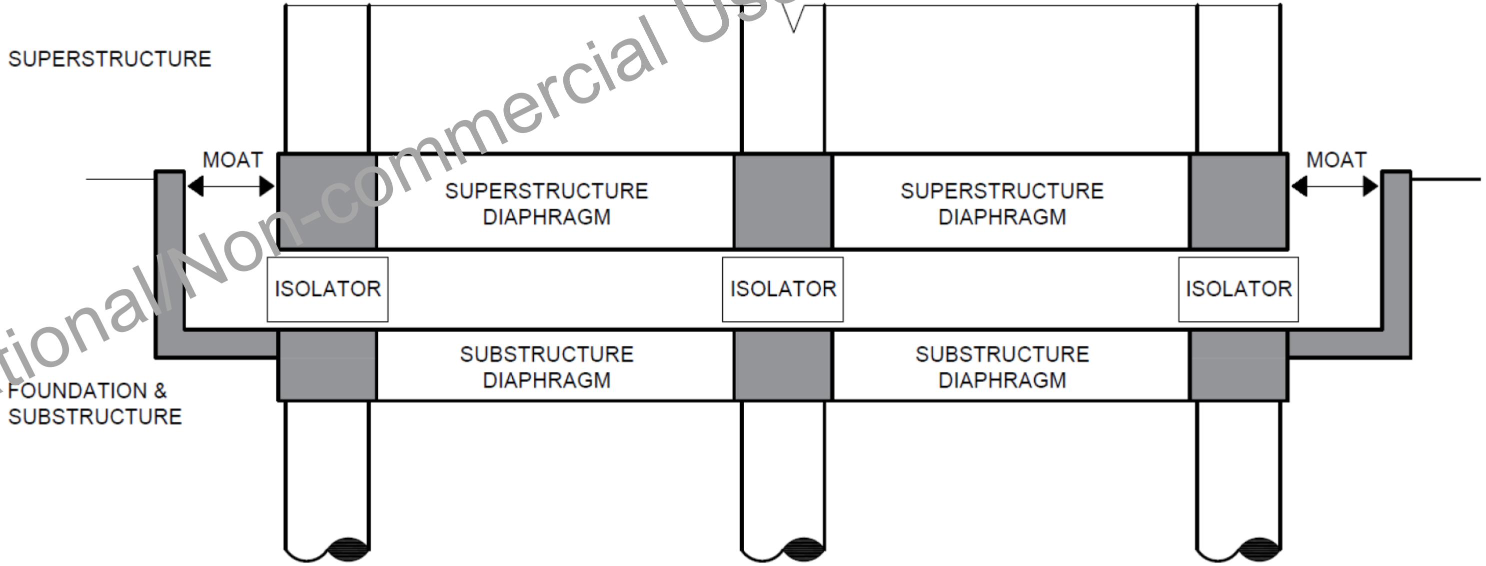


Figure 5.160: Out-of-plane bracing of existing full height heavy partition wall

Innovative Upgrading

Seismic Isolation



Summary

Key Takeaways

- Application of Tier 1 Quick Evaluation to an office building in Quebec
- Application of Tier 2 Deficiency-Based Evaluation to assess potential structural seismic deficiencies identified through Tier 1 evaluation
- Application of Deficiency-Based Upgrading to address structural seismic deficiencies identified through Tier 2 evaluation
- NRC's seismic guidelines are non-mandatory but have been used by PSPC/GAC for dozens of buildings
- NBC 2030 is expected to introduce new sections for existing buildings

NRC’s Published Seismic Tools/ Guidelines

- Level 1 – Preliminary Seismic Risk Screening Tool (PST)

  https://doi.org/10.4224/40001929 (Part 4)

  https://doi.org/10.4224/40002989 (Part 9)
- Level 2 – Semi-Quantitative Seismic Risk Screening Tool (SQST)

  https://doi.org/10.4224/40001931 (Part 4)

  https://doi.org/10.4224/40002988 (Part 9)
- Level 3 – Seismic Evaluation Guidelines (SEG)

  https://doi.org/10.4224/40003499
- Seismic Upgrading Guidelines (SUG)

  https://doi.org/10.4224/40003495
- Webpage Seismic Risk Screening Tool

  Semi-Quantitative Seismic Risk Screening Tool (SQST) - National Research Council Canada

Available in both official languages Level 1 – PST & Level 2 – SQST

French translation of Level 3 – SEG in progress

Available in both official languages

Peer-Reviewed Journal and Conference Papers

Peer-reviewed Journal Papers (Level 3 – SEG & SUG Related)

- Fathi-Fazl, R., Lounis, Z., & Cai, Z. (2020). Multicriteria and multilevel framework for seismic risk management of existing buildings in Canada. Journal of performance of constructed facilities, 34(2), 04020004.
- Fathi-Fazl, R., Lounis, Z., & Cai, Z. (2021). Semi-quantitative classification of consequences of failure for seismic risk management of existing buildings. Structure and Infrastructure Engineering, 17(5), 664-675.
- Fathi-Fazl, R., Kadhom, B., Cai, Z., & Fazileh, F. (2021). Benchmark NBC editions for seismic risk management of existing buildings in Canada. Canadian Journal of Civil Engineering, 48(8), 948-958.
- Motazedian, D., Fathi-Fazl, R., Cai, Z., & Fazileh, F. (2022). An update on the seismic categorization for seismic risk assessment of existing Canadian buildings. Canadian Journal of Civil Engineering, 50(4), 270-281.
- Fathi-Fazl, R., Fazileh, F., Cai, Z., & Cortés-Puentes, W. L. (2022). Development of quick seismic evaluation procedure for existing buildings in Canada. Canadian Journal of Civil Engineering, 50(5), 408-422.
- Fazileh, F., Fathi-Fazl, R., Cai, Z., & Bérubé, A. (2022). Nonlinear modelling parameters and acceptance criteria in ASCE/SEI 41: a critical review and applicability to Canada. Canadian Journal of Civil Engineering, 50(2), 137-142.
- Kim, T., Kwon, O. S., Acosta, J., Fathi-Fazl, R., Fazileh, F., & Cai, Z. (2023). Review of nonlinear modelling parameters and acceptance criteria in ASCE 41 for seismic evaluation and upgrading of steel structures in Canada. Canadian Journal of Civil Engineering, 50(8), 688-708.

Peer-Reviewed Journal and Conference Papers

- Doudak, G., Bérubé, A., Morshedi, E., Fathi-Fazl, R., Fazileh, F., & Cai, Z. (2023). Nonlinear modelling parameters for performance-based seismic evaluation of existing wood light-frame buildings in Canada. *Canadian Journal of Civil Engineering*, *51*(5), 561-576.
- Fathi-Fazl, R., Lounis, Z., Cai. Z., & Fazileh, F. (2026). Reliability-based minimum earthquake load factors for evaluation of existing buildings. Journal of Structures (under review).
- Toopchinezhad, M., Shamlu, M., Sadeghian, V., Fazileh, F., & Fathi-Fazl, R. (2026). Effect of Redundancy on Seismic Performance of Braced Frame Buildings in Eastern and Western Canada. Journal of Structures (under review).

Peer-reviewed Conference Papers (Level 3 – SEG & SUG Related)

- Fathi-Fazl, R., Fazileh, F., Cai, Z. and Cortes-Puentes, L. (2019). Overview of NBC 2015 Commentary for Seismic Evaluation and Upgrading of Existing Buildings. 12th Canadian Conference on Earthquake Engineering, Quebec City, Quebec, Canada, June 17-20, 2019.
- Fathi-Fazl, R., Fazileh, F., and Cai, Z. (2023). Toward Updating NRC's Seismic Evaluation Guidelines for Existing Buildings in Canada. Canadian Conference - Pacific Conference on Earthquake Engineering 2023, Vancouver, British Columbia, Canada, June 25-30, 2023.
- Fathi-Fazl, R., Fazileh, F., and Cai, Z. (2024). Multi-level Seismic Risk Assessment Guidelines for Existing Buildings in Canada. 18th World Conference on Earthquake Engineering, Milan, Italy, June 30 – July 5, 2024.

Thank you