

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

Webinar Series

Overview of Level 3 – Seismic Evaluation Guidelines (SEG)

By Seismic Resilience Team

November 5, 2025

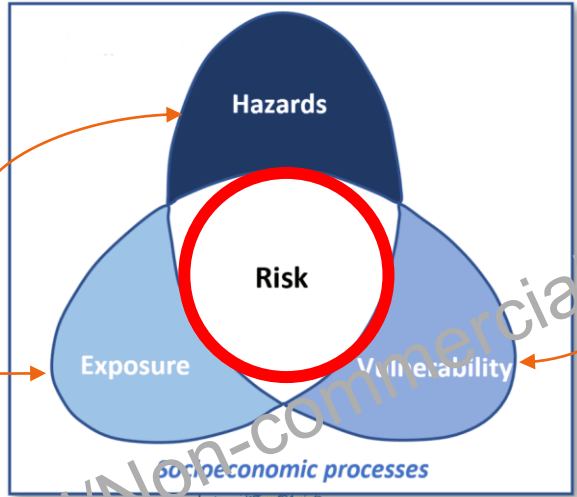
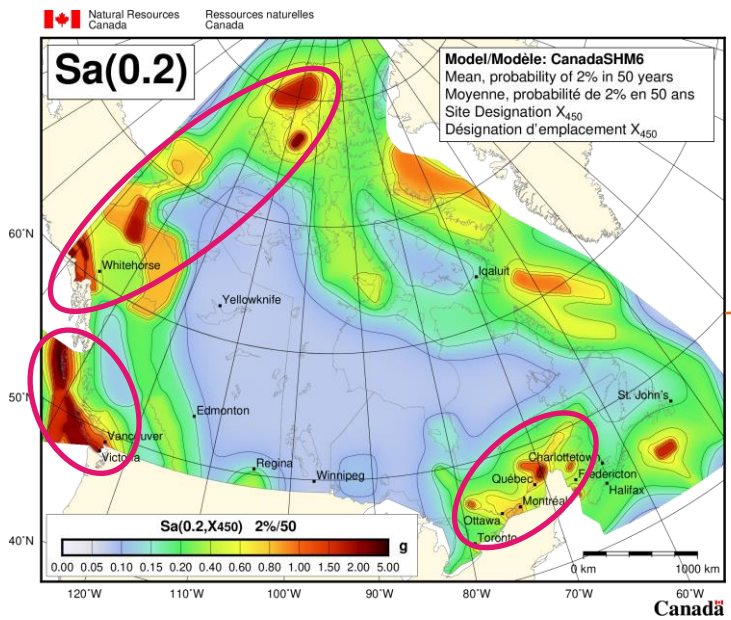
Outline

- Introduction
- Level 3 – SEG Methodology
- Tier 1 Quick Evaluation
- Tier 2 Deficiency-Based Evaluation
- Tier 3 Detailed Evaluation
- Summary

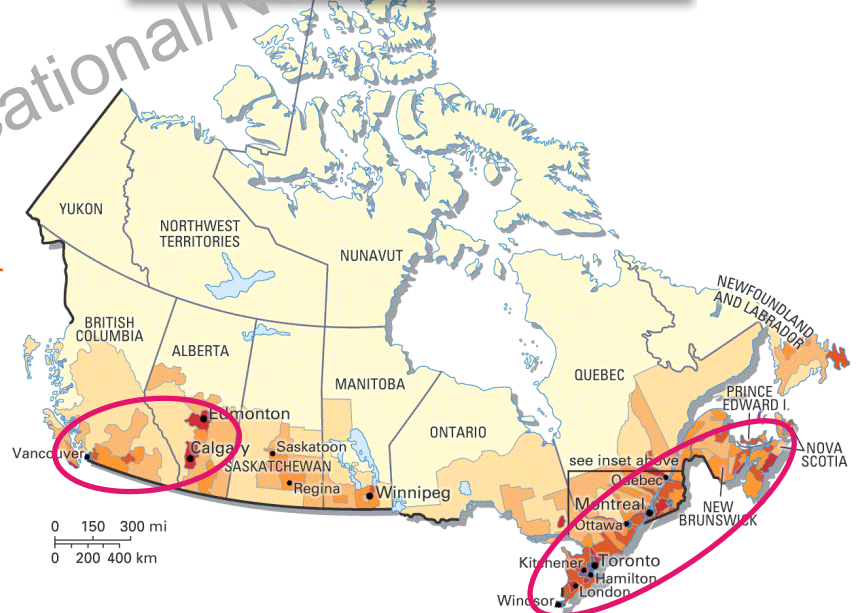
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Introduction

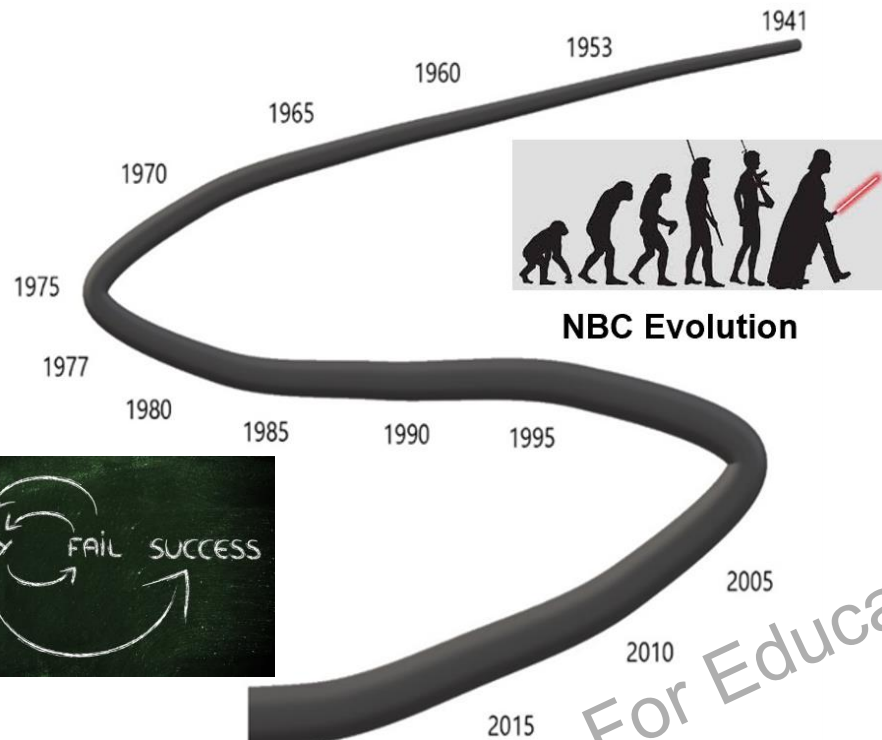
Earthquake Risk in Canada



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Seismic Risk Management of Existing Buildings

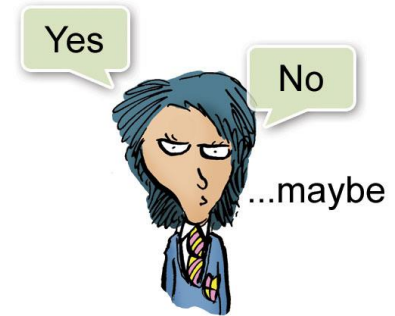


NBC Evolution

Large Building Inventory



Is Seismic Risk Acceptable?

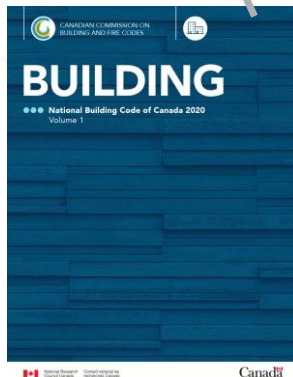


How to Find the Answer?

Economy

Accuracy

Time



Existing NRC's Seismic Guidelines

60% used in
NBC Commentary L
until 2015 edition



Compatible with **NBC 1990**

NBC 2015/2020 Commentary L

Inconsistent seismic upgrading levels for structural and non-structural components

Three seismic assessment/upgrading levels

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

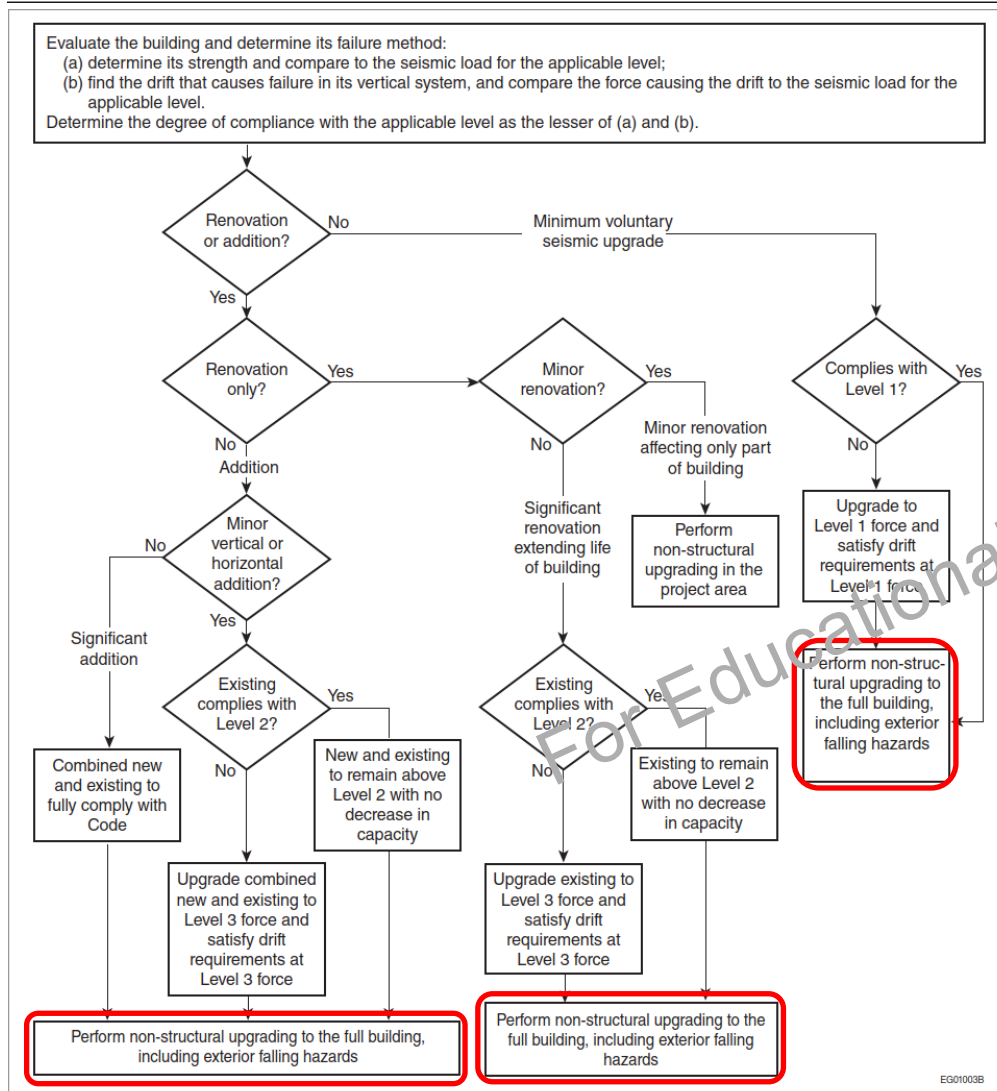


Figure L-1
 Flow chart for the seismic assessment and upgrading of existing buildings

EGBC Seismic Retrofit Guidance



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Seismic Retrofit Guidance

In 2004, the Ministry of Education (EDUC) engaged Engineers and Geoscientists British Columbia (BC), with support from the University of British Columbia (UBC) Civil Engineering Department, to assist with the implementation of a seismic upgrade program for low-rise school buildings in BC.

The long-term goal of this program is to mitigate, within a reasonable period of time, the risk of seismically deficient buildings in EDUC's inventory. The SRG were developed to achieve two important goals:

1. Implement seismic retrofits that achieve a life safety objective in a cost-effective manner
2. To adopt a common engineering approach to the seismic retrofit of low-rise school buildings

The EDUC has directed that the Seismic Retrofit Guidelines (SRG) be applied to all schools undergoing a seismic assessment and retrofit under their school seismic mitigation program. On a voluntary basis, with appropriate permissions from authorities having jurisdiction and/or project decision-makers, the SRG may be used for other low-rise buildings in BC.

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 Earthquake Management Frameworks



Pre-Earthquake Risk Management Framework



Post-Earthquake Safety Management Framework



Prepare



Protect



Survive



Respond



Recover and Repair

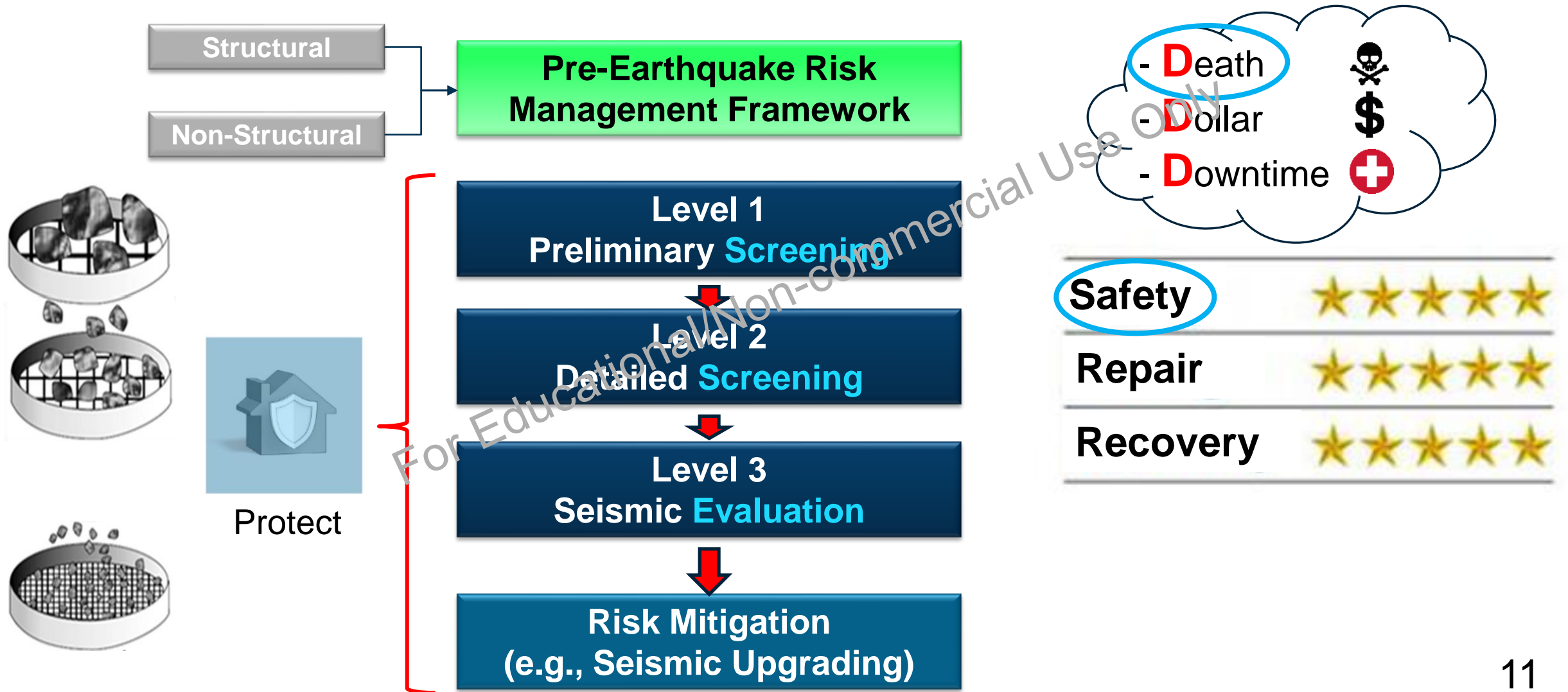
2016 – 2025



2022 – present



NRC's Pre-Earthquake Risk Management Framework



NRC's Updated Seismic Tools/ Guidelines



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[Search NRC Canada.ca](https://www.nrc.ca)

Canada.ca > National Research Council Canada > Research and development > Products and services > Software and applications

Semi-Quantitative Seismic Risk Screening Tool (SQST)

The Semi-Quantitative Seismic Risk Screening Tool (SQST) assesses the seismic risk of existing buildings. A copy of the Level 2 - SQST can be found in the [NRC directory](#).

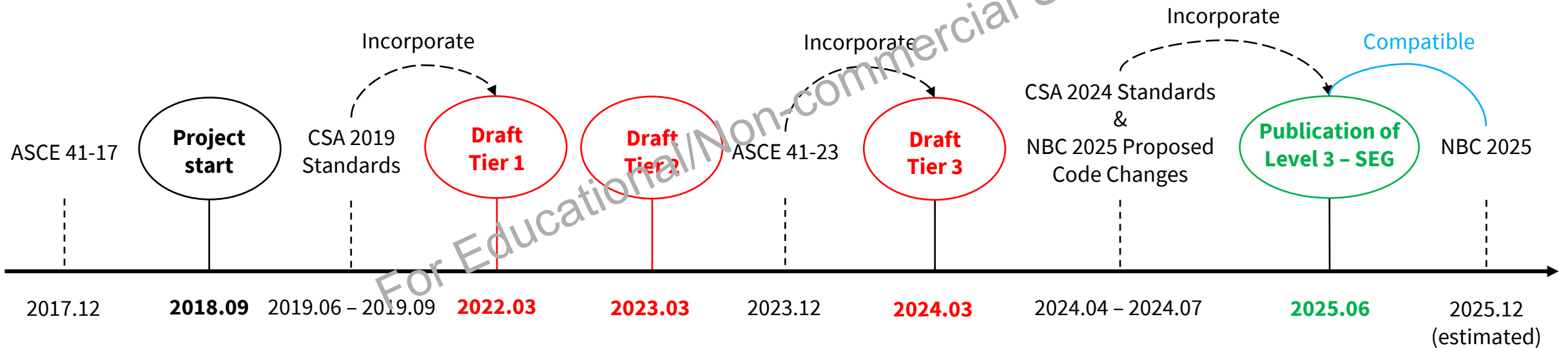
The Level 2 - SQST has been developed for assessing seismic risk in buildings. It is intended for use as a screening tool for seismic risk assessments.

The licence agreement must be read and accepted before being able to use the SQST application.

Web-page Tool

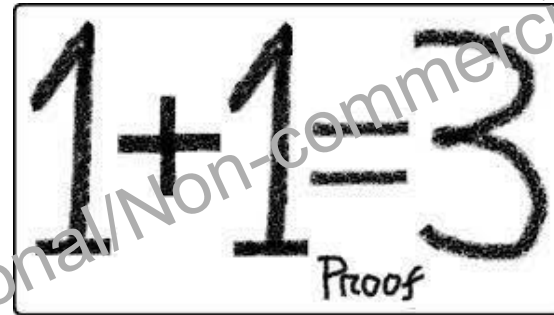
Timeline of Level 3 – SEG Development

Pilot studies have been undertaken using Level 3 – SEG



Collaborative Efforts

Engaged > 50
experts in earthquake
engineering



Public Services and
Procurement Canada

Services publics et
Approvisionnement Canada



Farzad Naeim, Inc.



Global Affairs
Canada
Affaires mondiales
Canada

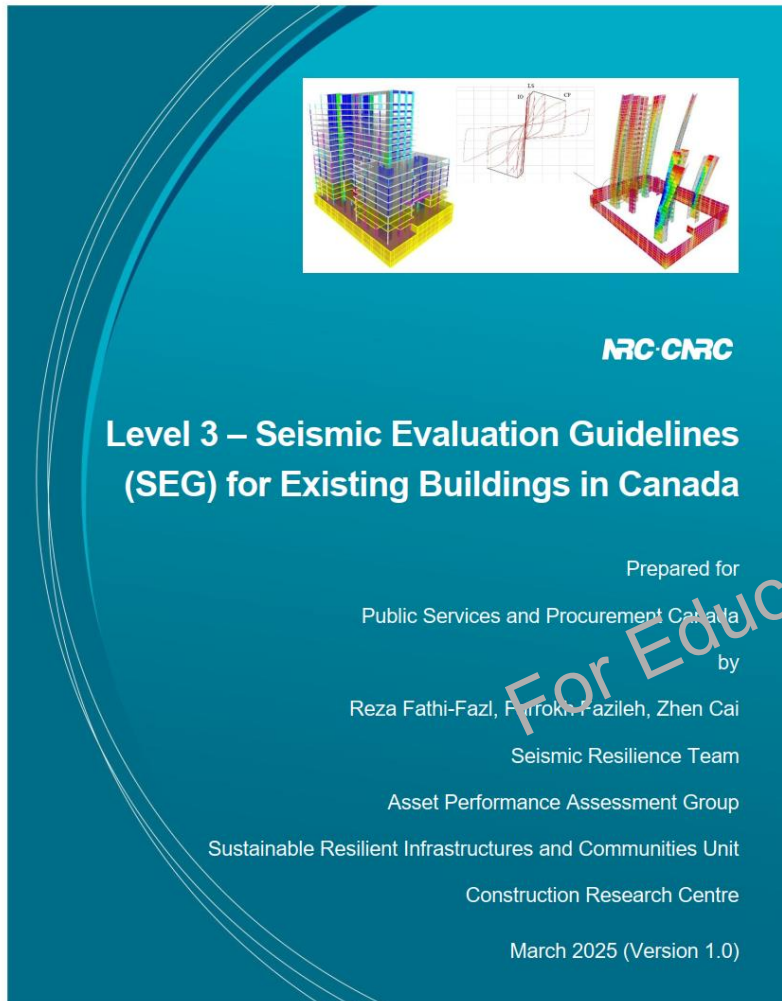


UNIVERSITY OF
TORONTO



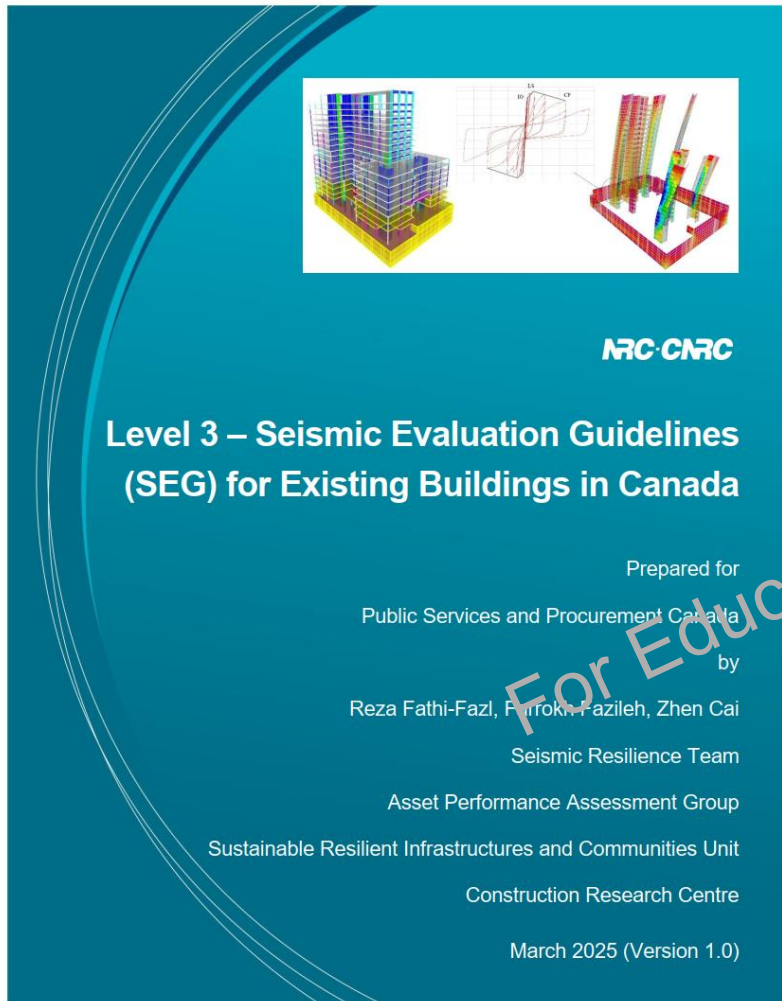
Level 3 – SEG Main Body

Available for free
download from the
[NRC Publications
Archive website](#)



1. Introduction
2. Evaluation Requirements and Performance Objectives
3. Tier 1 Quick Evaluation
4. Tier 2 Deficiency-Based Evaluation
5. Tier 3 Detailed Evaluation
6. Non-structural Evaluation
7. Evaluation of Foundations and Geologic Hazards
8. Evaluation of Seismically Isolated Buildings
9. Evaluation of Buildings Using Supplemental Energy Dissipation
10. References

Level 3 – SEG Appendices



Appendix A Characteristics of Different Model Building Types

Appendix B Tier 1 Quick Evaluation Checklists

Appendix C Commentaries for Tier 1 Evaluation Statements

Appendix D Minimum Design Base Shear Demands

Appendix E Visual Verification and Material Testing

Appendix F Recommended Non-linear Modelling Parameters (NMP) and Acceptance Criteria (AC) for Wood Structures

Appendix G Recommended NMP and AC for Steel Structures

Appendix H Recommended NMP and AC for Concrete Structures

Appendix I Recommended NMP and AC for Masonry Structures

Level 3 – SEG Methodology

ASCE 41 Methodology

Never updated
over the past three
decades

Prescriptive
requirements

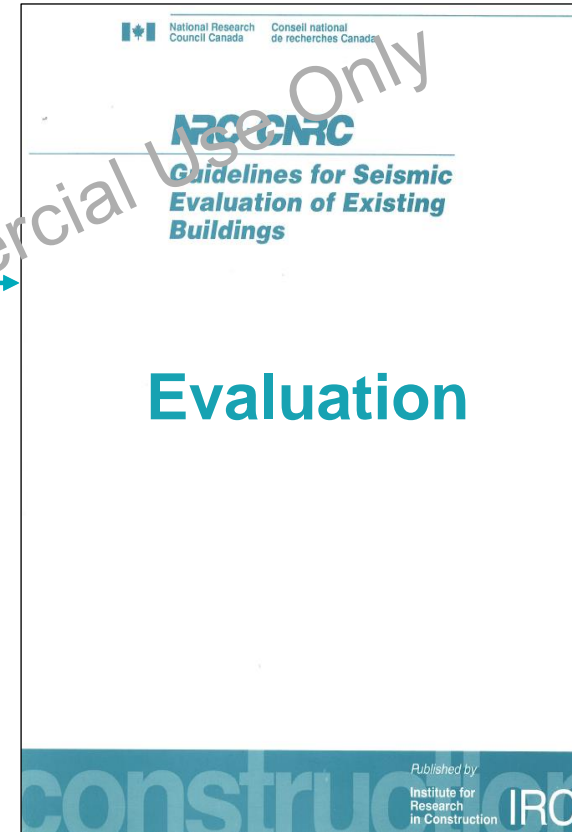
Force-based

Evaluation

ATC-14 (1987)

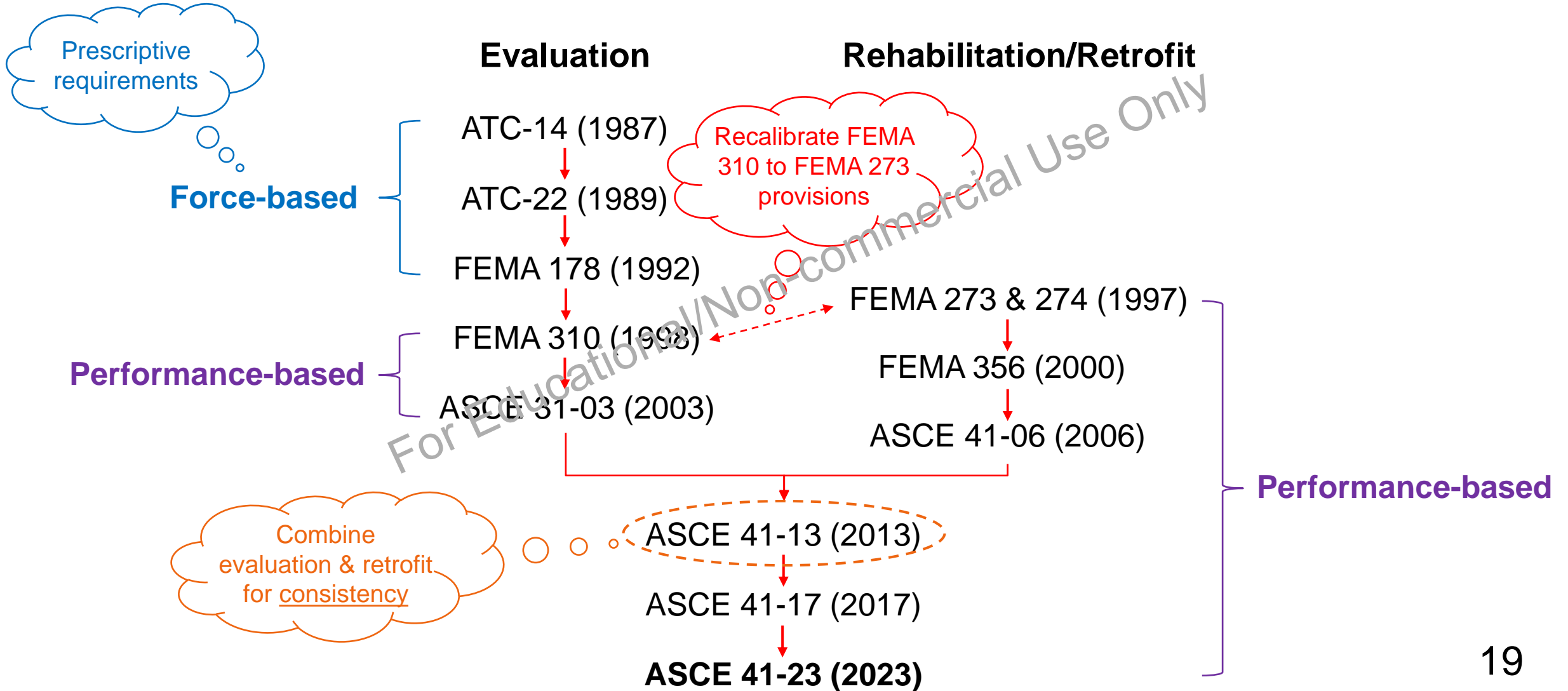
ATC-22 (1989)

FEMA 178 (1992)



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ASCE 41 Methodology



ASCE 41 vs ASCE 7

ASCE 7

For design

- Force-based design
- Linear + non-linear analysis procedures
- System response modification factor (R)
- Factored resistance ($\phi < 1.0$)



ASCE 41

For evaluation
and retrofit

- Performance-based evaluation
- Linear + non-linear analysis procedures
- System modification factor (M_s) for Tier 1, component capacity modification factor (m) or backbone curves for Tier 2 or Tier 3
- Expected capacity (μ) and lower-bound capacity ($\mu - 1.0\sigma$)

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Level 3 – SEG Methodology

Force-based

- **Linear** analysis procedures (**Tiers 1 – 3**)
- **Qualitative** objectives
 - **Life safety** for all Importance Categories
 - **Damage limitation** for High Importance and Post-disaster Categories

Performance-based

- **Non-linear** analysis procedures (**Tier 3 ONLY**)
- **Discrete** building performance levels
 - Immediate Occupancy
 - Damage Control
 - Life Safety
 - Collapse Prevention

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Level 3 – SEG Methodology

Force-based

- Linear analysis procedures (Tiers 1 – 3)
- Qualitative objectives
 - Life safety for all Importance Categories
 - Damage limitation for High Importance and Post-disaster Categories

Commentary J

Design for Seismic Effects

7. The primary objective of seismic design is to provide an acceptable level of life safety for building occupants and the general public as the building responds to strong ground motion—in other words, to minimize loss of life (for a discussion of the additional objectives for High Importance Category and post-disaster buildings, see Paragraph 11). This implies that, although there may be extensive structural and non-structural damage during the DGM, there is a reasonable degree of confidence that the building will not collapse nor will its attachments break off and fall on people near the building. This performance level is termed “extensive damage.” Although the structure may have lost a substantial amount of its initial strength and stiffness, it is expected to retain a margin of resistance against collapse. Some buildings may be damaged to such an extent that they have to be demolished.

Level 3 – SEG Methodology

Force-based

- **Linear** analysis procedures (**Tiers 1 – 3**)
- **Qualitative** objectives

Commentary J

Design for Seismic Effects

- **Life safety** for all Importance Categories

- **Damage limitation** for High Importance and Post-disaster Categories

11. For certain categories of buildings, the objectives of the NBC seismic design requirements include **limiting the damage caused by the DGM-level ground shaking**. Post-disaster buildings are expected to remain functional immediately following an earthquake. Therefore, the performance objective for post-disaster buildings can best be described as “functional.” High Importance Category buildings,

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Level 3 – SEG Methodology

Force-based

- Linear analysis procedures (Tiers 1 – 3)
- Qualitative objectives
 - Life safety for all Importance Categories
 - Damage limitation for High Importance and Post-disaster Categories

Commentary L

Application of NBC Part 4 of Division B for the Structural Evaluation and Upgrading of Existing Buildings

4. This Commentary aims to help overcome these difficulties by facilitating the application of the requirements of NBC Part 4 to existing buildings through relaxations where appropriate and alternatives where available (usually by reference to other documents). NBC Sentence 4.1.1.5.(2) allows structural alternatives that demonstrate a level of safety and performance in accordance with the requirements of NBC Part 4, but except for load testing, the provisions of this Sentence are directed primarily to new construction. Structural alternatives should comply with the requirements

An acceptably lower building performance is permitted for existing buildings, except post-disaster buildings

Level 3 – SEG Methodology

Enforced building code/act at federal, provincial/territorial, or municipal level

Force-based

- Linear analysis procedures
- Qualitative objectives
 - Life safety
 - Damage limitation

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

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

Relaxation on earthquake load and effects



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Level 3 – SEG Methodology

Force-based

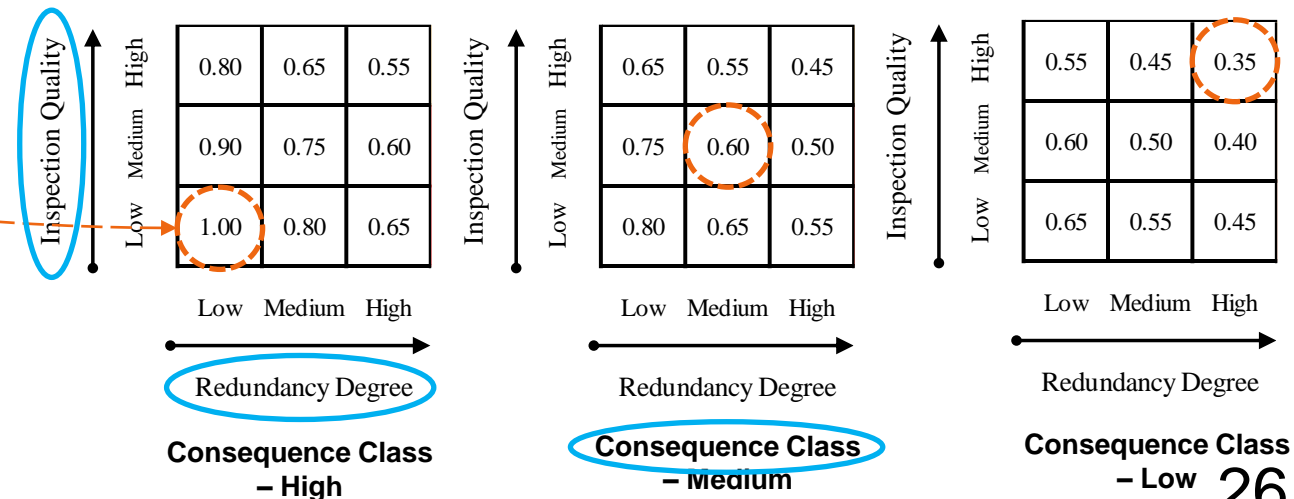
- Linear analysis procedures
- Qualitative objectives
 - Life safety
 - Damage limitation

Earthquake load factor for evaluation is a function of three key parameters

[0.35, 1.0]

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

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

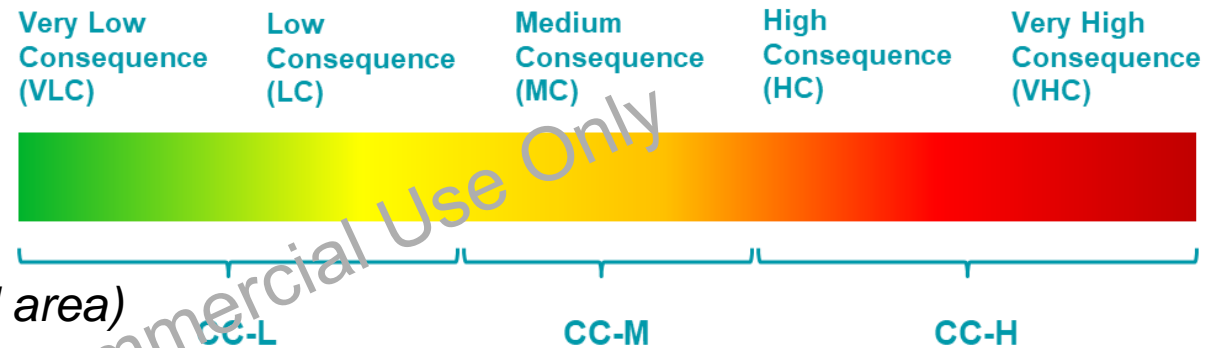


Consequence Class

Consequence Classification System

- *Occupancy Class (consistent with the NBC)*
- *Likelihood of Occupancy*
- *Building size (total floor area, excluding unoccupied area)*
- *Number of storeys (above grade)*
- *Occupants' age/mobility*

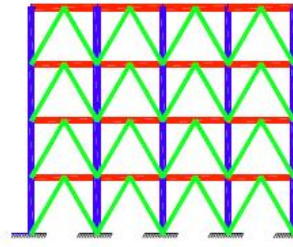
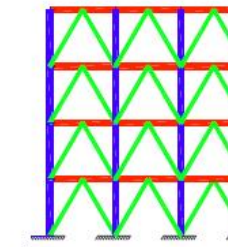
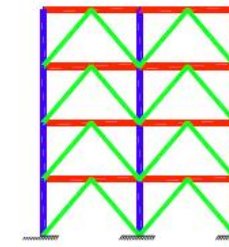
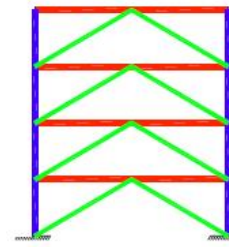
➔ **Fine-tune** the risk categories in NBC Commentary L



versus



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

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⁾	$r < 2$	$2 \leq r < 3$	$r \geq 3$
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⁾	$r < 2$	$2 \leq r < 3$	$r \geq 3$

⁽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) $r \geq 2.0$ 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

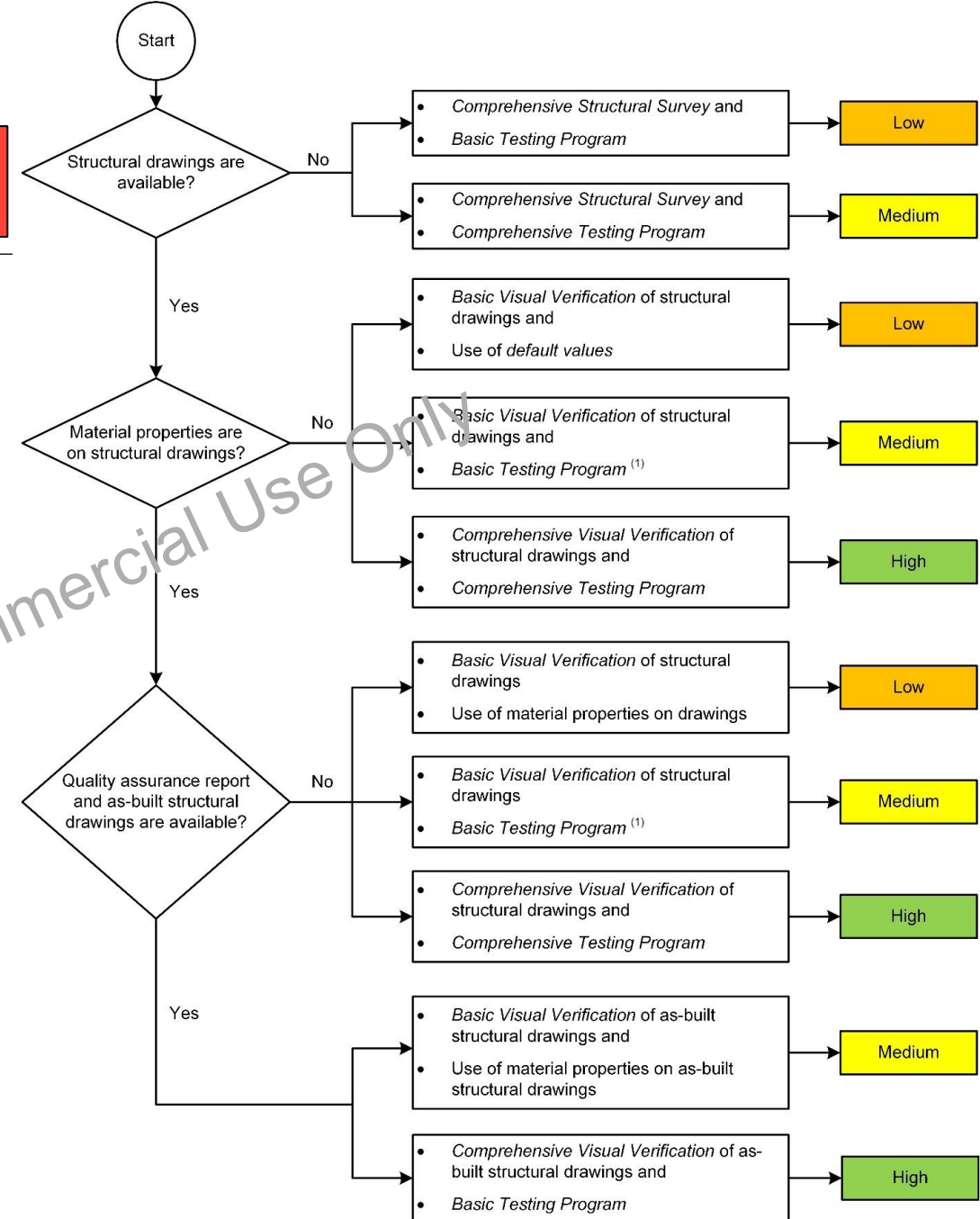


Inspection Quality Classification

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

Appendix E Guidance for Performing Visual Verification and Material Testing

This appendix provides guidance for conducting different levels of visual verification and material testing programs. The guidance sets the minimum requirements for achieving different levels of visual verification and material testing programs, based on a comprehensive literature review of state-of-the-practice building condition assessment for the evaluation and upgrading of *existing buildings* and infrastructure. More details about the investigation of the minimum requirements for visual verification and material testing programs can be found in WSP (2021).



⁽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.

Level 3 – SEG Methodology

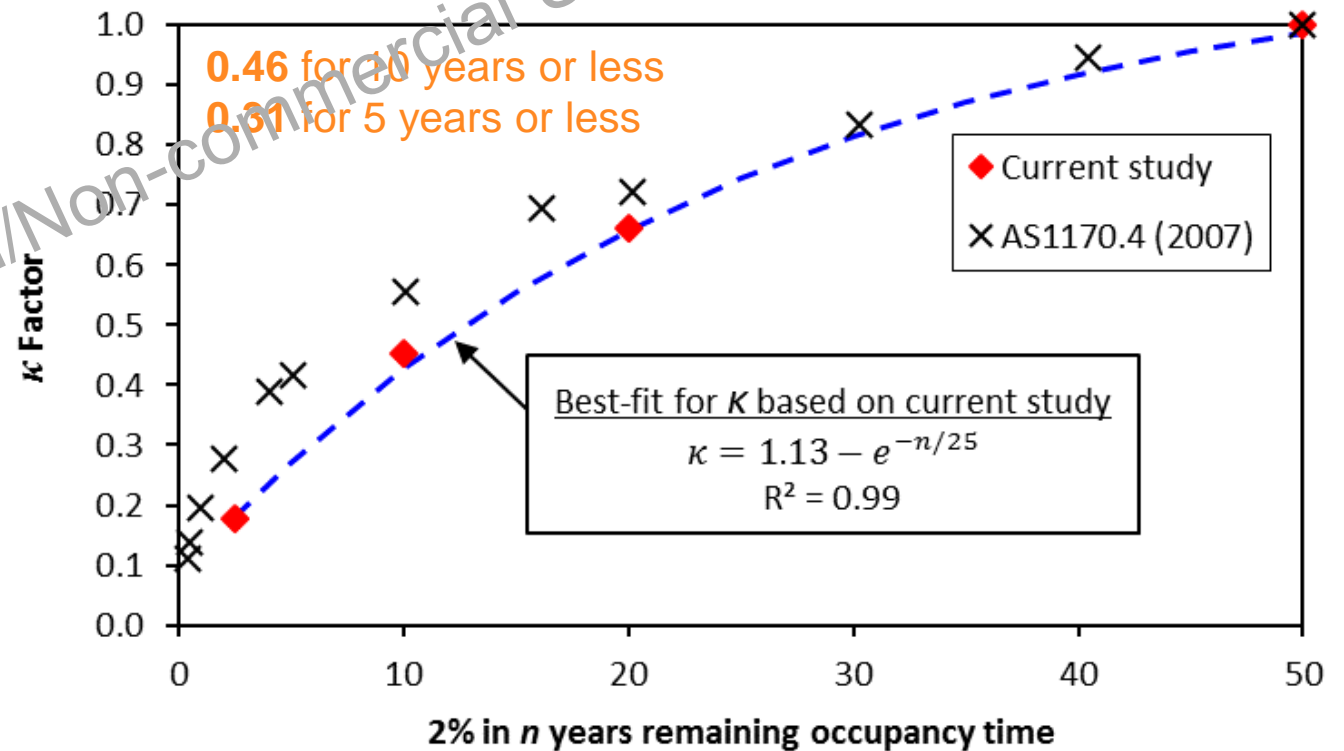
Force-based

- Linear analysis procedures
- Qualitative objectives
 - Life safety
 - Damage limitation

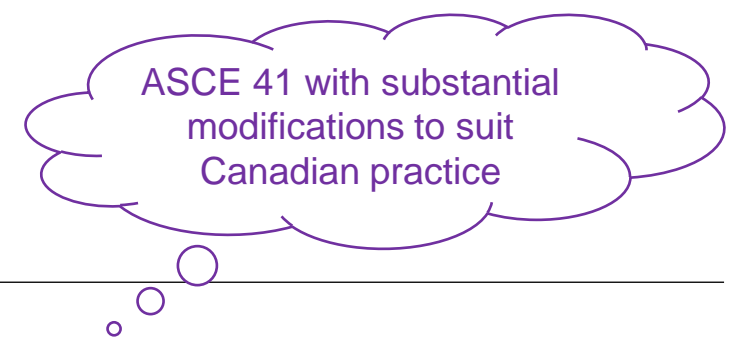
$$V_{QE} = \kappa \alpha_{QE} V_N$$

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

Remaining occupancy time does not apply to post-disaster buildings



Level 3 – SEG Methodology



Force-based

- Linear analysis procedures (Tiers 1 – 3)
- Qualitative objectives
 - Life safety for all Importance Categories
 - Damage limitation for High Importance and Post-disaster Categories

Performance-based

- Non-linear analysis procedures (**Tier 3 ONLY**)
- Discrete building performance levels
 - Immediate Occupancy
 - Damage Control
 - Life Safety
 - Collapse Prevention

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Level 3 – SEG Methodology

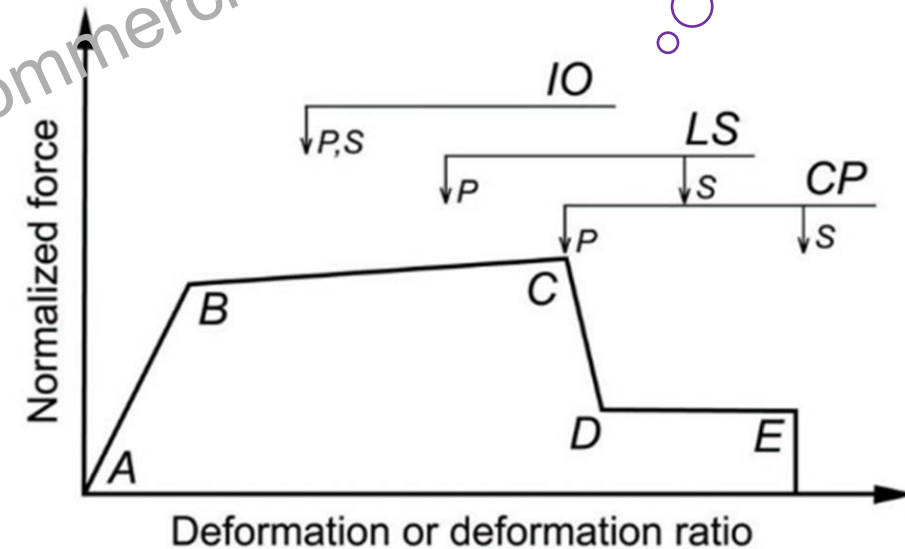
Performance-based

ASCE 41 definitions with necessary modifications

- Non-linear analysis procedure (Tier 3 ONLY)
- Discrete building performance levels
 - Immediate Occupancy
 - Damage Control
 - Life Safety
 - Collapse Prevention
 - Collapse Prevention Structural
 - Life Safety Non-structural

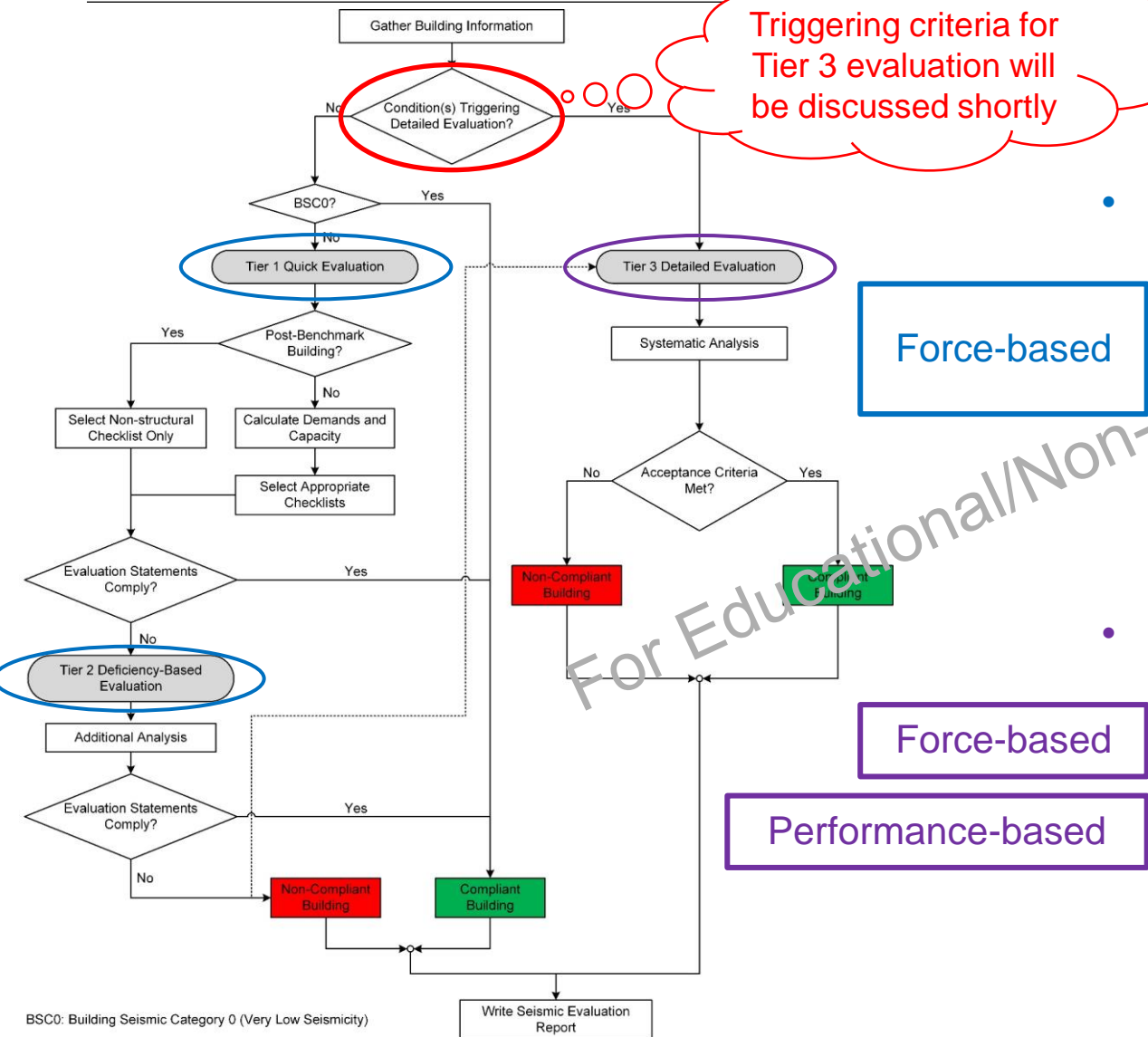
Life Safety considered for consistency with NBC

ASCE 41 modelling parameters and acceptance criteria with necessary modifications



Force-deformation relationship

Level 3 – SEG Evaluation Process



Triggering criteria for Tier 3 evaluation will be discussed shortly

Evaluate specific deficiencies

- Simplified evaluation procedures
 - Tier 1 Quick Evaluation
 - Tier 2 Deficiency-Based Evaluation

Force-based

- Systematic evaluation procedures
 - Tier 3 Detailed Evaluation – Linear
 - Tier 3 Detailed Evaluation – Non-linear

Force-based

Performance-based

Evaluate everything

BSC0: Building Seismic Category 0 (Very Low Seismicity)

Tier 1 Quick Evaluation

Tier 1 Quick Evaluation

May be used to gain a deeper understanding of the building if any listed condition is present

Tier 1 evaluation is not permitted for:

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

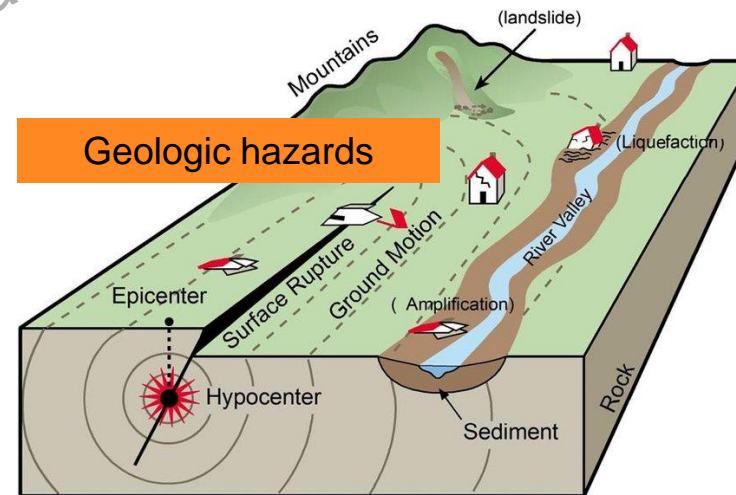
Structural deterioration



Seismic isolation



Supplemental energy dissipation



Tier 1 Quick Evaluation

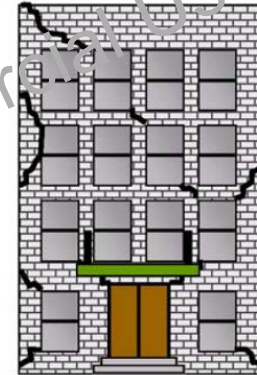
Intent and Scope

Tier 1 evaluation

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

Evaluating engineers must receive proper training

The completed report must be reviewed



Life Safety



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:

Low Seismicity Checklist

Low Seismicity Checklist
does not apply to CC-H
buildings

Table B.1: Low Seismicity Checklist for CC-L or CC-M buildings in BSC1

Status	Evaluation Statement	Tier 2 Evaluation Reference	Commentary Reference
Structural Components			
<input type="checkbox"/> C <input type="checkbox"/> NC <input type="checkbox"/> N/A <input type="checkbox"/> 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
<input type="checkbox"/> C <input type="checkbox"/> NC <input type="checkbox"/> N/A <input type="checkbox"/> U	WALL ANCHORAGE: Exterior concrete or masonry walls that are dependent on the diaphragm to provide out-of-plane 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 adequate capacity to resist the connection force calculated by Eq. (3.1) in Section 3.9.	Sec. 4.8.1	Sec. C.6.1

Note: C = Compliant, NC = Non-compliant, N/A = Not Applicable, and U = Unknown.

Low Seismicity Checklist

- Load path
- Wall anchorage

Basic Configuration Checklist

Additional statements need to be checked for higher seismicity

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			
<input type="checkbox"/> C <input type="checkbox"/> NC <input type="checkbox"/> N/A <input type="checkbox"/> 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
<input type="checkbox"/> C <input type="checkbox"/> NC <input type="checkbox"/> N/A <input type="checkbox"/> U	REDUNDANCY: The building has a required degree of redundancy as per Table 3.5.	Sec. 4.4.1	Sec. C.2.1
<input type="checkbox"/> C <input type="checkbox"/> NC <input type="checkbox"/> N/A <input type="checkbox"/> 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

Basic Configuration Checklist

- Building system characteristics
- Building irregularities
- Foundations
- Geologic hazards

Structural Checklists

Structural Checklists are available for 17 model building types

Table B.3: Structural Checklist for CC-L or CC-M WLF buildings

Status	Evaluation Statement	Tier 2 Evaluation Reference	Commentary Reference
Moderate Seismicity (BSC2) and			
Moderately High Seismicity (BSC3)			
Seismic-Force-Resisting System			
<input type="checkbox"/> C <input type="checkbox"/> NC <input type="checkbox"/> N/A <input type="checkbox"/> U	<p>SHEAR STRESS CHECK: The shear stress in the shear walls, calculated by Eq. (3.8) in Section 3.14.2.2.2, is less than the following values:</p> <ul style="list-style-type: none"> Structural panel plywood sheathing (4.0 kN/m) Diagonal sheathing (5.6 kN/m) All other conditions (1.0 kN/m) <p>Shear stress check is not required for WLF-P9 buildings.</p>	Sec. 4.6.2.6	Sec. C.4.2.6
<input type="checkbox"/> C <input type="checkbox"/> NC <input type="checkbox"/> N/A <input type="checkbox"/> U	<p>STUCCO (EXTERIOR PLASTER) SHEAR WALLS: Multi-storey buildings do not rely on exterior stucco walls as the primary seismic-force-resisting system.</p>	Sec. 4.6.2.6	Sec. C.4.2.6
<input type="checkbox"/> C <input type="checkbox"/> NC <input type="checkbox"/> N/A <input type="checkbox"/> U	<p>SHEAR WALL ASPECT RATIO: Wood shear walls with an aspect ratio greater than 2-to-1 are not used to resist seismic forces.</p>	Sec. 4.6.2.6	Sec. C.4.2.6

Structural Checklists

- Seismic-force-resisting system
- Connections
- Diaphragms

Non-structural Checklist

Consequence class and seismicity have been incorporated in each evaluation statements

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 <input type="checkbox"/> C <input type="checkbox"/> NC <input type="checkbox"/> N/A <input type="checkbox"/> U Means of egress <input type="checkbox"/> C <input type="checkbox"/> NC <input type="checkbox"/> N/A <input type="checkbox"/> 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. <ul style="list-style-type: none"> • 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 <input type="checkbox"/> C <input type="checkbox"/> NC <input type="checkbox"/> N/A <input type="checkbox"/> U Means of egress <input type="checkbox"/> C <input type="checkbox"/> NC <input type="checkbox"/> N/A <input type="checkbox"/> 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

Non-structural Checklist

- Architectural components
- Electric/mechanical equipment
- Other components & building content

Limits/Thresholds in Statements

The limits and thresholds have been made compatible with the NBC and CSA design/assessment standards

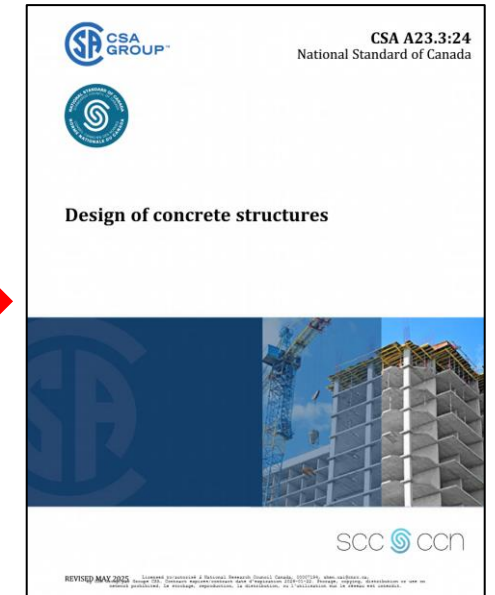
Substantial efforts have been made to investigate the rationales behind the limits/thresholds & adapt to Canada

Material	Canada	United States
Steel	CSA S16	ANSI/AISC 341 ANSI/AISC 360
Concrete	CSA A23.3	ACI 318
Wood	Part 9 of the NBC Wood Design Manual CSA O86	IRC SPDWS
Masonry	CSA S304	TMS 402/602
Cold-formed steel	CSA S136	AISI S100

Reinforcing Steel (SCW, CSW, PCF)

Level 3 – SEG statement: 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.

Standards/ Guidelines	Life Safety	Collapse Prevention
FEMA 178	0.0025 in both vertical and horizontal directions	N/A
FEMA 310	0.0015 in the vertical direction 0.0025 in the horizontal direction	N/A
ASCE 31-03	0.0015 in the vertical direction 0.0025 in the horizontal direction	N/A
ASCE 41-13	0.0012 in the vertical direction 0.0020 in the horizontal direction	N/A
ASCE 41-17/23	N/A	0.0012 in the vertical direction 0.0020 in the horizontal direction



map
→

0.0015

14.1.8.2.4 Minimum distributed vertical reinforcement

Except as required in Clause [14.1.8.2.5](#), the minimum area of distributed vertical reinforcement between boundary elements shall be $0.0015A_g$, except for squat shear walls in which the minimum area of distributed vertical reinforcement shall be $0.002A_g$.

0.002

14.1.8.2.8 Distributed horizontal reinforcement

The minimum area of distributed horizontal reinforcement shall be $0.002A_g$, except as otherwise required in Clauses [14.1.8.2.5](#) and [14.1.8.2.6](#). However, where crack control is critical, or wall geometry or the length of the wall between joints causes significant restraint of shrinkage or thermal strains, reinforcement additional to that specified in this Clause or other crack control measures shall be considered.

Limits/Thresholds in Statements

The limits and thresholds have been made compatible with the NBC and CSA design/assessment standards

Substantial efforts have been made to investigate the rationales behind the limits/thresholds & customize them to Canada

Non-Structural System	Design and Assessment Standards and Guidelines	
Non-structural components (operational and functional components)	CSA S832	FEMA E74
Steel storage racks	CSA S16 CSA A344.1 CSA A344.2	ANSI MH16.1
Fire suppression systems	NFPA-13	NFPA-13 ASCE/SEI 25
HVAC systems	ASHRAE 2012 SMACNA 2009	ASHRAE 2012 SMACNA 2009
Life safety systems	CSA C282	NFPA 110
Elevators and escalators	CSA B44	ASME A17.1-2019
Ceilings	CAN/CSA-A82.31	ASTM C635/C635M ASTM C841 ASTM E3090/E3090M
Masonry partitions, parapets, and veneers	CSA S304 CSA A370	TMS 402

Tier 1 Quick Evaluation Procedure

Key elements in the Tier 1 evaluation procedure

1. Seismicity
2. Benchmark code editions
3. Building height limits
4. Base shear calculations
5. Quick Checks

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Seismicity

Thresholds obtained from empirical MMI-Sa relationships

Definitions of Seismic Categories (SC) in the NBC and Building Seismic Categories (BSC) in Level 3 – SEG

BSC (Level 3 – SEG)		$I_{ES}(0.2)$		$I_{ES}(1.0)$	
		>	≤	>	≤
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	0.15g	0.30g
BSC4	High Seismicity	0.75g	1.15g	0.30g	0.5g
BSC5	Very High Seismicity	1.15g		0.5g	

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Seism

Thresholds are adjusted to align with the NBC

Definitions of Seismic Categories (SC) in the NBC and Building Seismic Categories (BSC) in Level 3 – SEG

SC (NBC)	BSC (Level 3 – SEG)		$I_{ES}(0.2)$		$I_{ES}(1.0)$	
			>	\leq	>	\leq
SC1	BSC0	Very Low Seismicity		0.10g		0.05g
	BSC1	Low Seismicity	0.10g	0.20g	0.05g	0.10g
SC2	BSC2	Moderate Seismicity	0.20g	0.35g	0.10g	0.20g
SC3	BSC3	Moderately High Seismicity	0.35g	0.75g	0.15g	0.30g
SC4	BSC4	High Seismicity	0.75g	1.15g	0.30g	0.5g
	BSC5	Very High Seismicity	1.15g		0.5g	

- BSC0 is used to exempt buildings from seismic evaluation provided that certain conditions are not present
- BSC 5 is used to help building owners prioritize their buildings in most need of seismic evaluation

Seismicity

CC-H buildings are assessed for one level higher seismicity

Additional Evaluation Statements in the Basic Configuration Checklist and Structural Checklists to Be Assessed for CC-H Buildings

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

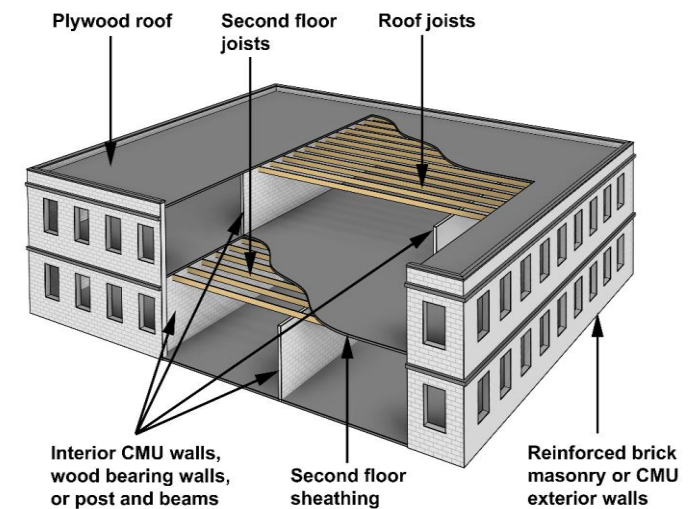
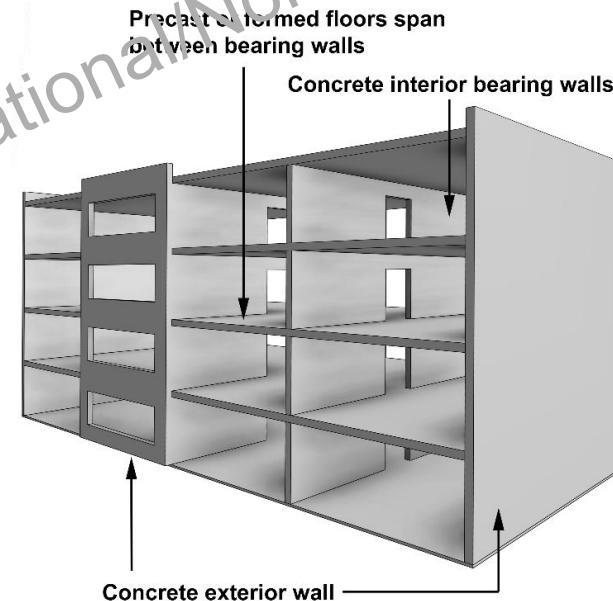
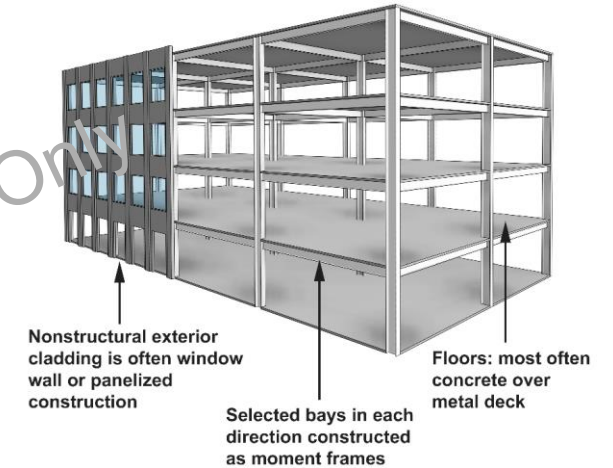
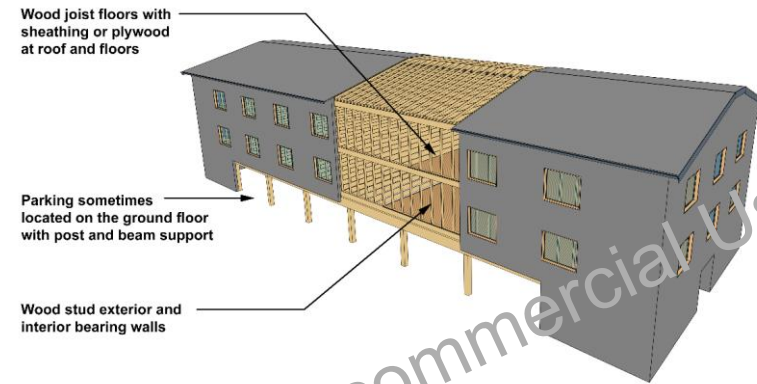
(1) Basic Configuration Checklist and Structural Checklists do not apply to CC-L or CC-M buildings in BSC1. Instead, the Low Seismicity Checklist should be selected and completed according to Section 3.9.

Appendix A Characteristics of Different Model Building Types

Benchmark Code Editions

This appendix provides additional information about different *model building types* considered in the *Level 3 – SEG*, including detailed descriptions of their characteristics, typical seismic performance, and earthquake damage.

Model building type
WLF-P9
WLF
WPB
SMF
SBF
SLF
SCW
SIW
CMF
CSW
CIW
PCW
PCF (PCF1 and PCF2)
RML
RMC
URM
CFS (CFS1 and CFS2)



Benchmark Code Editions

Post-benchmark buildings are eligible to be exempt from structural seismic evaluation

Model building type	Benchmark NBC edition
WLF-P9	2010
WLF	2005 (≤ 4 storeys); 2015 ($4 < \text{storeys} \leq 6$)
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

Benchmark Code Editions

Benchmark provincial codes/acts are also identified

Model building type	Benchmark NBC edition
WLF-P9	2010
WLF	2005 (≤ 4 storeys); 2015 ($4 < \text{storeys} \leq 6$)
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

Building Height Limits

Building height limits for
CC-L/CC-M buildings are
adapted from NBC Table
4.1.8.9

Building height limits

- Model building type
- Seismicity
- Consequence class

(stricter limits for CC-H buildings)

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.

Base Shear Calculations

Estimated minimum seismic base shear capacity (V_E) of existing buildings

$$V_E = \alpha_Q V_D$$

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).

Base Shear Calculations

Estimated minimum seismic base shear capacity (V_E) of existing buildings


$$V_E = \alpha_Q V_D$$


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

Base Shear Calculations

Seismic base shear for evaluation (V_{QE}) of existing buildings

0.46 for 10 years or less
0.31 for 5 years or less

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

Inspection Quality ↑

High	0.80	0.65	0.55
Medium	0.90	0.75	0.60
Low	1.00	0.80	0.65

Low Medium High

Redundancy Degree →

Consequence Class
– High

Inspection Quality ↑

High	0.65	0.55	0.45
Medium	0.75	0.60	0.50
Low	0.80	0.65	0.55

Low Medium High

Redundancy Degree →

Consequence Class
– Medium

Inspection Quality ↑

High	0.55	0.45	0.35
Medium	0.60	0.50	0.40
Low	0.65	0.55	0.45

Low Medium High

Redundancy Degree →

Consequence Class
– Low

Base Shear Calculations

This is a new feature
in Level 3 – SEG

Select appropriate Tier 1 Quick Evaluation Checklists

$$V_E \geq V_{QE}$$



Basic Configuration + Non-structural

$$0.3kV_N \leq V_E < V_{QE}$$



Basic Configuration + Structural + Non-structural

$$V_E < 0.3kV_N$$



Skip Checklists & → Tier 3 Detailed Evaluation

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Quick Checks

Hand calculations

Storey Shear Forces		$F_t = 0.07T_a V_{QE}$
		$F_x = (V_{QE} - F_t) W_x h_x / \left(\sum_{i=1}^{n_s} W_i h_i \right)$
		$V_j = \sum_{x=j}^{n_s} F_x$
Flexible Diaphragms	Connection Force	$T_c = \psi \alpha_{QE} S(0.2) w_p A_p$
Shear Walls	Shear Stress	$v_j^{avg} = \frac{V_j}{A_w}$
Concrete Columns	Shear Stress	$v_j^{avg} = \frac{n_c}{n_c - n_f} \left(\frac{V_j}{A_c} \right)$
	Axial Stress	$p_{ot} = \frac{2}{3} \left(\frac{V_{QE} h_n}{L_f n_f} \right) \left(\frac{1}{A_{col}} \right)$
Steel Moment Frames	Flexural stress	$f_j^{avg} = \frac{n_c}{n_c - n_f} \left(\frac{h_s}{2} \right) \left(\frac{V_j}{Z} \right)$
Bracing Elements	Axial Stress	$p_j^{avg} = \frac{V_j}{s N_{br}} \cdot \frac{L_{br}}{(1 + C_r/T_r)} \frac{1}{A_{br}}$
Pre-stressed Elements	Axial Stress	$f_{pr} = \frac{f_{pe} n_{pr}}{A_{pr}}$
Precast Connections	Connection Strength	$M_{gj} = \frac{V_j}{n_c - n_f} \left(\frac{h_c}{2} \right)$
Steel Moment Frames	Storey Drift	$D_r = \left(\frac{k_b + k_c}{k_b k_c} \right) \left(\frac{h_s}{12E} \right) V_c$

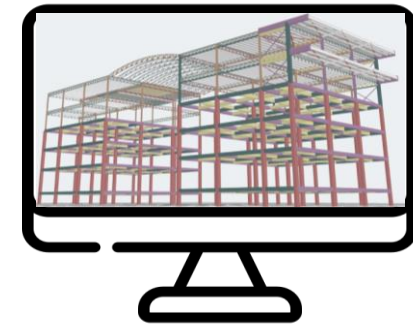
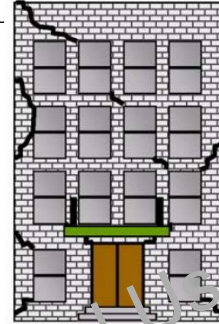
Tier 2 Deficiency-Based Evaluation

Tier 2 Deficiency-Based Evaluation

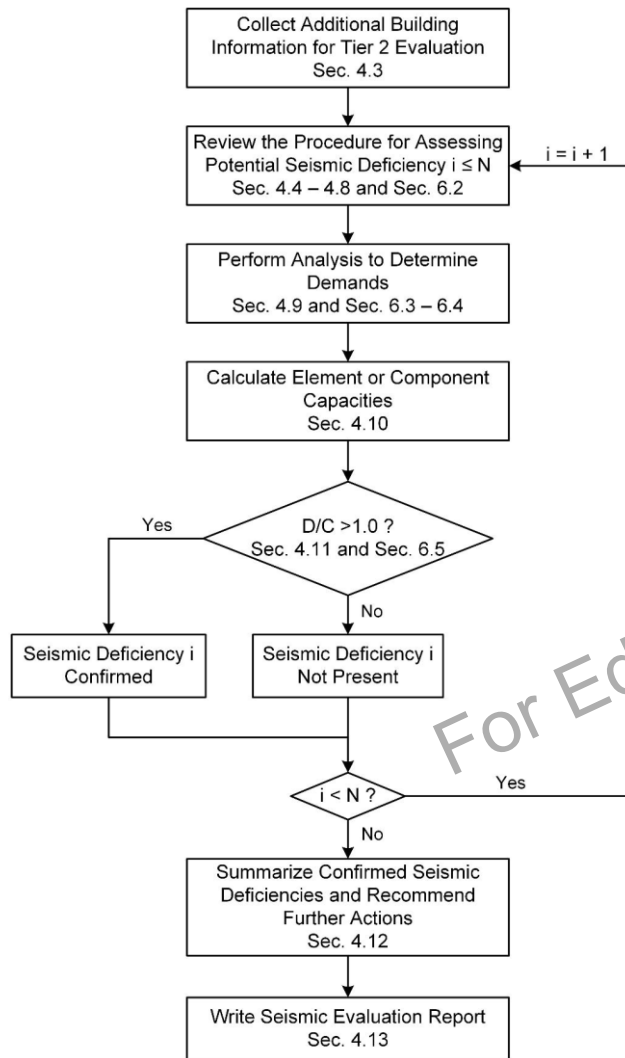
Follow-up visit may be required to collect additional information for Tier 2 evaluation

Intent and Scope

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



Tier 2 Evaluation Process



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

Evaluation Procedures

Tier 2 evaluation contains procedures

- Building system characteristics
- Foundations and geologic hazards
- Seismic-force-resisting systems
- Diaphragms
- Connections

4.4 Procedures for building system characteristics and basic configuration

This section provides the procedures to help assess potential seismic deficiencies that are related to building system characteristics and basic configuration.

4.4.1 Building system characteristics

Load Path. *The structure has a clearly defined load path (or paths), including structural elements and connections, that will transfer the inertial forces generated by the earthquake to the foundations and supporting ground.*

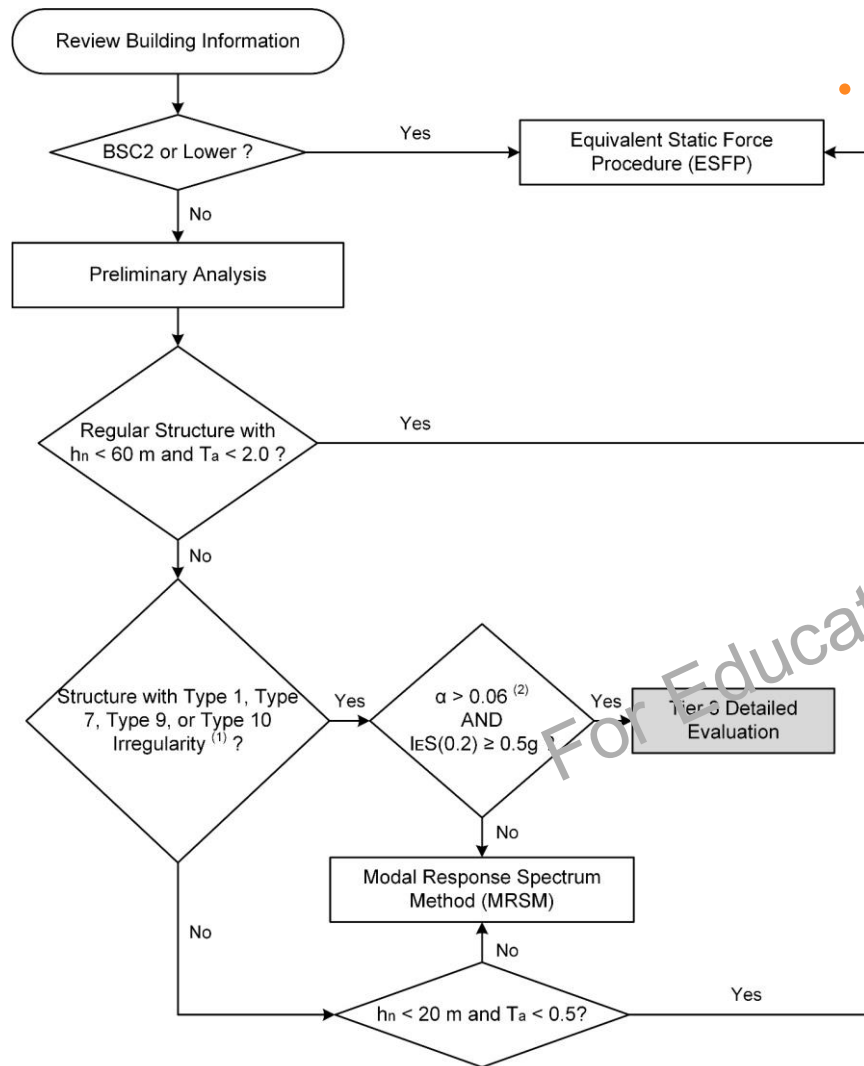
No Tier 2 evaluation procedure is available for buildings without a compliant *load path*. Risk mitigation is recommended to address the deficiency.

Redundancy. *The building has a required degree of redundancy as per Table 3.5.*

Perform an analysis of the building in accordance with Section 4.9 to evaluate the adequacy of all elements and connections of the SFRS in all non-compliant storeys in accordance with Section 4.11.

Building Analysis

Analysis procedure selection



- Criteria for analysis method selection have been made consistent with the NBC
- Linear Time History Analysis is not recommended as it requires selecting spectrum-compatible ground motions which could be challenging to some structural engineers
- Modelling and analysis requirements have been made consistent with the NBC
- Earthquake load factor for evaluation (α_{QE}) and remaining occupancy time factor (κ) need to be applied to calculate seismic base shear demands

⁽¹⁾ Definitions of irregularities are provided in Article 4.1.8.6 of the NBC 2025.

⁽²⁾ 0.2 should be used for an SFRS with self-centering characteristics.

Acceptance Criteria: Capacity Check

- Acceptance criteria for elements/ components with compliant detailing

$$D/C \leq 1.0$$

- Acceptance criteria for elements/ components with non-compliant detailing

$$D/C \leq 1.0$$



Rational analysis or testing demonstrates that the deformation demand on each element or component with non-compliant detailing can be adequately resisted by the element or component

Acceptance Criteria: Drift Check

- The calculated drift (δ) is considered acceptable if the following acceptance criteria are met:

$\delta \leq 0.025$ Low/Normal Importance Category

$\delta \leq 0.02$ High Importance Category

$\delta \leq 0.01$ Post-disaster Importance Category



Consistent with the
NBC drift limits

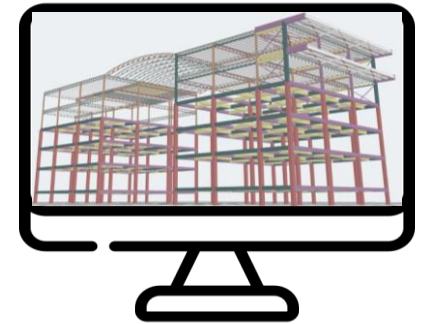
Tier 3 Detailed Evaluation

Tier 3 Detailed Evaluation

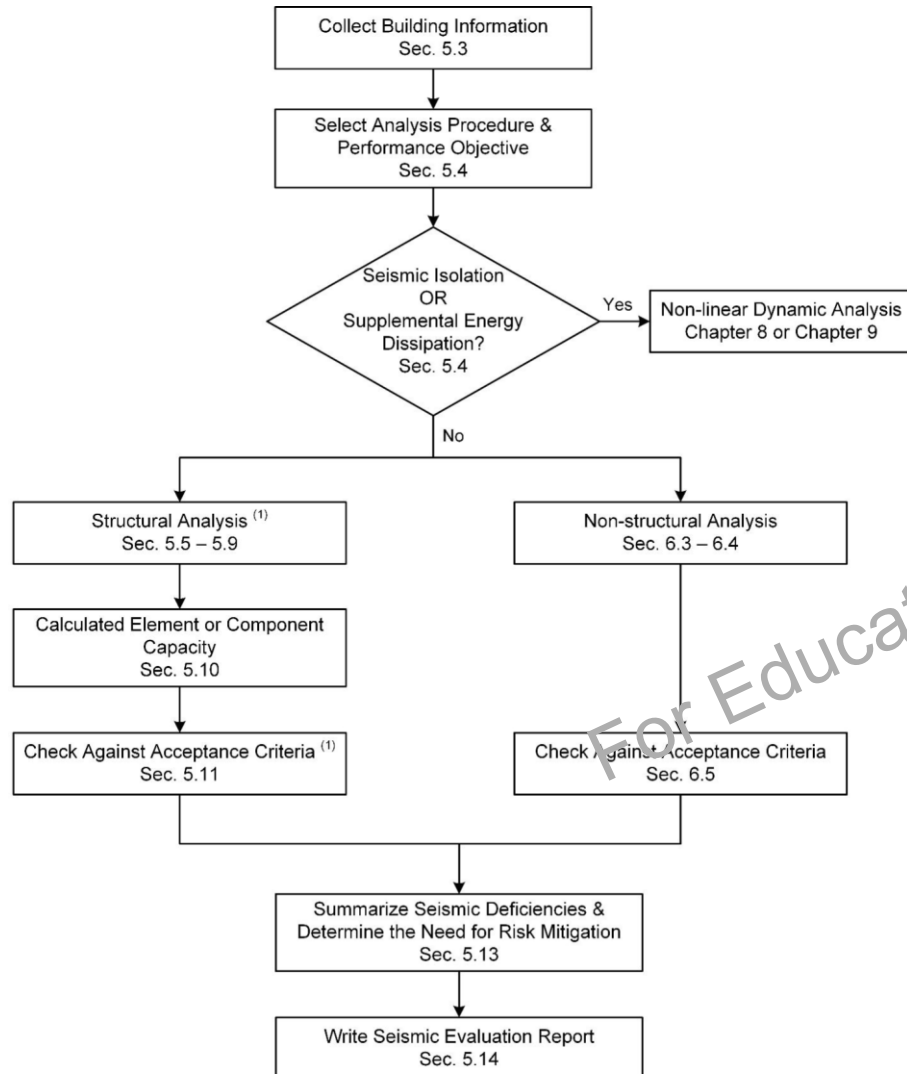
Intent and Scope

- Tier 3 evaluation is used
 - where the use of Tier 1 or Tier 2 is not permitted, or
 - to systematically assess the building
- Tier 3 evaluation requires modelling/ analyzing the whole building
- Independent peer review is strongly recommended for
 - Non-linear (static or dynamic) analysis is performed, or
 - Modelling parameters and acceptance criteria are obtained experimentally from subassemblage tests

Seismic isolation, building damage/ deterioration, geologic hazards, etc.



Tier 3 Evaluation Process

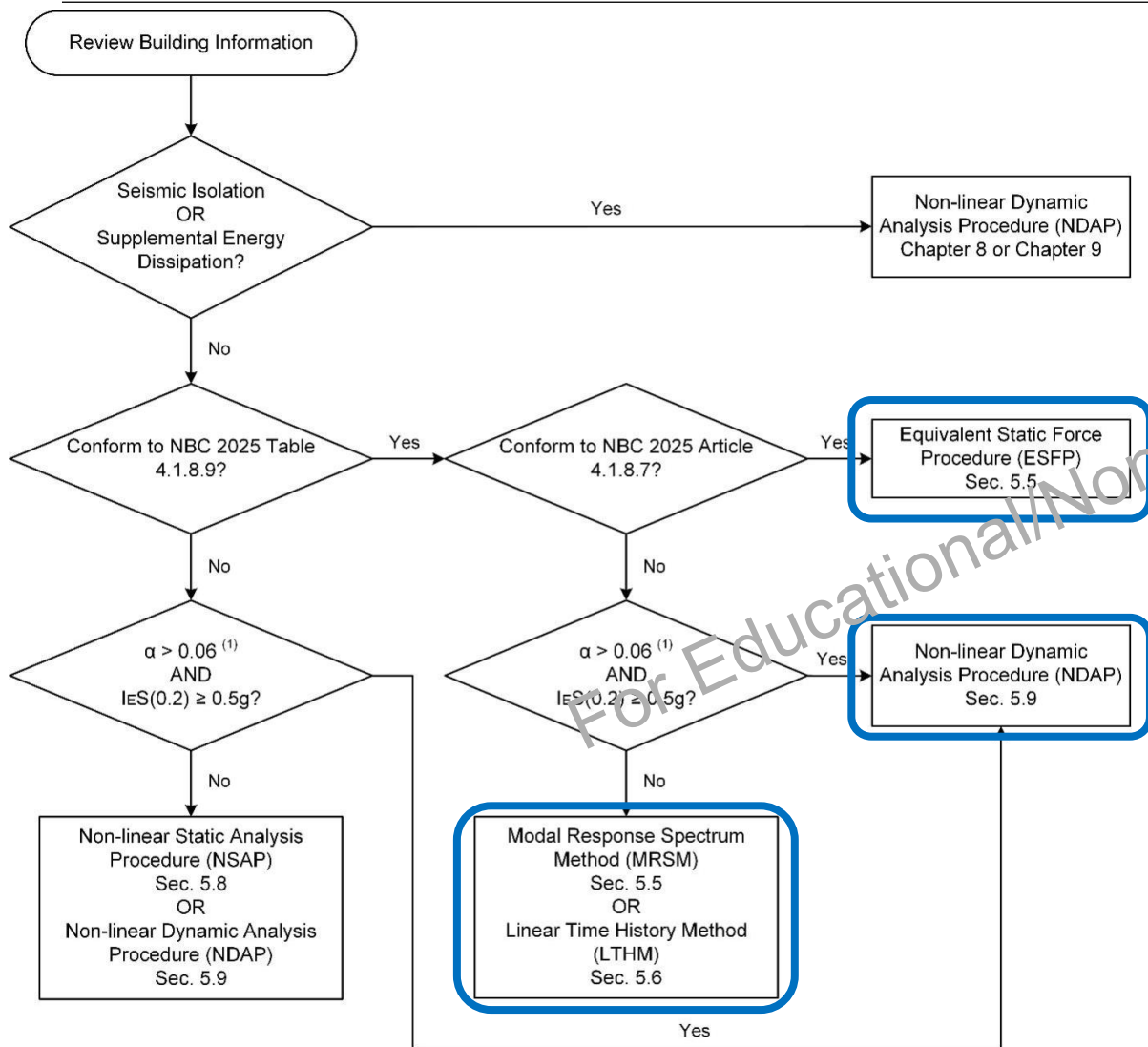


1. Collect building information
2. Select analysis procedure & performance objective
3. Calculate force and deformation demands
4. Calculate element/component capacities
5. Check the acceptance criteria
6. Summarize seismic deficiencies & determine the need for risk mitigation
7. Prepare seismic evaluation report

⁽¹⁾ Section 5.12 should be followed if experimentally derived nonlinear modelling parameters and acceptance criteria are used.

Analysis Procedures

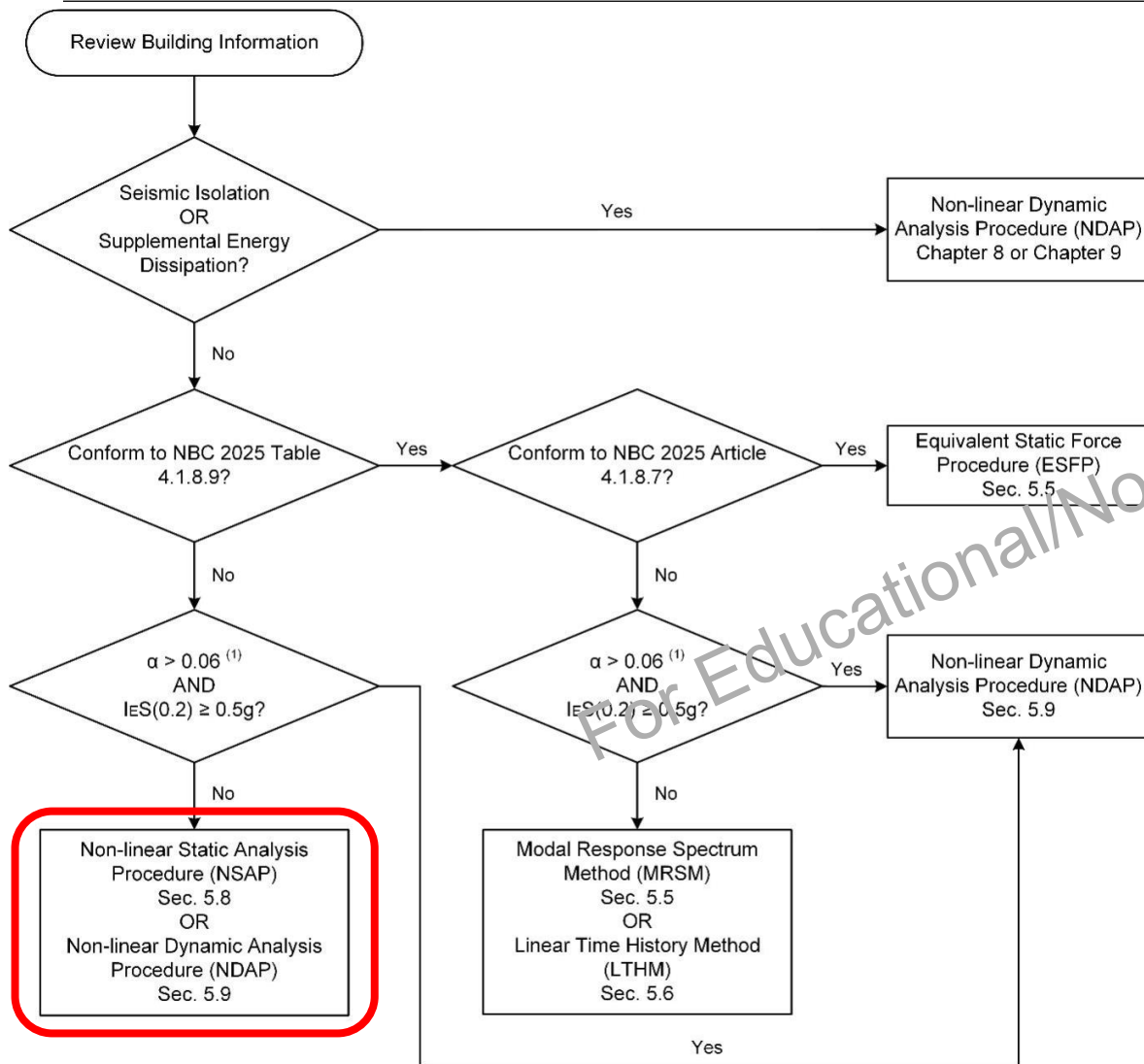
Selection criteria and analysis requirements are consistent with NBC



1. Linear Static Analysis
 - Equivalent Static Force Procedure
2. Linear Dynamic Analysis
 - Modal Response Spectrum Method
 - Linear Time History Analysis
3. Non-linear Static Analysis
 - Multi-modal Pushover Analysis
4. Non-linear Dynamic Analysis
 - Non-linear Time History Analysis

⁽¹⁾ 0.2 should be used for an SFRRS with self-centering characteristics.

Analysis Procedures



⁽¹⁾ 0.2 should be used for an SFRS with self-centering characteristics.

1. Linear Static Analysis

- Equivalent Static Force Procedure

2. Linear Dynamic Analysis

- Modal Response Spectrum Method
- Linear Time History Analysis

New Procedure
in Level 3 – SEG

3. Non-linear Static Analysis

- Multi-modal Pushover Analysis (MPA)

4. Non-linear Dynamic Analysis

- Non-linear Time History Analysis

Linear Analysis Procedures

Differences Between Tier 2 and Tier 3 Linear Analysis Procedures

	Tier 2 Evaluation	Tier 3 Evaluation
Building inspection quality	Low to High	At least Medium
Scope of structural modelling	Not required, portion or whole, depending on the types of deficiencies	Whole building
Scope of building analysis	Identified deficiencies	Whole building
Analysis method	<ul style="list-style-type: none">• Equivalent Static Force Procedure• Modal Response Spectrum Method	<ul style="list-style-type: none">• Equivalent Static Force Procedure• Modal Response Spectrum Method• Linear Time History Analysis
Acceptance criteria	Only potentially deficient elements/ components need to be checked	All elements/ components need to be checked

Non-linear Analysis Procedures

Key elements in a non-linear analysis

- Performance objectives
- Backbone curves / hysteresis models
- Component capacity calculations
 - Force-controlled actions vs. deformation-controlled actions
 - Lower-bound material properties vs. expected material properties
- Acceptance criteria
 - Acceptance criteria for force-controlled actions
 - Acceptance criteria for deformation-controlled actions

ASCE 41 Basic Performance Objectives

Table 2-3. Basic Performance Objective for Existing Buildings (BPOE).

Risk Category	BSE-1E	BSE-2E
I and II	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Collapse Prevention Structural Performance Hazards Reduced Nonstructural Performance* (5-D)
III	Damage Control Structural Performance Position Retention Nonstructural Performance (2-B)	Limited Safety Structural Performance Hazards Reduced Nonstructural Performance* (4-D)
IV	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Life Safety Structural Performance Hazards Reduced Nonstructural Performance* (3-D)

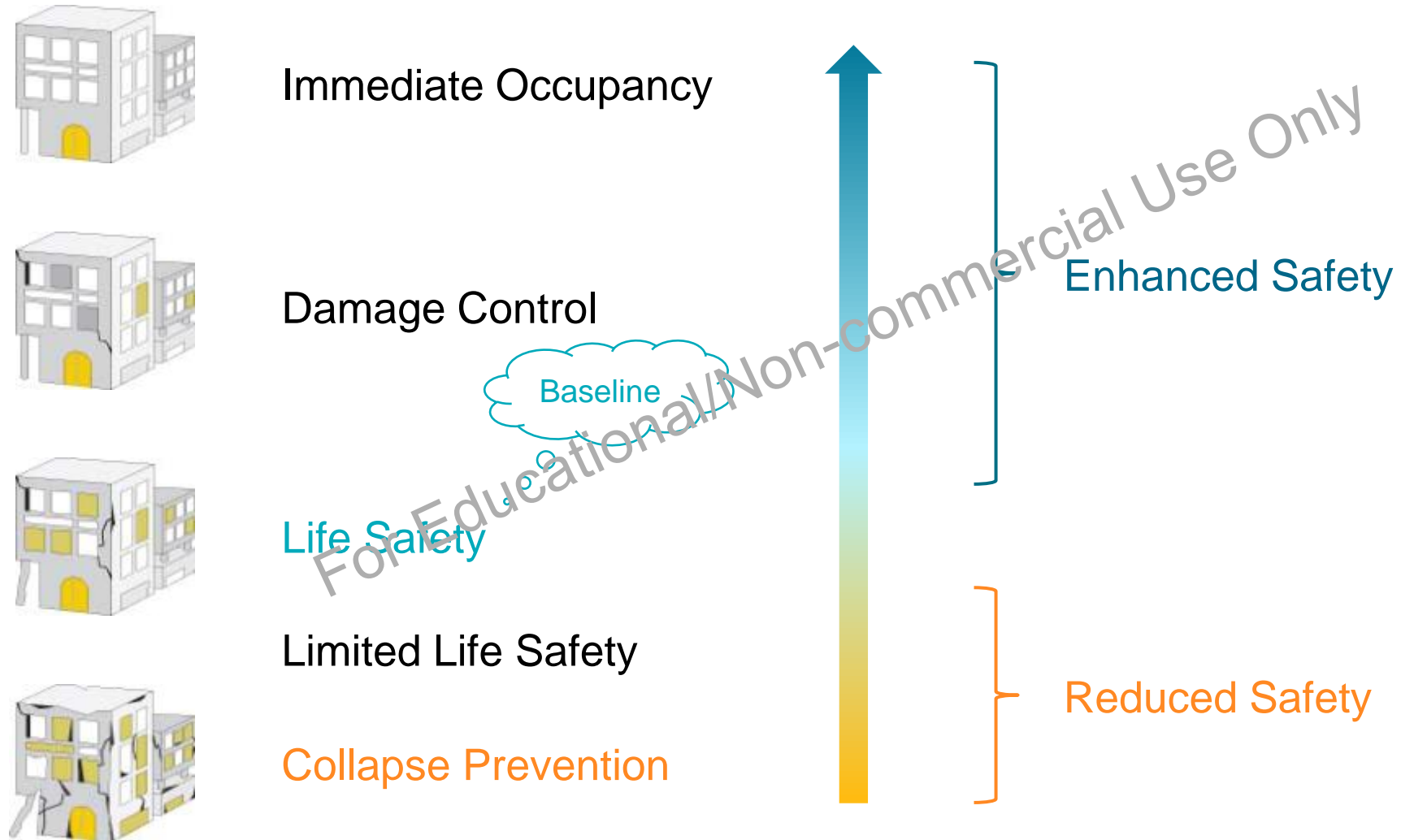
20%/50 yr.

5%/50 yr.

*Compliance with ASCE 7 provisions for new construction is deemed to comply.

$$\text{Performance Objective} = \text{Seismic Hazard Level} + \text{Building Performance Level} = \text{Structural Performance Level} + \text{Non-structural Performance Level}$$

ASCE 41 Structural Performance Levels



ASCE 41 Non-structural Performance Levels

Operational

Position Retention

Baseline

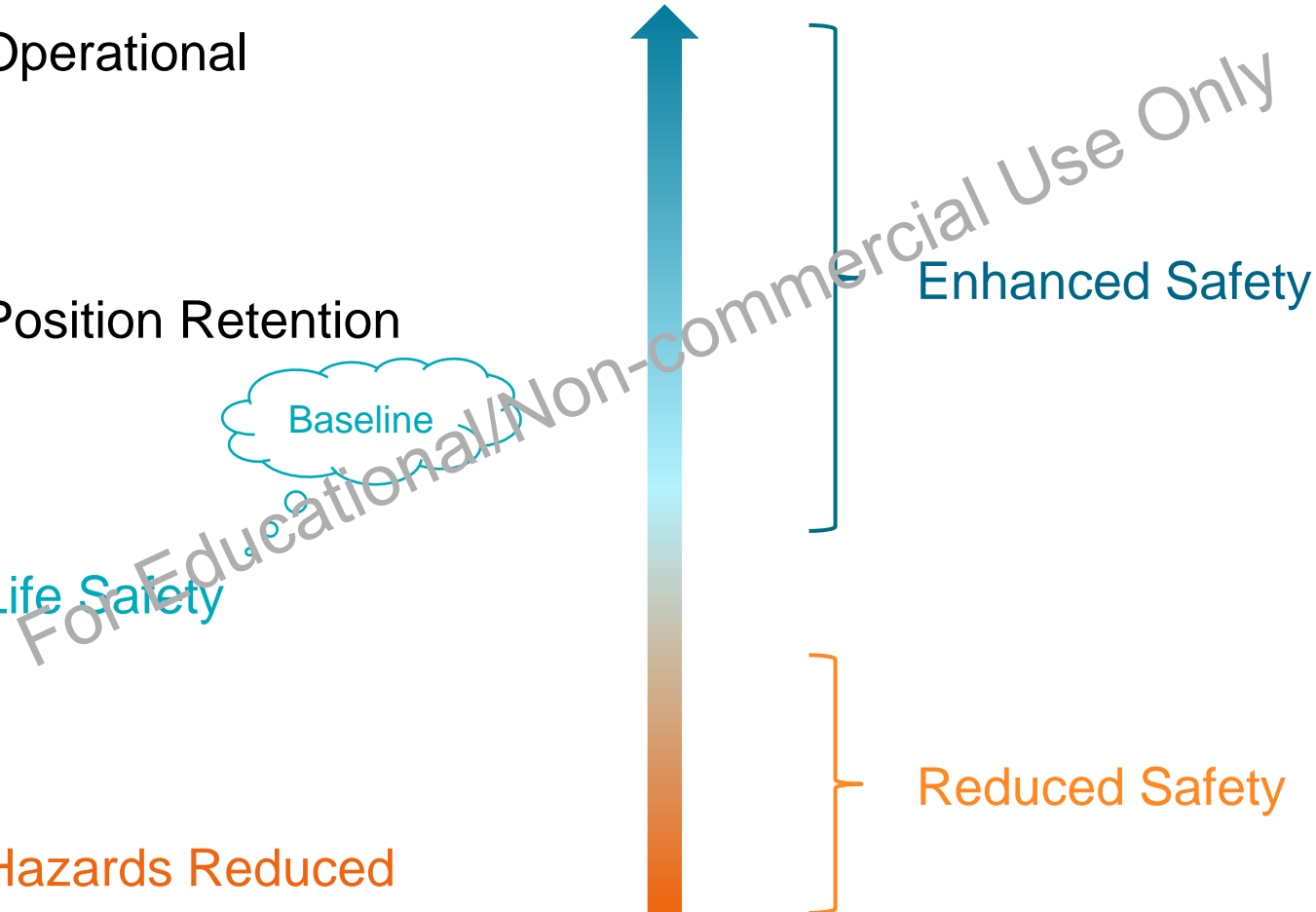
Life Safety

Hazards Reduced

Enhanced Safety

Reduced Safety

High-risk falling hazards addressed but means of egress not addressed



Level 3 – SEG Performance Objectives

Consequence Class	Seismic Hazard		
	20% in 50 yrs. ⁽¹⁾	5% in 50 yrs.	2% in 50 yrs.
CC-L & CC-M	Life Safety Structural Performance	Collapse Prevention Structural Performance	N/A
	Life Safety Non-structural Performance	Life Safety Non-structural Performance	
CC-H (HC)	Damage Control Structural Performance	Limited Life Safety Structural Performance	N/A
	Position Retention Non-structural Performance	Life Safety Non-structural Performance	
CC-H (VHC)	N/A	Immediate Occupancy Structural Performance	Life Safety Structural Performance
		Position Retention Non-structural Performance	Life Safety Non-structural Performance

• Seismic Hazard Levels

- 20% in 50 years (BSE-1E)
- 5% in 50 years (BSE-2E)
- 2% in 50 years (NBC Code Level)

• Non-structural Performance Levels

- Position Retention
- Life Safety

No relaxation for post-disaster buildings

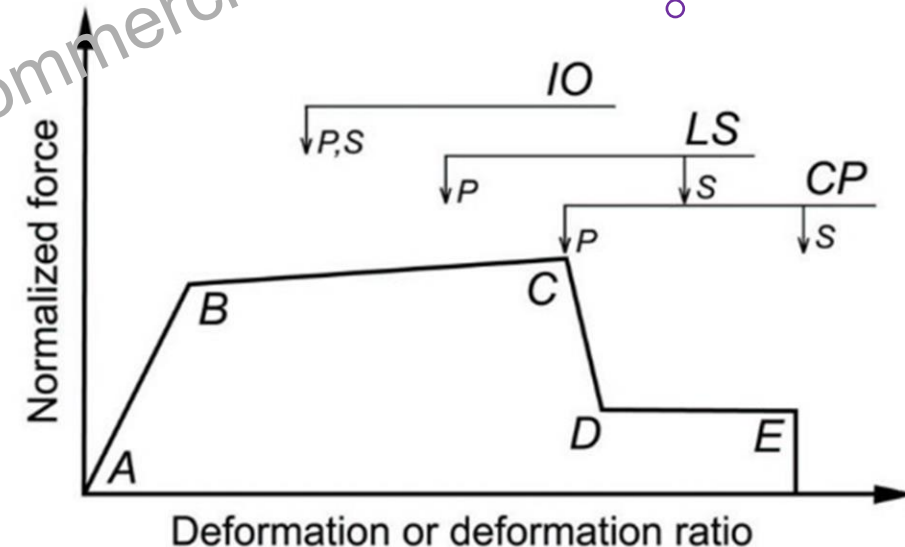
Operational & Hazards Reduced NOT considered in Level 3 – SEG

Level 3 – SEG Non-linear Modelling Parameters (NDP) and Acceptance Criteria (AC)

Performance-based

- Non-linear analysis procedures (Tier 3 ONLY)
- Structural Performance Levels
 - Immediate Occupancy
 - Damage Control
 - Life Safety
 - Limited Life Safety
 - Collapse Prevention

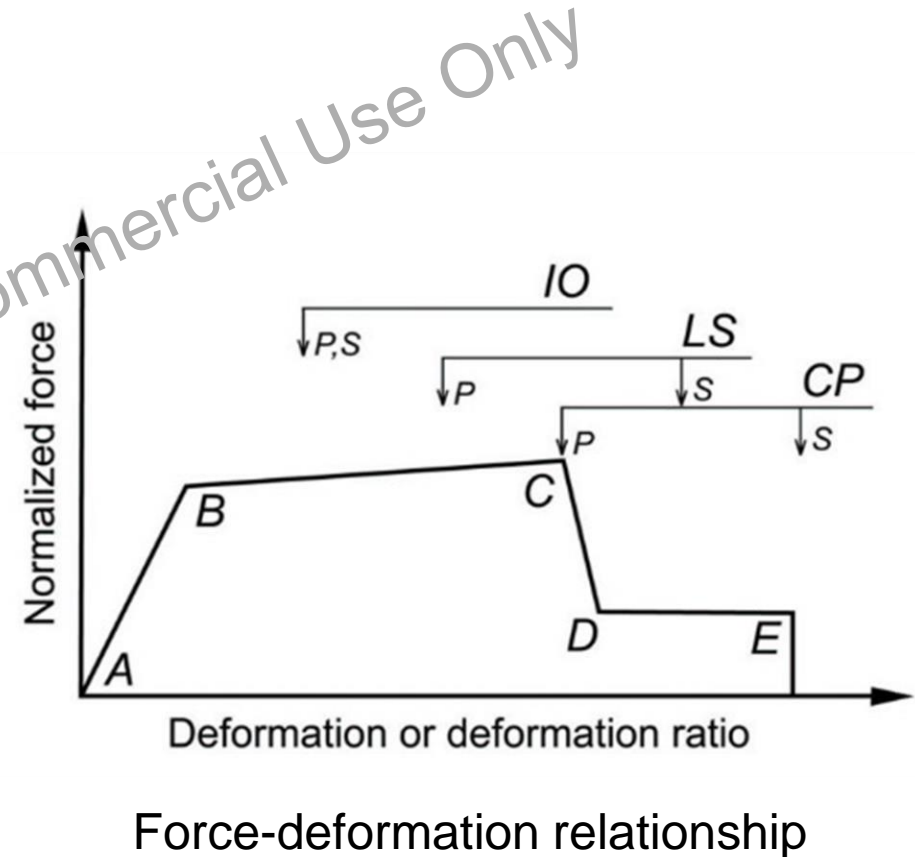
Investigation of the applicability of ASCE 41 to the Canadian context



Force-deformation relationship

Level 3 – SEG NDP & AC

Recommendations on the use of NDP & AC for Seismic Evaluation of Existing Buildings



Level 3 – SEG NDP & AC

Task #1: Critique Review (e.g., ASCE 41, NIST GCR 17-917-45, etc.)

- Modelling Parameters
- Acceptance Criteria (i.e., CP, LS, IO)
- Mathematical Modelling

Task #2: Applicability Investigation

- Modelling Parameters
- Acceptance Criteria (i.e., CP, LS, IO)

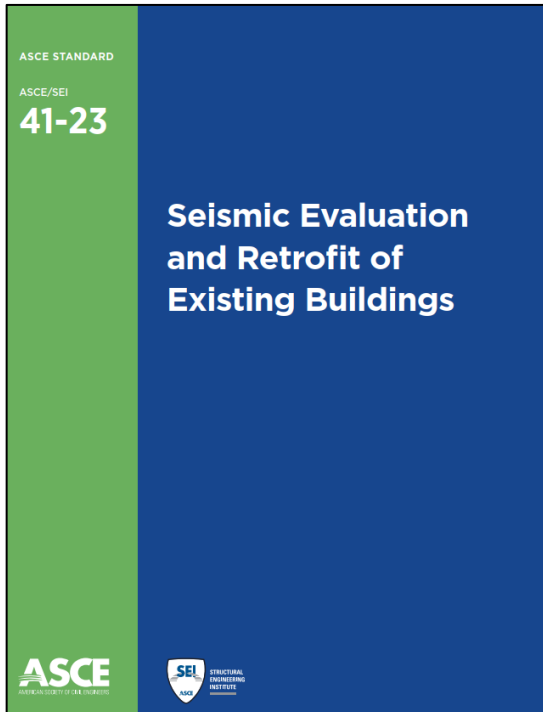
Task #3: Recommendations for Canada

- Modelling parameters
- Acceptance criteria (i.e., CP, LS, IO)
- Mathematical Modelling

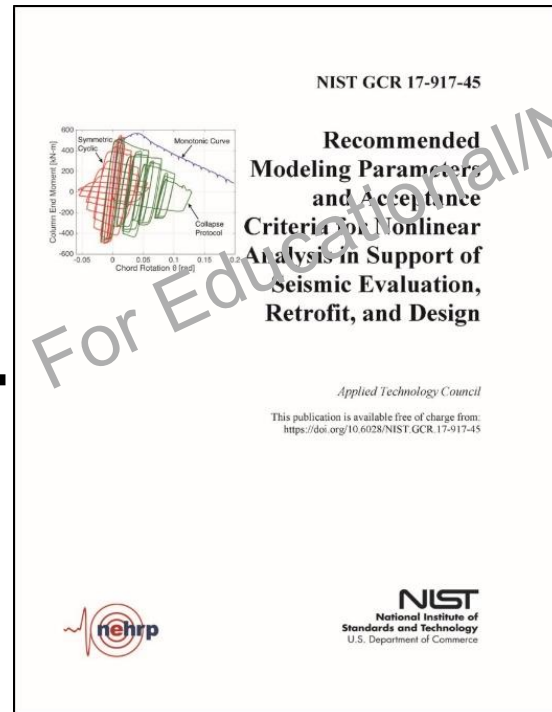
Level 3 – SEG NDP & AC

Task #1: Critique Review (e.g., ASCE 41, NIST GCR 17-917-45, etc.)

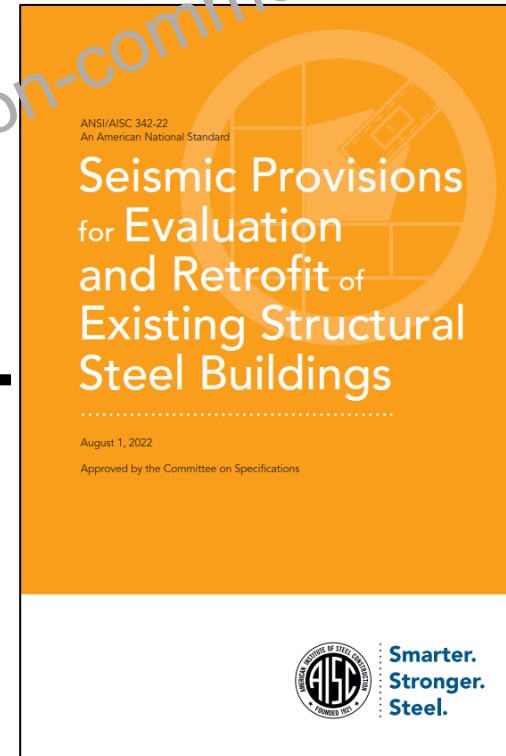
- Modelling Parameters
- Acceptance Criteria (i.e., CP, LS, IO)
- Mathematical Modelling



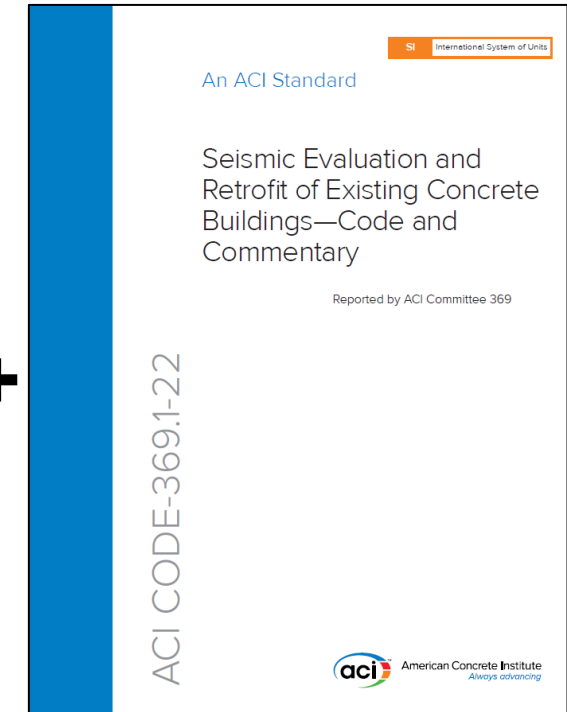
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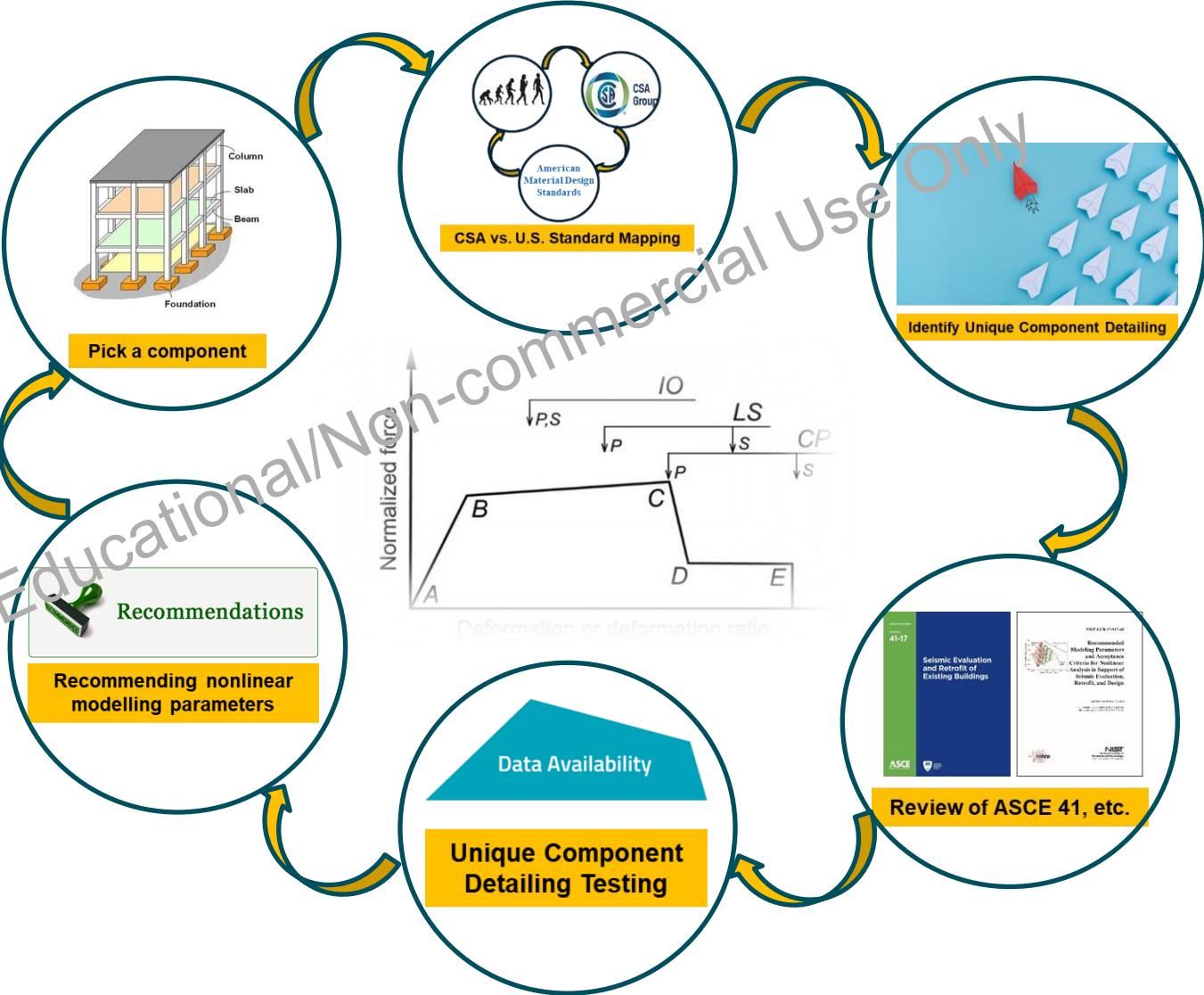


Level 3 – SEG NDP & AC

Task #2:

APPLICABILITY

WHY?



Level 3 – SEG NDP & AC

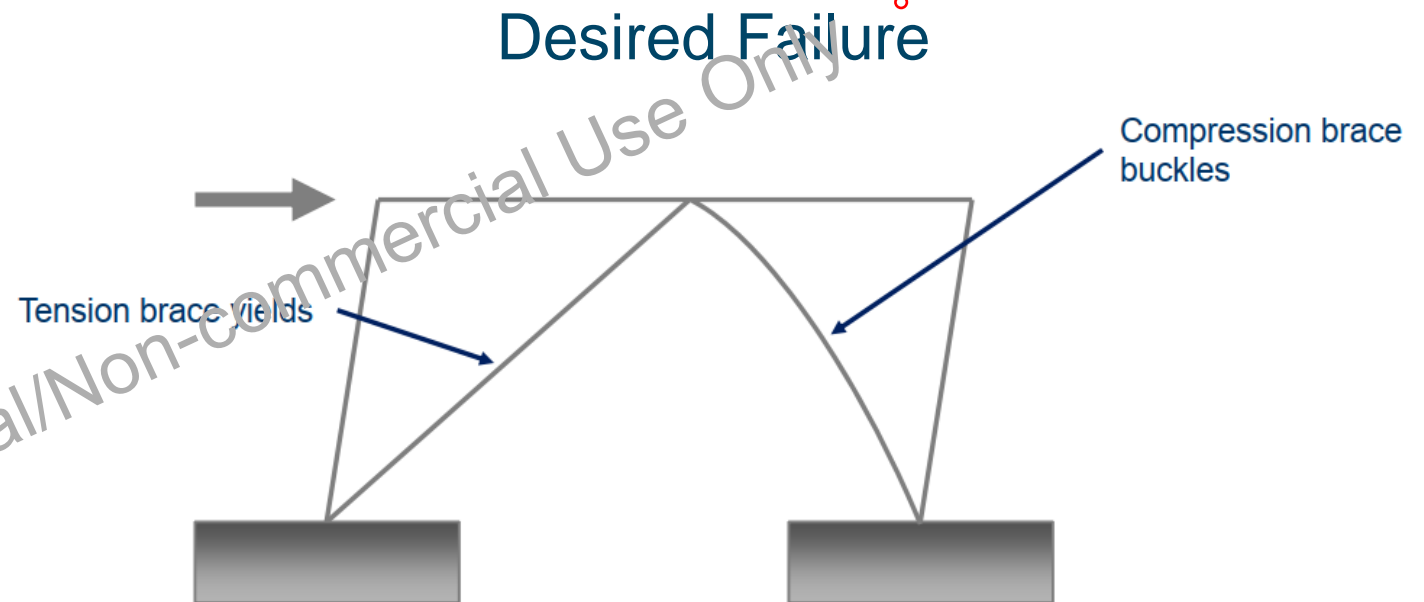
Task #3: Recommendations for Canada

Type	Description	Recommendation
1	Most deformation-related modelling parameters that are not presented in design standards but are only in ASCE 41-23	Adopt as is
2	Equations in ASCE 41-23 with relevant and identical expressions in Canadian and American standards	Adopt as is
3	Equations in ASCE 41-23 with relevant yet inconsistent expressions in Canadian and American standards	Adopt the equations in CSA design standards
4	Equations in ASCE 41-23 with relevant expressions only in American standards	Adopt as is
5	Modelling parameters that directly refer to design standards	Refer to the corresponding equations in CSA standards

Force-controlled vs. Deformation-controlled

Warning of impending failure

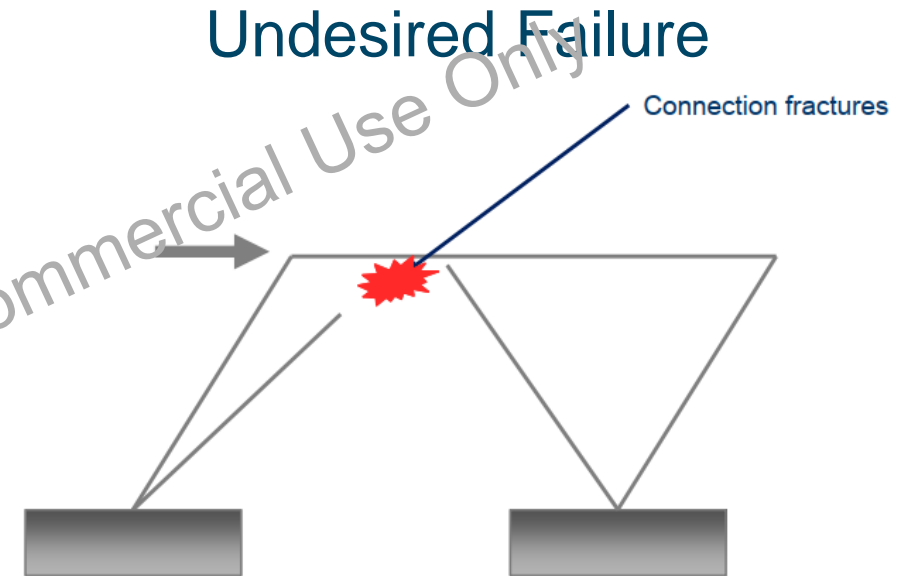
- Deformation-controlled actions
 - Ductile non-linear response under reversed cyclic loading
 - Plastic rotation in beams of ductile steel moment-resisting frames
 - Flexural yielding at the base of ductile RC shear walls
 - Etc.



Force-controlled vs. Deformation-controlled

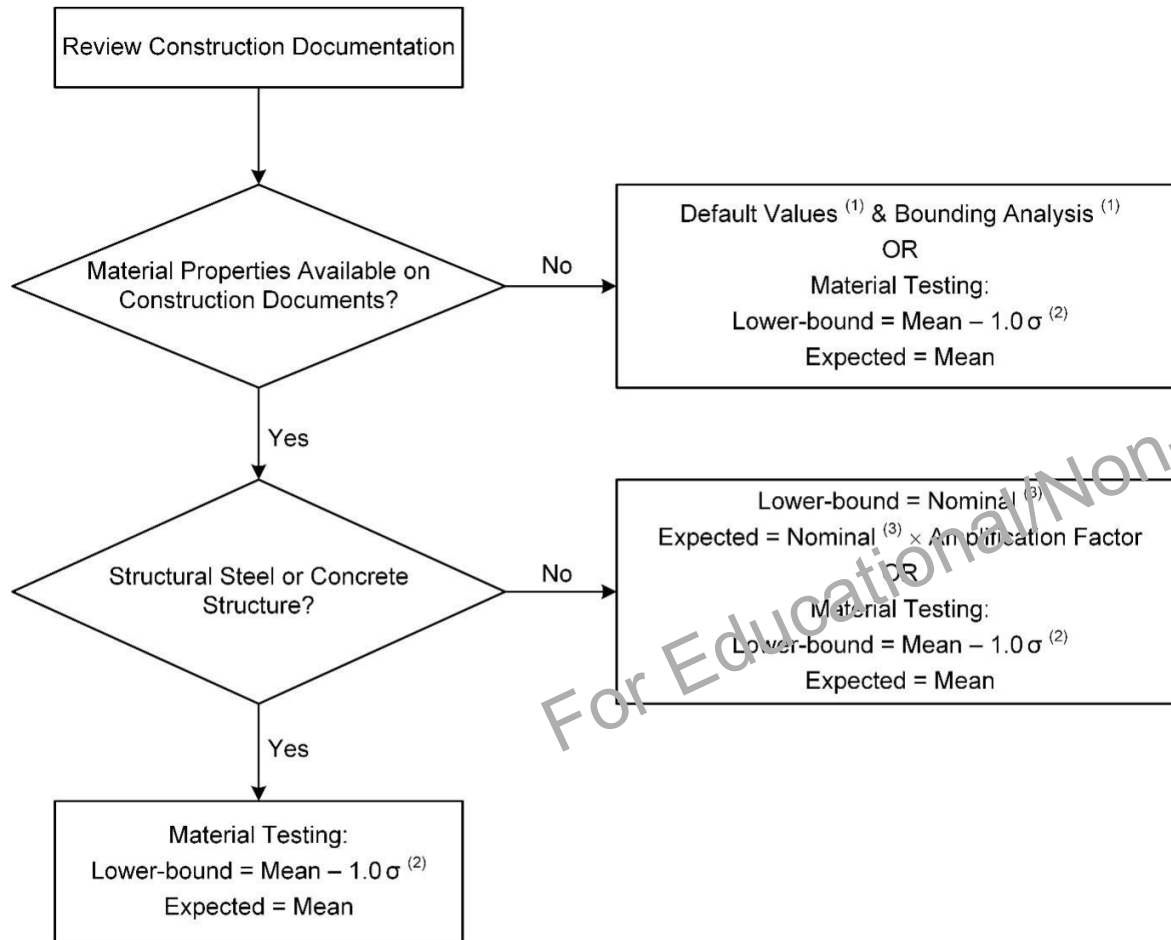
Little or no warning

- Force-controlled actions
 - Actions that are not considered deformation-controlled
 - Fracture of beam-column connections in steel moment-resisting frames
 - Crushing failure of columns in concrete moment-resisting frames
 - Etc.



Prevent force-controlled components from failing before deformation-controlled components

Material Properties in Non-linear Analysis



Material properties

- Force-controlled actions
 - Lower-bound material properties should be used
- Deformation-controlled actions
 - Expected material properties should be used
- Material testing is required for concrete and steel structures
- Default values are permitted for wood and masonry structures with bounding analysis

⁽¹⁾ Default values & bounding analysis are not permitted for structural steel and concrete structures

⁽²⁾ σ stands for standard deviation

⁽³⁾ A reduction factor of 0.8 should be applied to account for the effects of masonry condition when the building under evaluation is made of masonry

Level 3 – SEG Acceptance Criteria

- Force-controlled actions

Amplification factors

$$S_f = \gamma\chi(S_t - S_{ns}) + S_{ns}$$

Cause a failure likely to lead to partial or total structural collapse

S_f = Total force demand, kN;

S_t = Total force demand from non-linear analysis, including gravity load effects, kN;

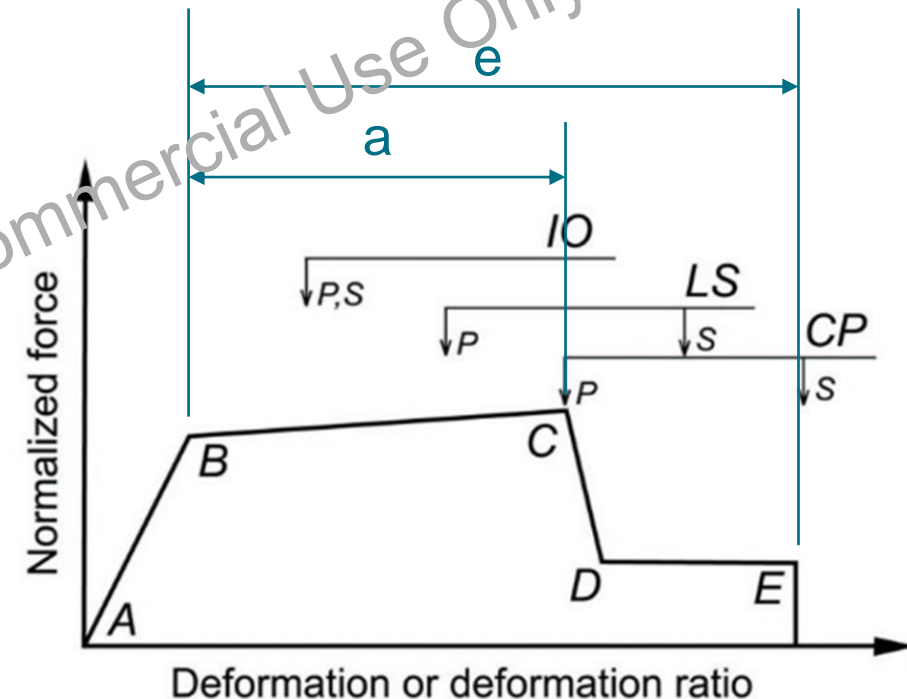
S_{ns} = Force demand from (non-seismic) gravity loads, kN;

γ = Load factor for force-controlled actions, 1.3 for critical actions and 1.0 for non-critical actions

χ = 1.3 for Life Safety and Immediate Occupancy and 1.0 for Collapse Prevention.

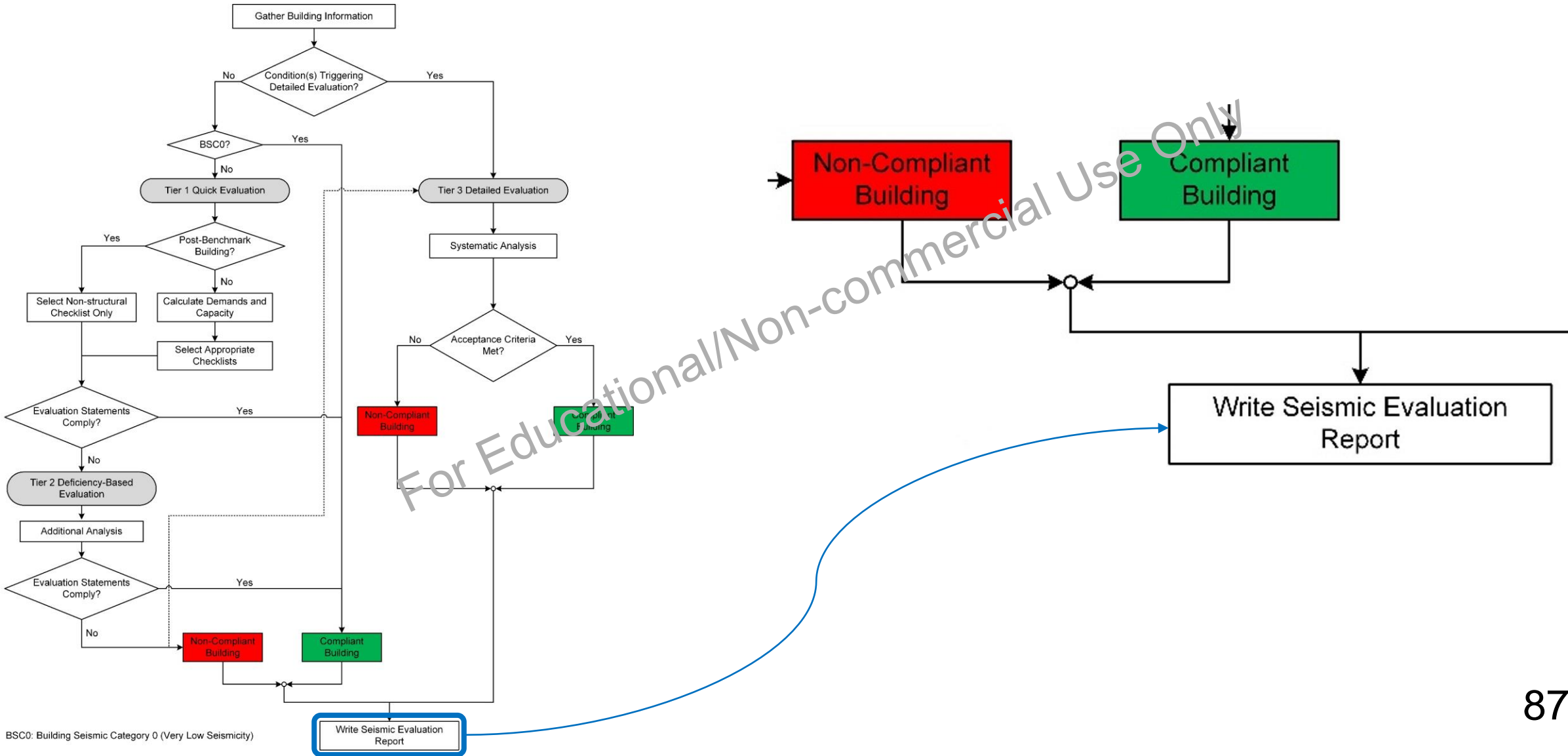
Level 3 – SEG Acceptance Criteria

- Deformation-controlled actions
 - The acceptance criteria for IO, LS and CP Structural Performance Levels are based on “a” and “e” points on force-deformation relationships
 - The acceptance criteria for Damage Control (DC) Structural Performance Level are taken as the average of the criteria for Immediate Occupancy and Life Safety
 - The acceptance criteria for Limited Life Safety (LLS) Structural Performance Level are taken as the average of the criteria for Life Safety and Collapse Prevention



Force-deformation relationship

Reporting Requirements and Further Actions

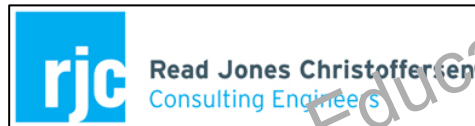


Pilot Studies Commissioned by NRC

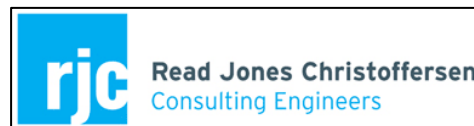
- Tier 1 Quick Evaluation (12 PSPC buildings)



- Tier 2 Deficiency-Based Evaluation (1 PSPC building)



- Tier 3 Detailed Evaluation (1 PSPC building + 1 GAC building)



Summary

Key Takeaways

- Level 3 – SEG methodology (force-based + performance-based)
- Tier 1 Quick Evaluation (a set of checklists → identify potential major deficiencies)
- Tier 2 Deficiency-Based Evaluation (linear analysis → focus on evaluating identified deficiencies)
- Tier 3 Detailed Evaluation (linear + non-linear analysis → evaluate all elements and components)
- 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)

Available in both
official languages

- 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)

French translation
of Level 3 – SEG in
progress

- Level 3 – Seismic Evaluation Guidelines (SEG)

<https://doi.org/10.4224/40003499>

- Seismic Upgrading Guidelines (SUG)

<https://doi.org/10.4224/40003495>

Available in both
official languages

- Webpage Seismic Risk Screening Tool

[Semi-Quantitative Seismic Risk Screening Tool \(SQST\) - National Research Council Canada](#)

- Performance-Based Unified Procedure for Determination of R_d , R_o Factors in NBC

<https://doi.org/10.4224/40003049>

Peer-Reviewed Journal and Conference Papers

Peer-reviewed Journal Papers (Level 3 – SEG 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. (2025). 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. (2025). 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 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

