



Construction

NRC-CNRC

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

Webinar Series

Overview of Seismic Upgrading Guidelines (SUG)

By Seismic Resilience Team

December 3, 2025

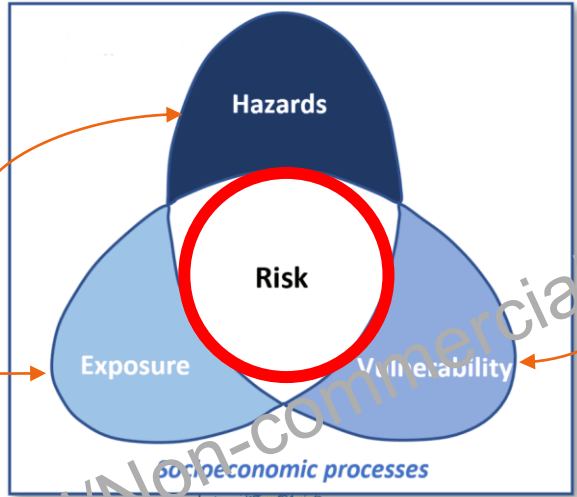
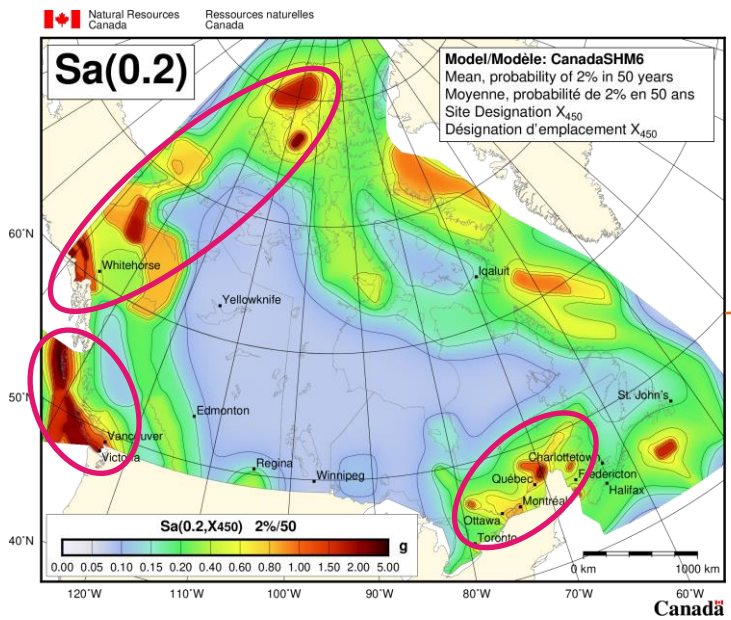
Outline

- Introduction
- Seismic Deficiencies
- Seismic Upgrading Principles
- Seismic Upgrading Design Requirements
- Upgrading Techniques
- Summary

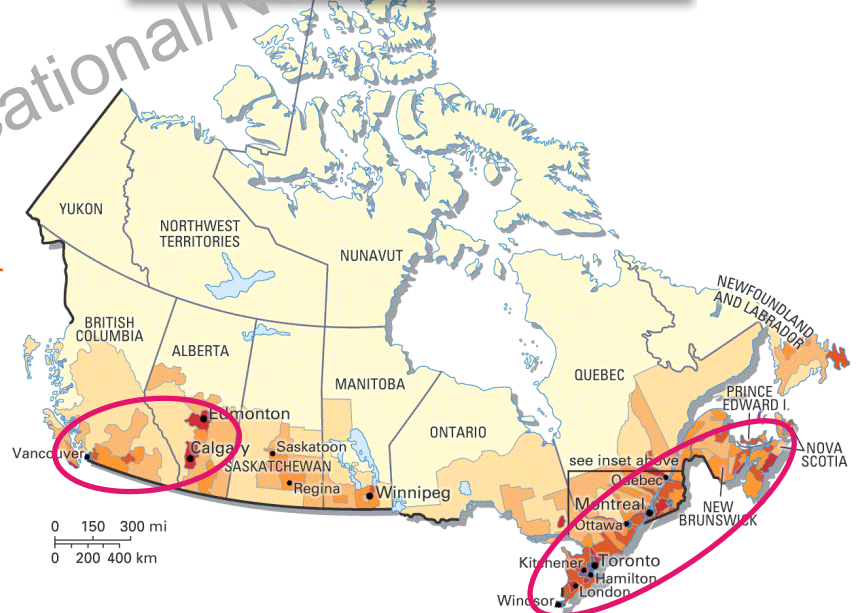
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Introduction

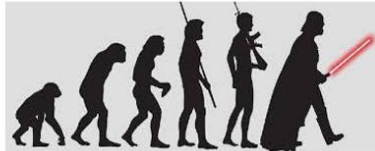
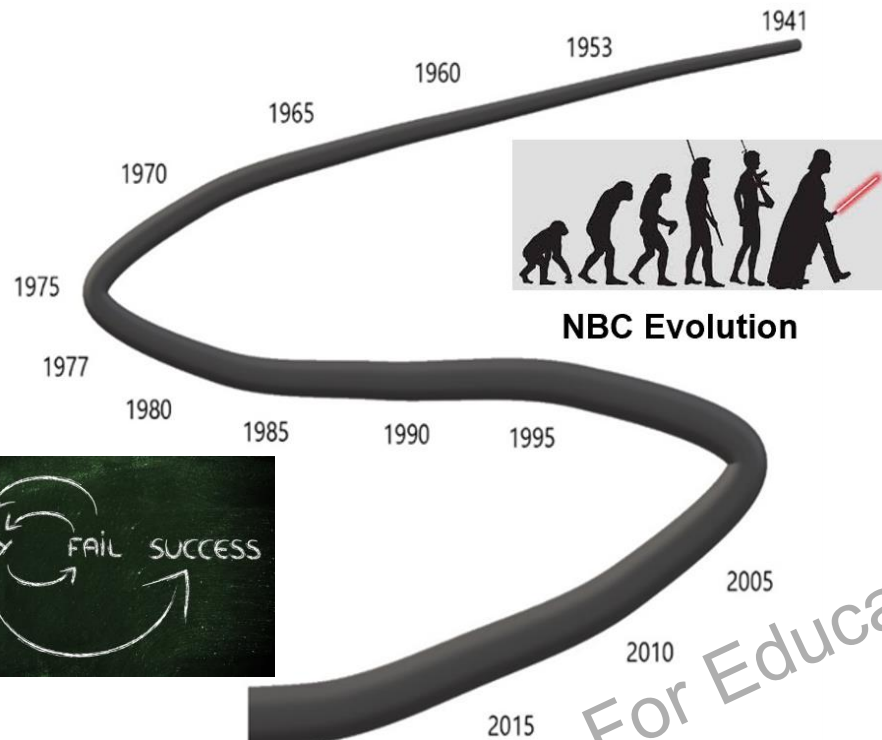
Earthquake Risk in Canada



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Seismic Risk Management of Existing Buildings

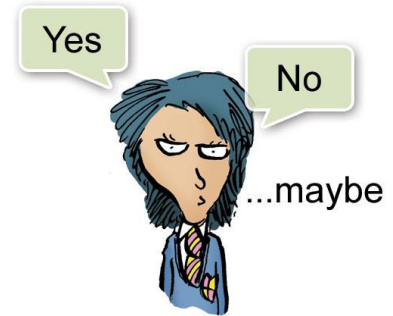


NBC Evolution

Large Building Inventory



Is Seismic Risk Acceptable?

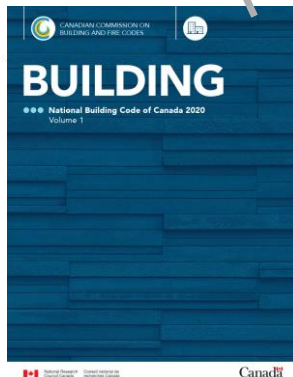


How to Find the Answer?

Economy

Accuracy

Time



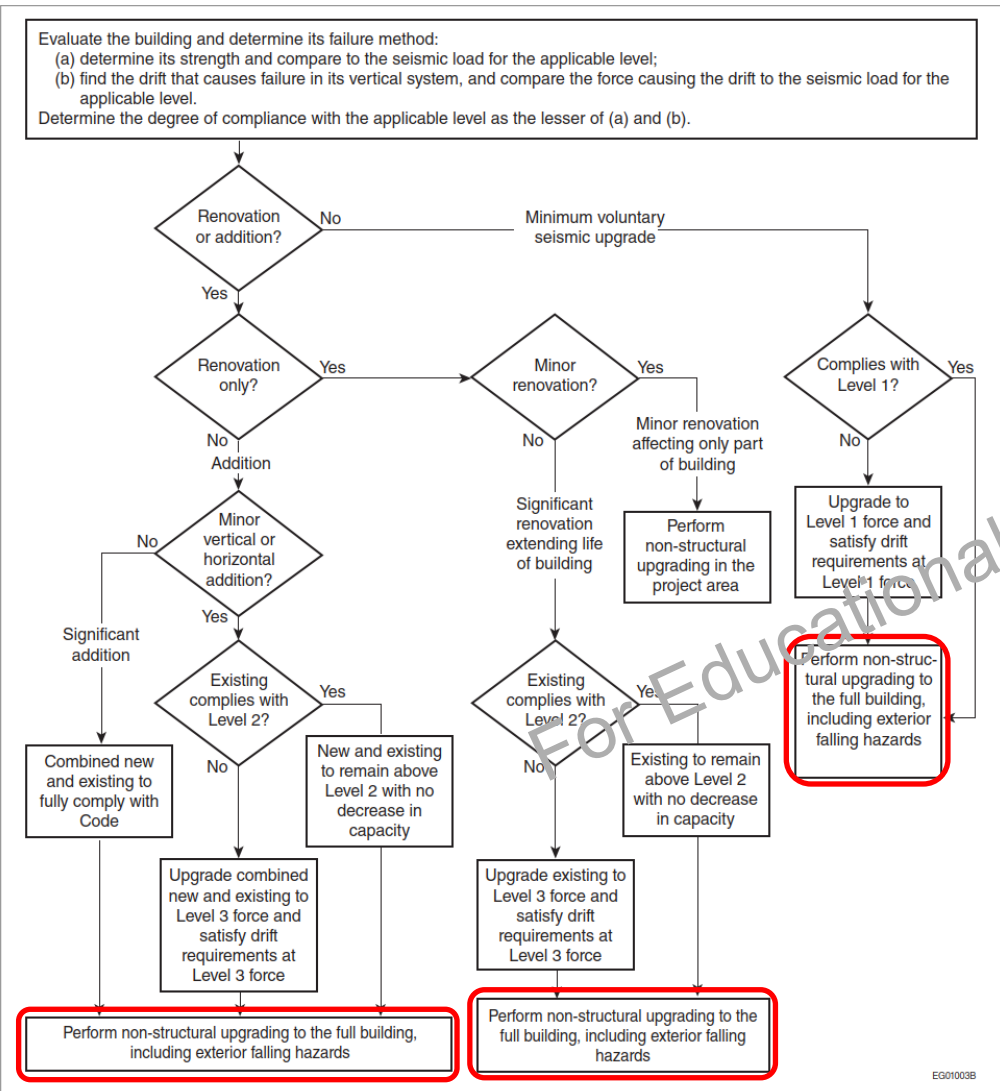
Existing NRC's Seismic Guidelines



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 × 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 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

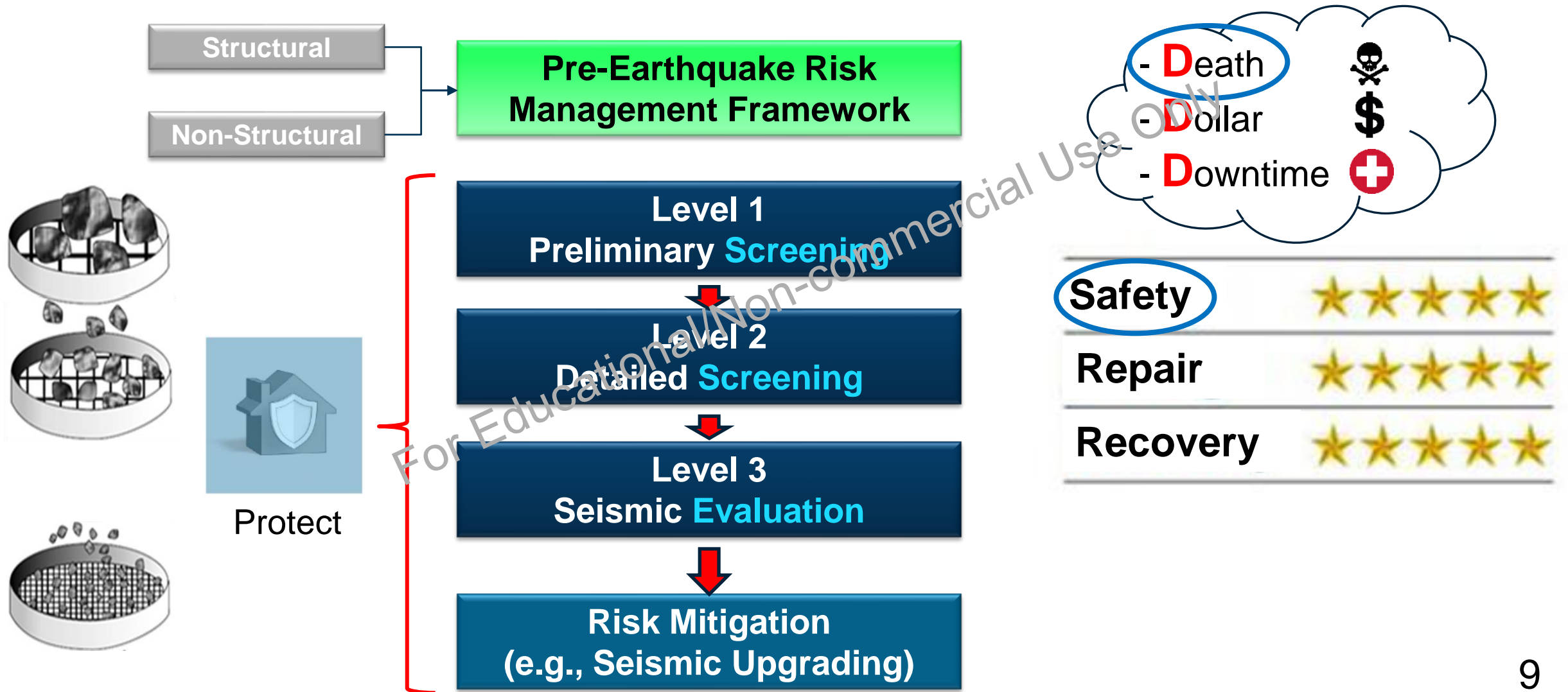
Methodology

- [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 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](#).

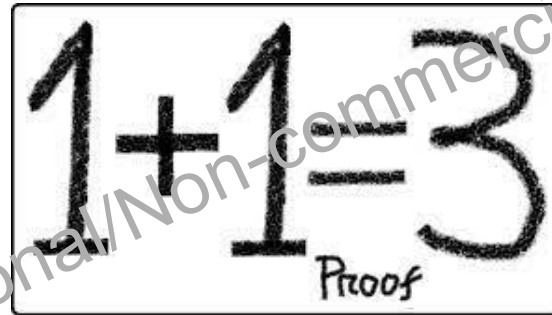
The Level 2 - SQST has been developed for assessing seismic risk in buildings. It is intended for use as a screening tool for seismic risk assessments.

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

Web-page Tool

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

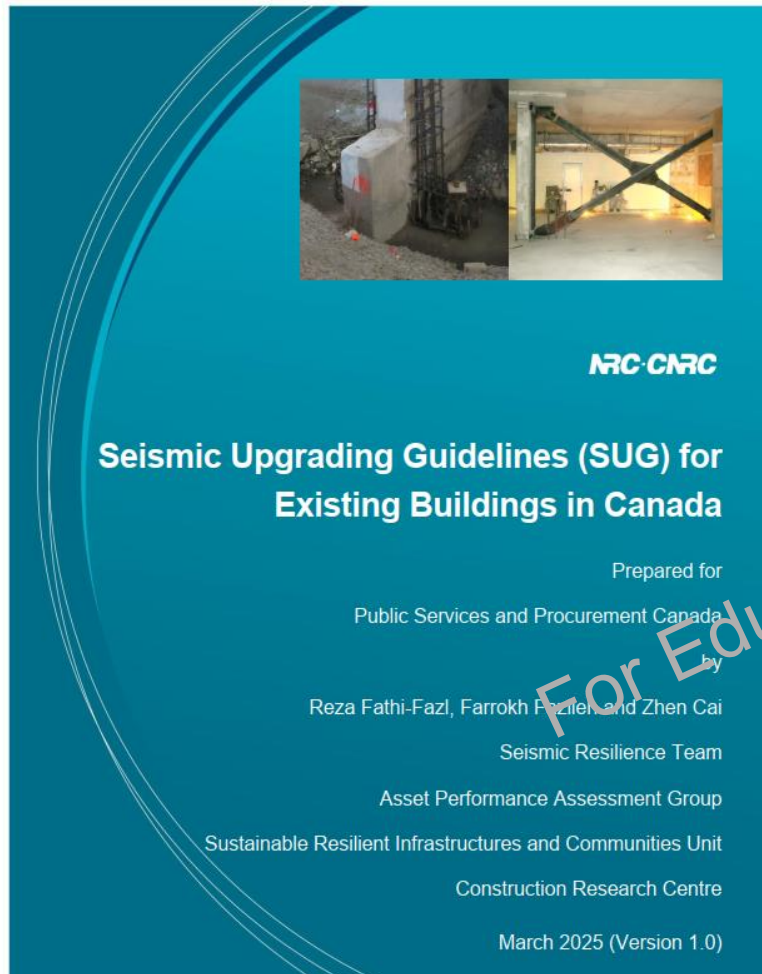


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SUG Organization

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



1. Introduction
2. Seismic Deficiencies
3. Seismic Upgrading Principles
4. Seismic Upgrading Design Requirements
5. Seismic Upgrading Techniques
6. References

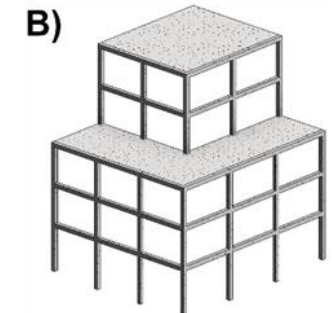
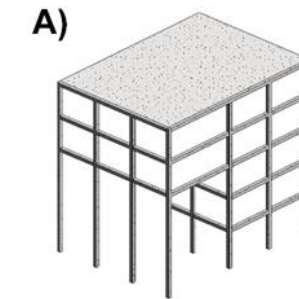
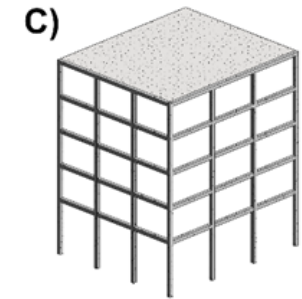
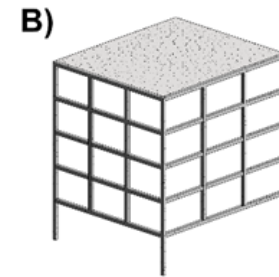
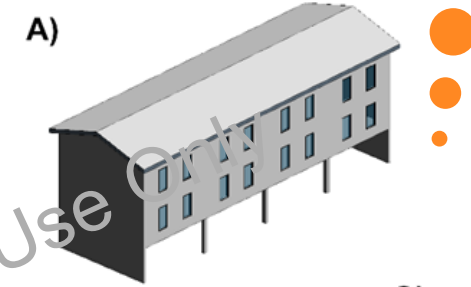
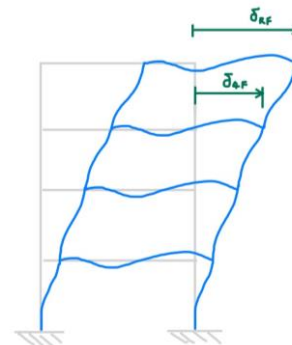
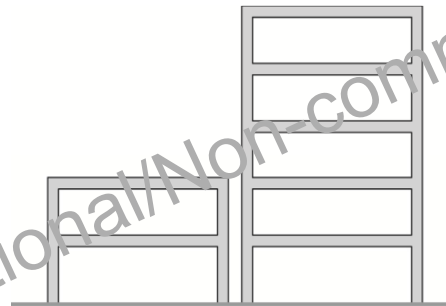
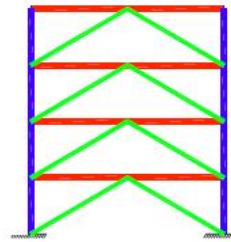
Appendix A Common Issues Associated with Seismic Upgrading

Seismic Deficiencies

Categories of Seismic Deficiencies

Many types of irregularities were not explicitly addressed until NBC 2005

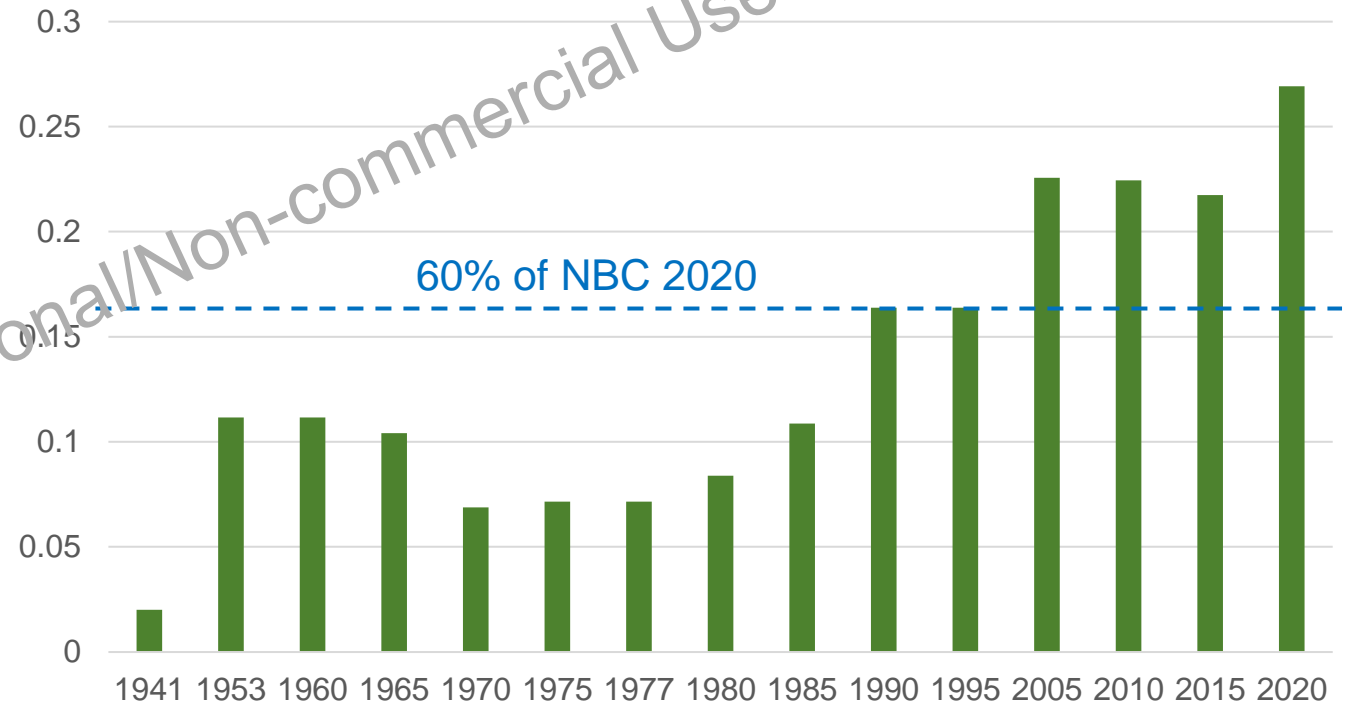
- Lack of load path
- Lack of redundancy
- Adjacent buildings
- Irregularities
- Inadequate stiffness
- Inadequate strength
- Inadequate component detailing
- Non-structural hazards
- Other types of deficiencies



Categories of Seismic Deficiencies

- Lack of load path
- Lack of redundancy
- Adjacent buildings
- Irregularities
- Inadequate stiffness
- **Inadequate strength**
- Inadequate component detailing
- Non-structural hazards
- Other types of deficiencies

Base Shear Factor for three-storey Steel Braced Frame in Vancouver



Categories of Seismic Deficiencies

- Lack of load path
- Lack of redundancy
- Adjacent buildings
- Irregularities
- Inadequate stiffness
- Inadequate strength
- Inadequate component detailing
- Non-structural hazards
- Other types of deficiencies

CSA A23.3-1973

19.9.4 Concentrated Reinforcement

19.9.4.1 A ductile flexural wall shall have vertical reinforcement concentrated near each end of the wall.

19.9.4.2 The amount of such reinforcement shall be determined as follows:

(a) Calculate the design tension steel A_{sw} taking the largest value obtained from the following two load effects:

(i) M_v and the accompanying axial load with the appropriate load factors;

(ii) the total axial service load P and M_{cr} where M_{cr} is calculated as:

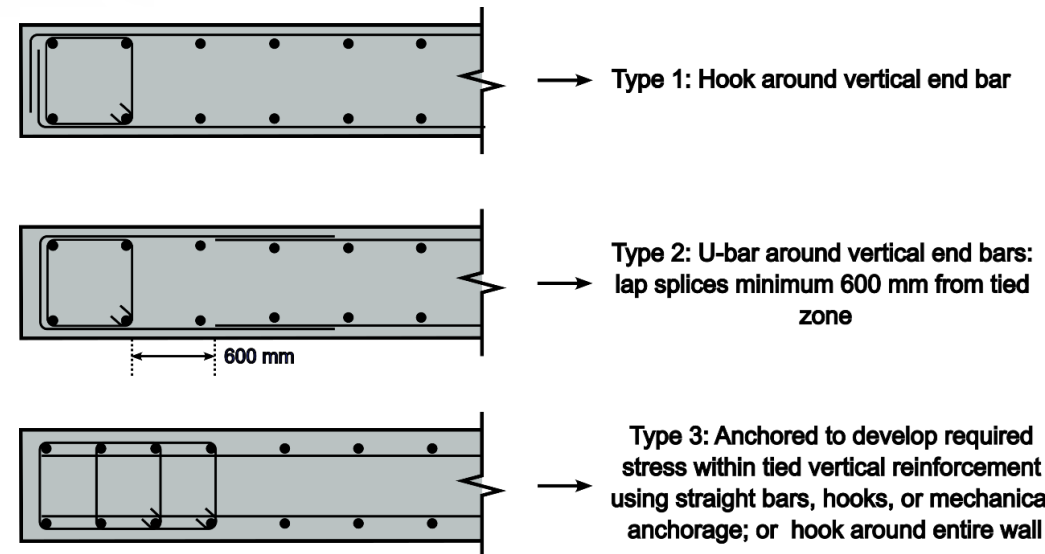
$$M_{cr} = S (7.5 \sqrt{f'_c} + P/A_g); \quad (85)$$

(b) Calculate the minimum tension steel A_{sm} where $A_{sm} = 0.002 b_w d$ for intermediate or hard grade steel or $0.0018 b_w d$ for steel conforming to Grade 60;

(c) Use the larger of A_{sv} and A_{sm} .

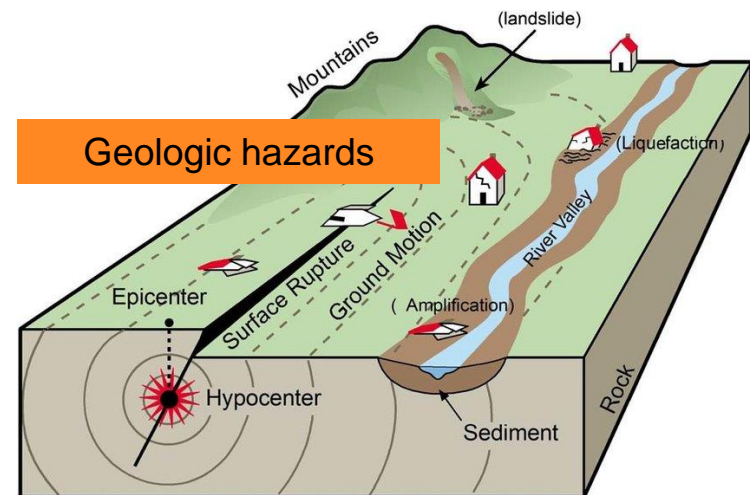
Detailing requirements evolve with CSA design standards' periodical publications

CSA A23.3-2024



Categories of Seismic Deficiencies

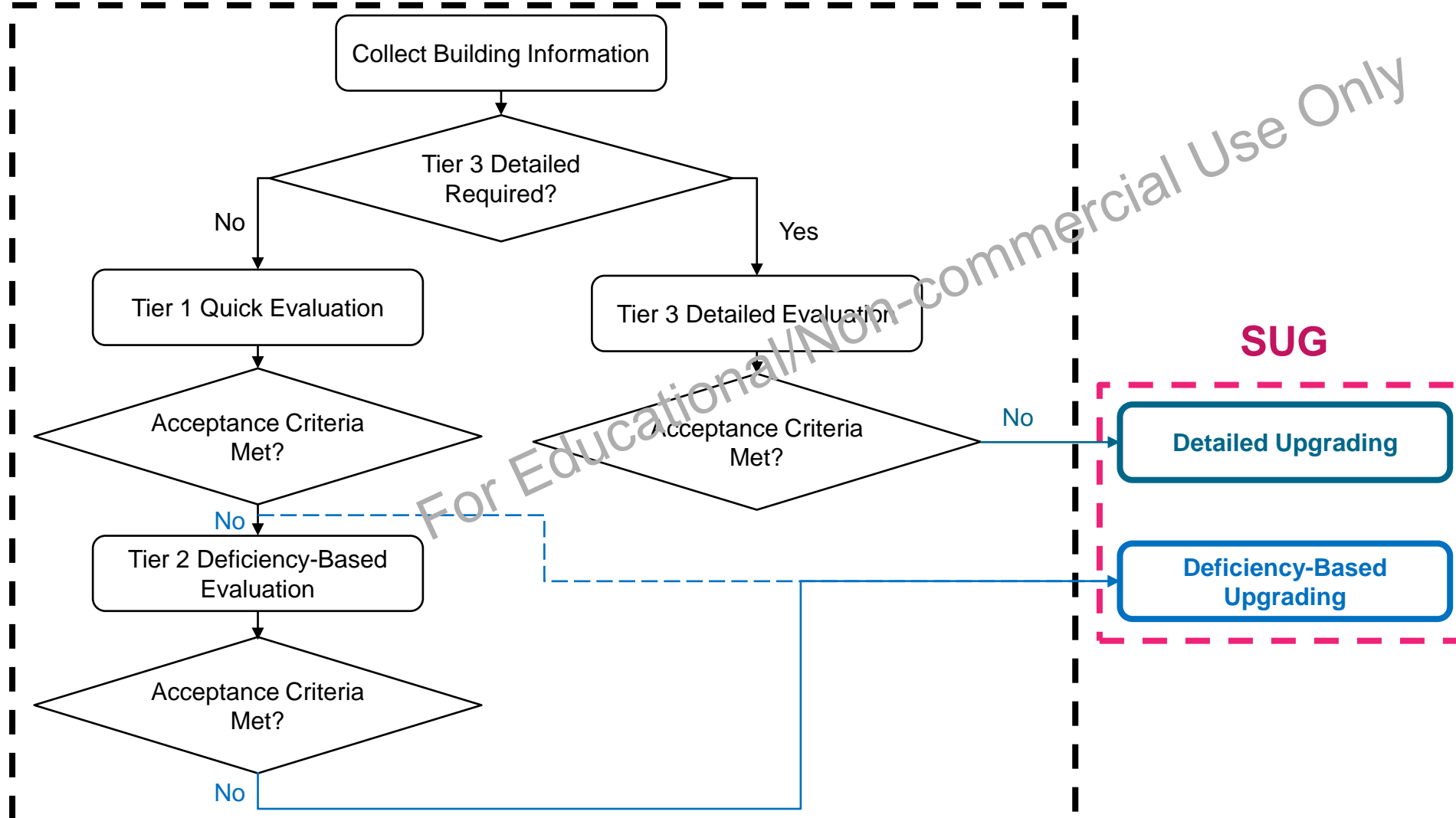
- Lack of load path
- Lack of redundancy
- Adjacent buildings
- Irregularities
- Inadequate strength
- Inadequate stiffness
- Inadequate component detailing
- Non-structural hazards
- Other types of deficiencies (e.g., geologic hazards)



Seismic Upgrading Principles

Seismic Upgrading Categories

Level 3 – SEG



Classes of Upgrading Techniques

1. Add new elements

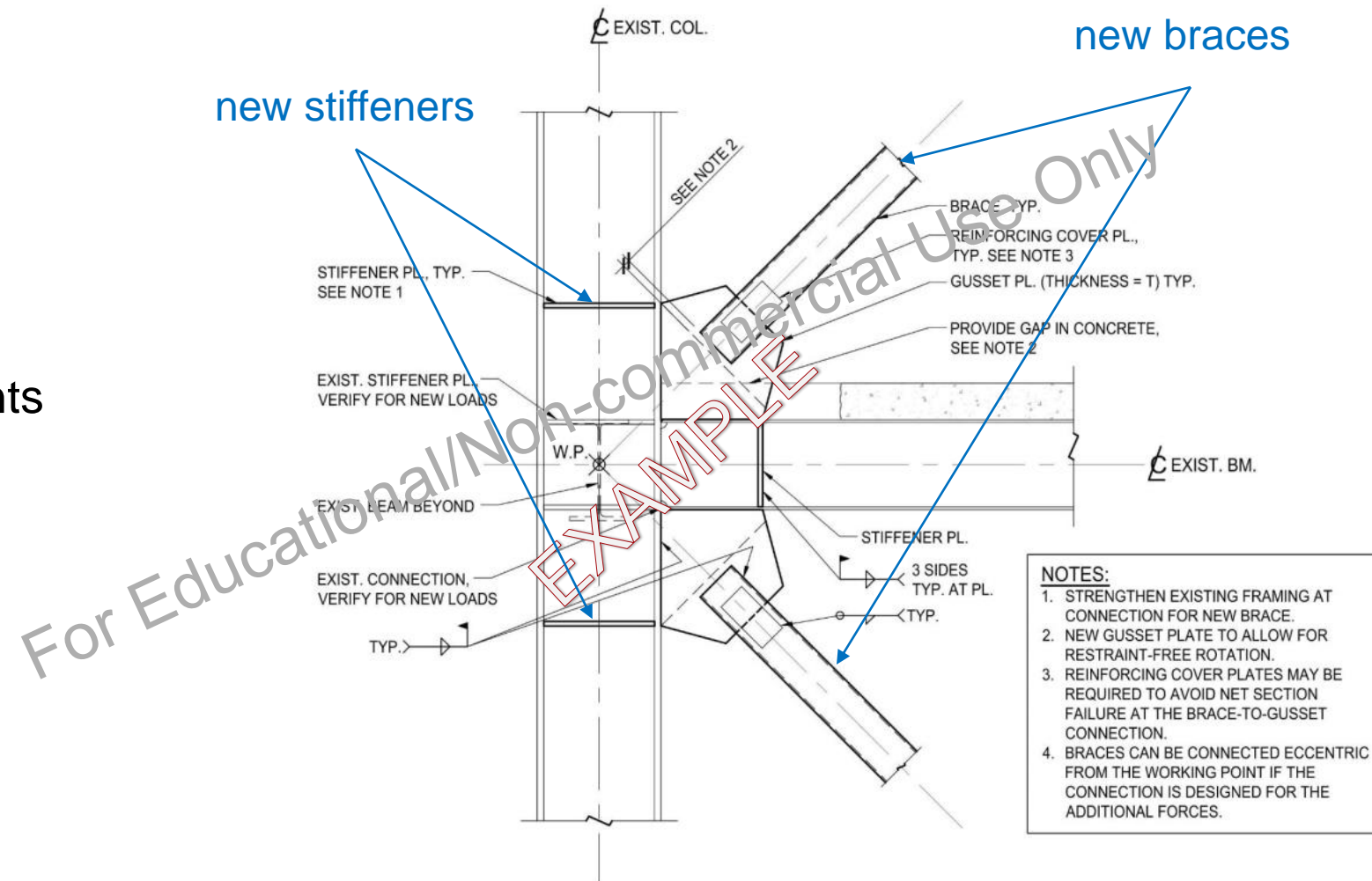


Figure 5.29: Connection of new steel brace to existing beam-column junction in moderately ductile CBF

Classes of Upgrading Techniques

2. Enhance the performance of existing elements

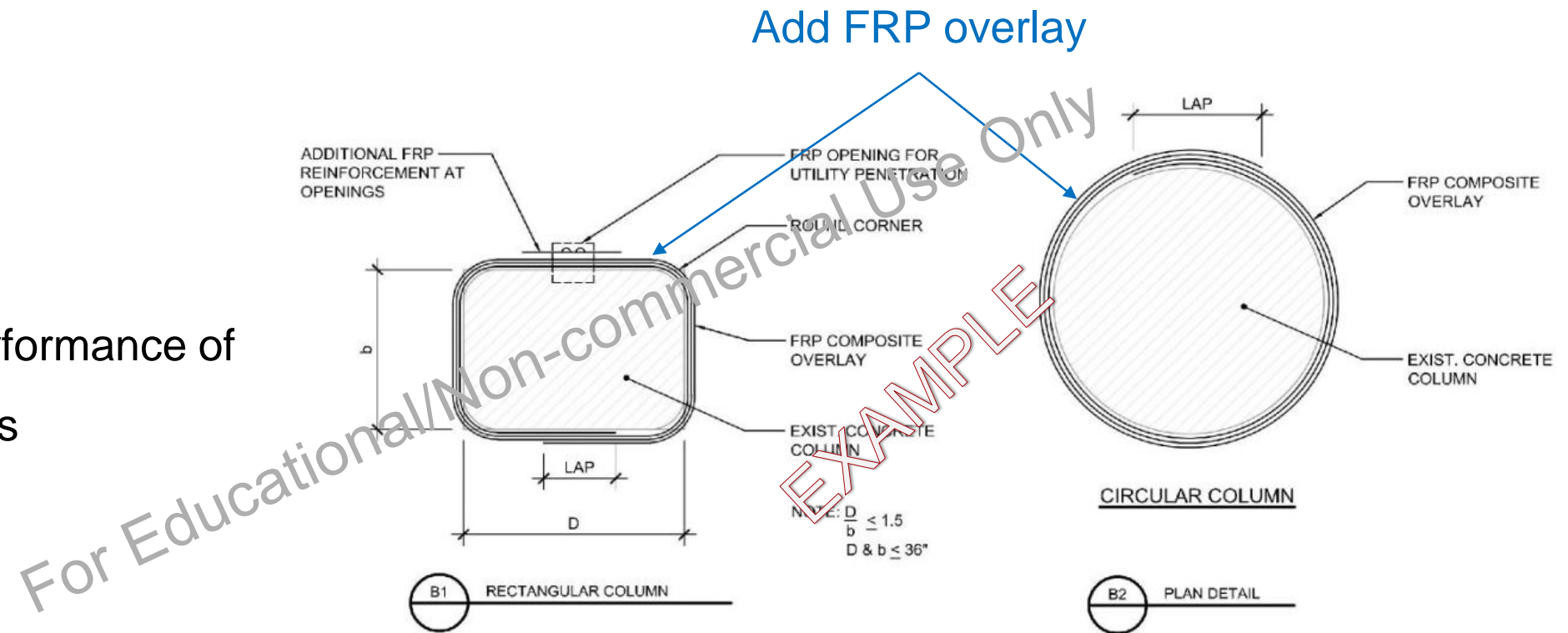


Figure 5.2: FRP overlay of concrete columns

Classes of Upgrading Techniques

3. Improve the connections between components

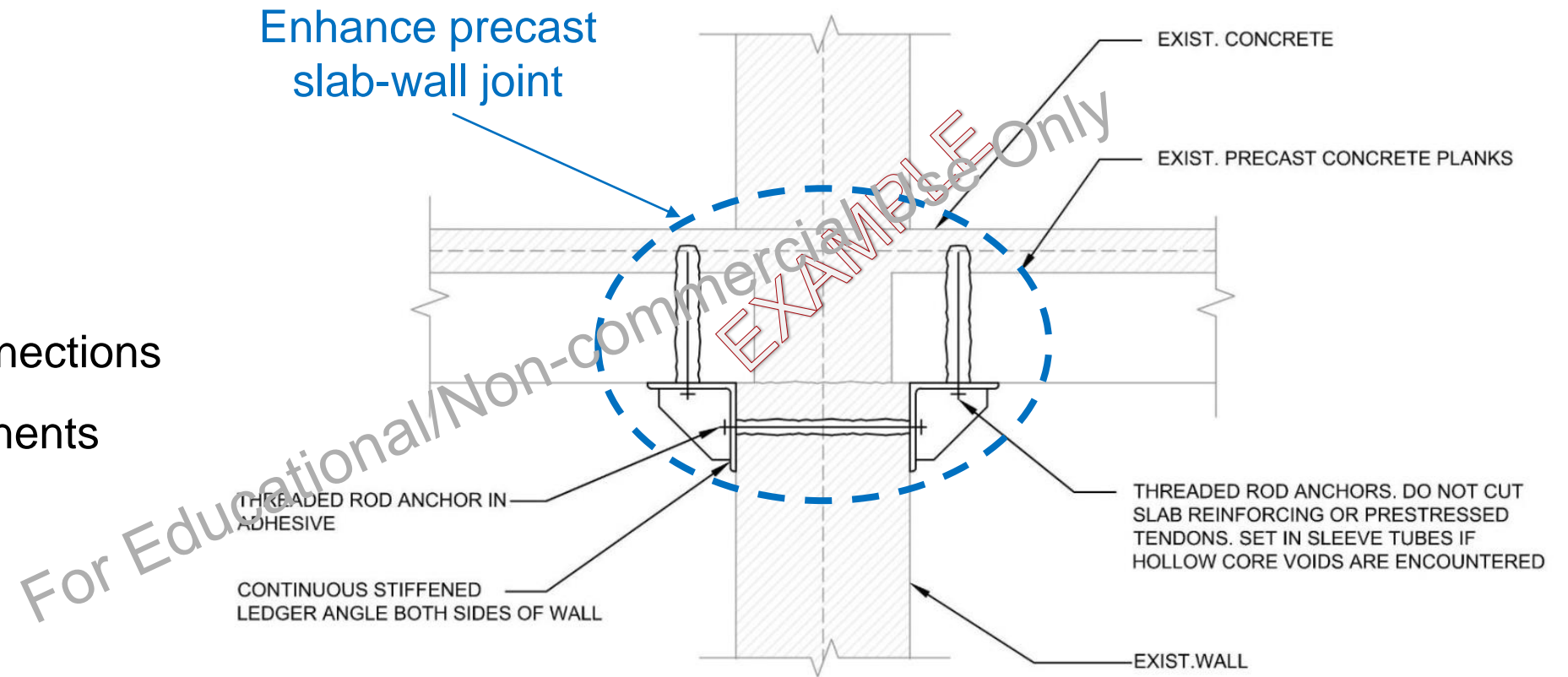


Figure 5.18: Steel ledger added at precast slab-wall joint

Classes of Upgrading Techniques

4. Reduce seismic demand



Technical Considerations in Seismic Upgrading

- **Seismicity:** In low seismicity, main concerns are typically connections
In higher seismicity, broader range of seismic deficiencies may be present
- **Irregularities:** Strengthening load path & critical locations can effectively address irregularities
- **Compatibility:** Deformation capacities of different elements must be considered
- **Foundations:** Foundation upgrading is usually expensive and can be disruptive. It is preferable to avoid or minimize foundation upgrading if possible
- **System behaviour:** It is desirable to achieve a system behaviour with composite or fuse action
- **Damage to non-structural components & building contents:** Control of damage may be required for life safety and higher performance levels

Non-technical Considerations in Seismic Upgrading

- **Accessibility:** Difficulty in access is a major factor affecting upgrading techniques and cost
- **Disruption:** Disruption in the use and occupancy is another major consideration if the building has to remain in operation
- **Building function:** Adding new elements can negatively affect the functionality of the building
- **Aesthetics:** Some upgrading techniques are aesthetically unacceptable
- **Heritage values:** Additional considerations regarding the heritage values of the building may make some upgrading techniques (e.g., seismic isolation) more appealing
- **Cost:** The full cost impact of available upgrading techniques should be considered

Other Design Considerations in Seismic Upgrading

1. Design of alternative solutions

- NBC permits the use of alternative solutions
- Design of alternative solutions should be supported by rational analysis/testing
- Peer review is strongly recommended to determine the design of alternative solutions
- The level of performance required for the alternative solution should be at least the minimum level of performance required by Division B of the NBC

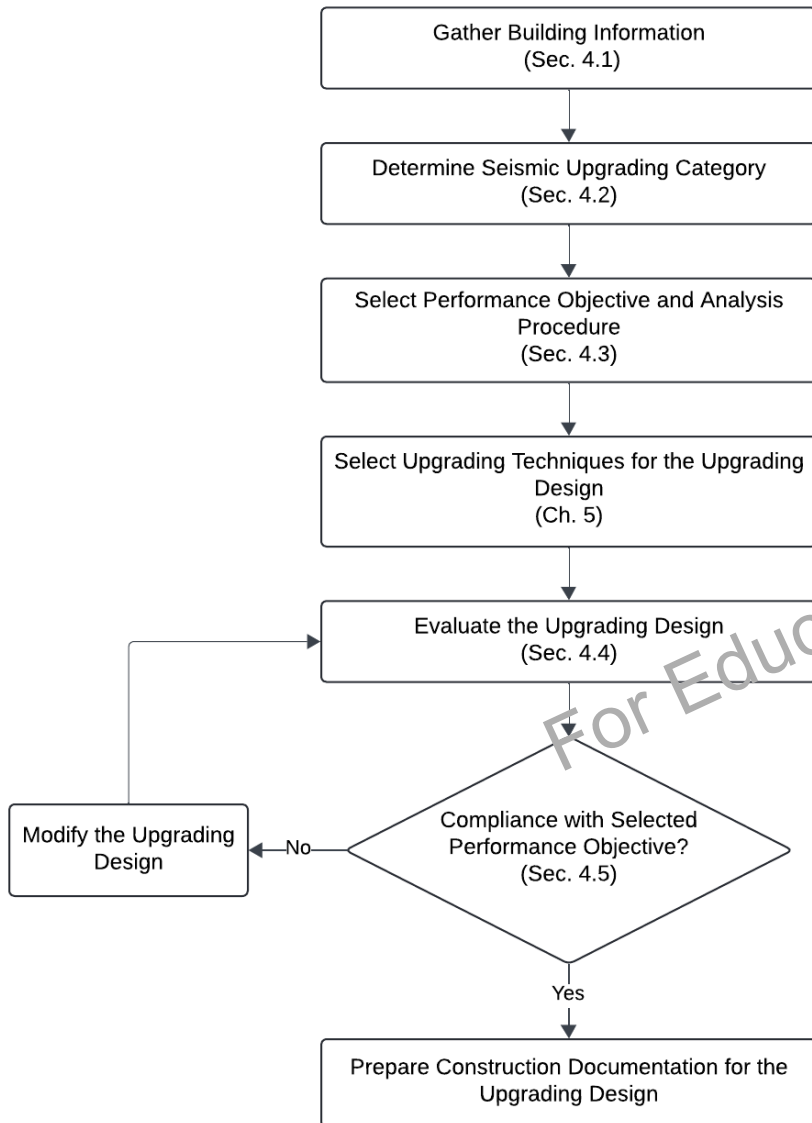
Other Design Considerations in Seismic Upgrading

2. Consideration of negative effects of seismic upgrading on existing elements

- The negative effects of seismic upgrading can be global or local
 - Adding new elements or altering existing elements can change demand, stiffness, torsional properties, etc.
 - Elements not considered part of the SFRS can also be impacted by seismic upgrading

Seismic Upgrading Design Requirements

Seismic Upgrading Design Process



1. Collect building information
2. Determine Seismic Upgrading Category
3. Select Performance Objective and Analysis Procedure
4. Select Upgrading Techniques for the Upgrading Design
5. Evaluate the Upgrading Design
6. Modify the Upgrading Design if Acceptance Criteria are Not Met
7. Repeat the Design Process Until Acceptance Criteria are Met
8. Prepare the Upgrading Design Documentation

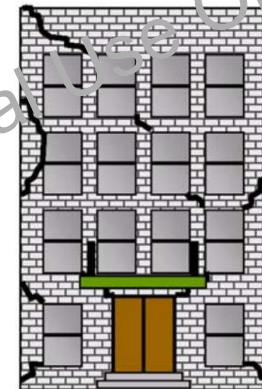
Deficiency-Based Upgrading (DBU)

Intent and Scope

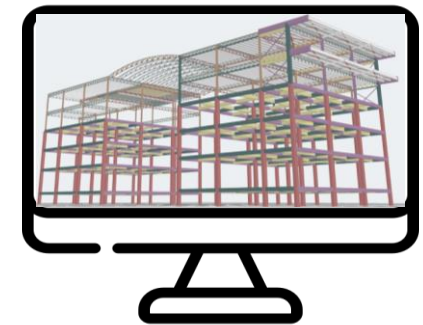
- focuses on identified seismic deficiencies through Tier 1 or Tier 2 procedures of Level 3 – SEG
- addresses life safety associated with ultimate limit states
- addresses additional performance requirements specified in the NBC
- modelling may be required, but the analysis only addresses identified deficient elements/ components & existing elements/ components that are negatively impacted by seismic upgrading

Upgrading design engineers must receive proper training

The upgrading design documentation must be reviewed



Life Safety



DBU Methodology

Force-based

- Linear analysis procedures
- Qualitative objectives
 - Life safety for all Importance 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.

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DBU Methodology

Force-based

- **Linear** analysis procedures
- **Qualitative** objectives

- 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,

Commentary J

Design for Seismic Effects

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DBU: Design Hazard Levels

Design hazard levels are made compatible with NBC Article 4.1.8.23

Design hazard levels for SLS/ULS

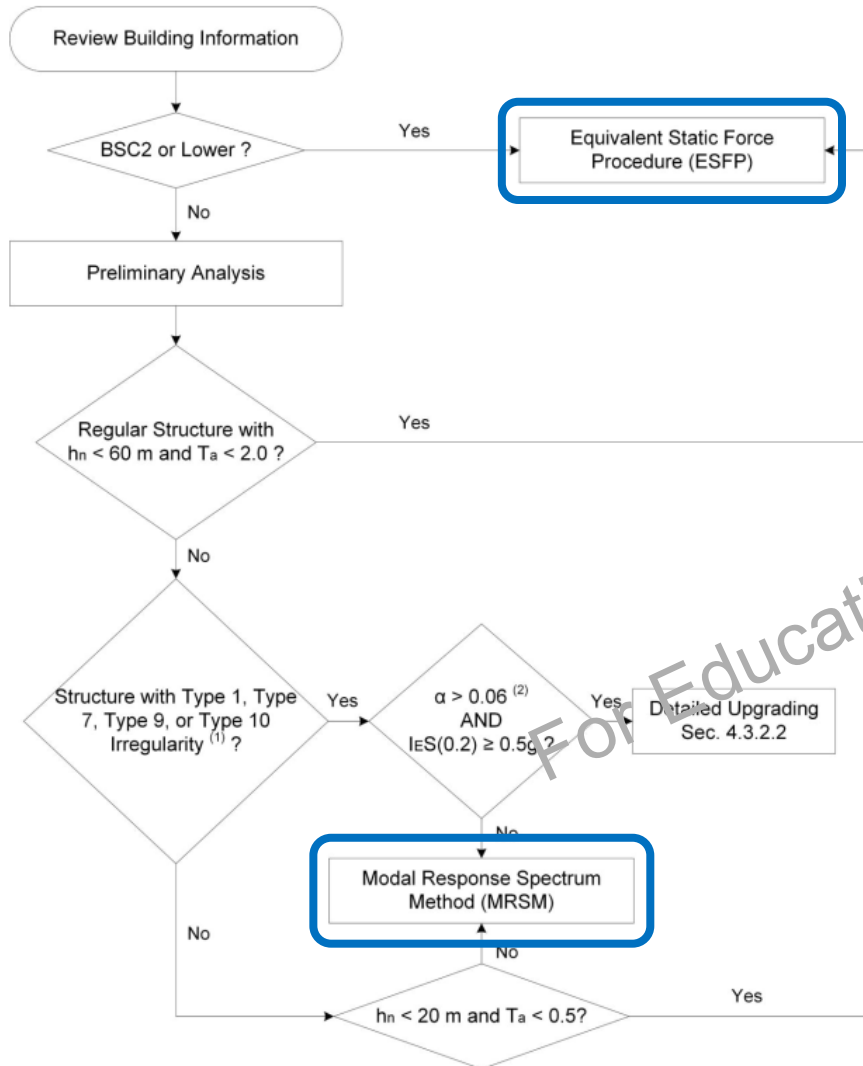
- Importance Category
- Seismicity
- Building height

Importance Category	SLS				ULS	
	BSC in which the SLS check is required	CC in which the SLS check is required	Seismic Hazard	I_E	Seismic Hazard	I_E
Low	N/A	N/A	N/A	N/A	2% in 50 yrs.	0.8
Normal $h_n \leq 30m$	N/A	N/A	N/A	N/A	2% in 50 yrs.	1.0
Normal $h_n > 30m$	BSC4-5	CC-H (HC)	10% in 50 yrs.	1.0	2% in 50 yrs.	1.0
High	BSC3-5	CC-H (HC)	10% in 50 yrs.	1.0	2% in 50 yrs.	1.3
Post-disaster	BSC2-5	CC-H (VHC)	5% in 50 yrs.	1.0	2% in 50 yrs.	1.5

SLS = Service limit state. ULS = Ultimate limit state.

BSC = Building Seismic Category. CC = Consequence Class

DBU: Building Analysis



- Criteria for analysis procedure selection have been made consistent with the NBC
 - Seismicity
 - Building height
 - Importance category
 - Building configuration
- Modelling and analysis requirements 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

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

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

DBU: Min. Seismic Design Base Shear & Resistance

Force-based

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

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

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



Resistance



DBU: Exceptions

Force-based

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

With AHJ or building owner approval !!!

α_{QE} must accounts for the effect of planned seismic upgrading

[0.35, 1.0]

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

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

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

DBU: Acceptance Criteria for ULS – Capacity Check

- New elements/ components

$$D/C \leq 1.0$$

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DBU: Acceptance Criteria for ULS – Capacity Check

- Existing elements/ components with compliant detailing that are negatively impacted by the seismic upgrading

$$D/C \leq 1.0$$

- Existing elements/ components with non-compliant detailing that are negatively impacted by the seismic upgrading

$$D/C \leq 1.0$$



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

DBU: Acceptance Criteria for ULS – 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

DBU: Acceptance Criteria for SLS

Acceptance for SLS are made compatible with NBC Article 4.1.8.23

Importance Category	Design Hazard Level	Max. Interstorey Drift	Items Required to Behave Elastically
Normal $h_n > 30\text{m}$	10% in 50 yrs.	N/A	Structural framing elements not considered part of the SFRS
High Importance	10% in 50 yrs.	$0.005 h_s$	Building, including the SFRS and structural framing elements not considered part of the SFRS Connections of elements and components described in Table 4.1.8.18 of the NBC 2025 with $R_d R_o = 1.3$ and $R_p > 1.3$.
Post-disaster	5% in 50 yrs.	$0.005 h_s$	Building, including the SFRS and structural framing elements not considered part of the SFRS Connections of elements and components described in Table 4.1.8.18 of the NBC 2025 with $R_d R_o = 1.3$ and $R_p > 1.3$.

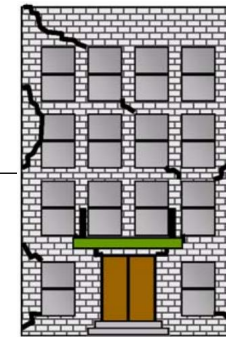
Detailed Upgrading (DEU)

Detailed Upgrading (DEU)

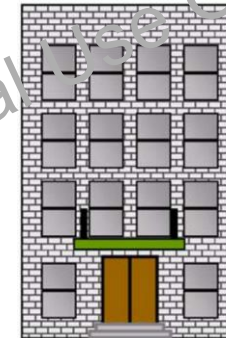
- models and analyzes the whole building
- evaluate the compliance of each new & existing element
- addresses life safety associated with ultimate limit states
- capable of addressing higher performance objectives (e.g., Immediate Occupancy)

Independent peer review is strongly recommended for

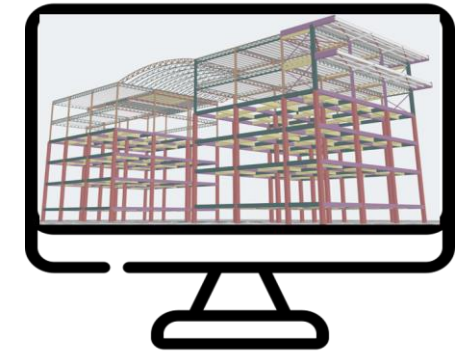
- Non-linear analysis is performed, or
- Modelling parameters and acceptance criteria are obtained experimentally from subassemblage tests



Life Safety



Immediate Occupancy



DEU Methodology

Force-based

- Linear analysis procedures
- Qualitative objectives
 - Life safety for all Importance Categories
 - Damage limitation for High Importance and Post-disaster Categories

Performance-based

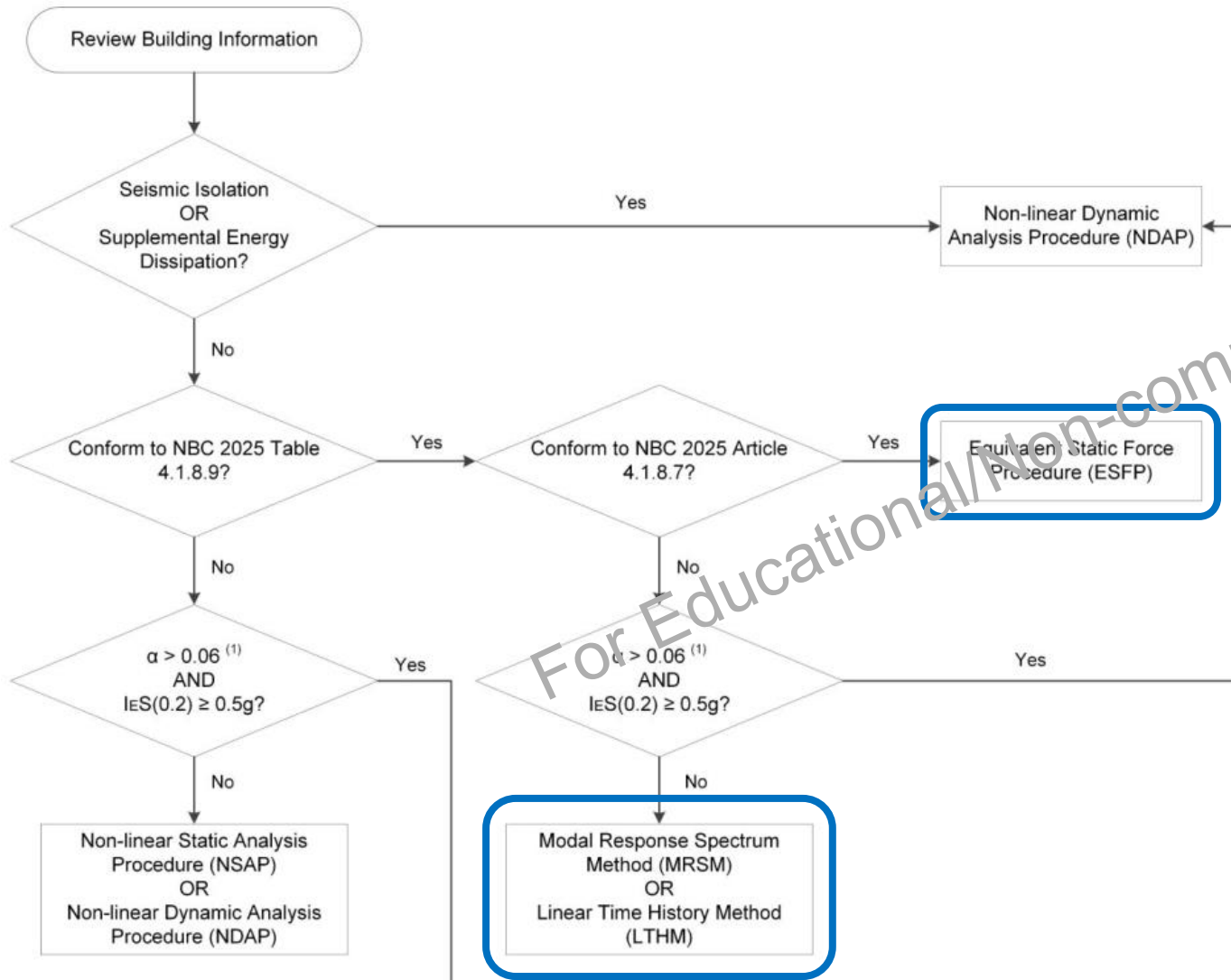
- Non-linear analysis procedures
- Discrete building performance levels
 - Immediate Occupancy
 - Damage Control
 - Life Safety
 - Collapse Prevention



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DEU: Building Analysis

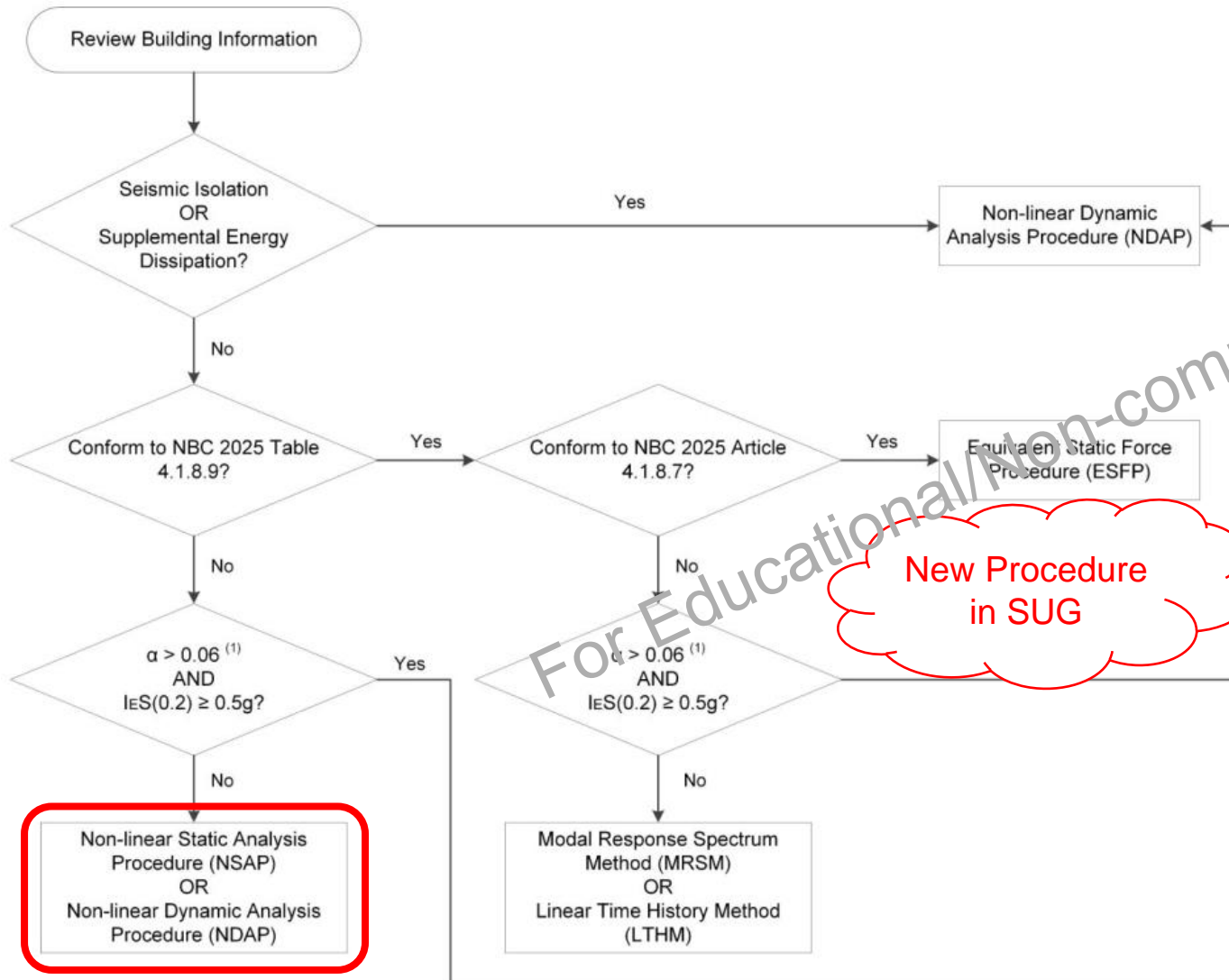
Selection criteria and analysis requirements are consistent with NBC



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 SFRS with self-centering characteristics.

DEU: Building Analysis



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 (MPA)
4. Non-linear Dynamic Analysis
 - Non-linear Time History Analysis

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

DEU: Linear Analysis Procedures

Differences Between DBU and DEU Linear Analysis Procedures

	Deficiency-Based Upgrading	Detailed Upgrading
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 & negative effects of seismic upgrading	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	Deficient elements/ components and those negatively impacted by seismic upgrading	All elements/ components need to be checked

DEU Methodology

Force-based

- Linear analysis procedures
- Qualitative objectives
 - Life safety for all Importance Categories
 - Damage limitation for High Importance and Post-disaster Categories

Performance-based

- Non-linear analysis procedures
- Discrete building performance levels
 - Immediate Occupancy
 - Damage Control
 - Life Safety
 - Collapse Prevention

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DEU: Performance Objectives for Seismic Upgrading

Consequence Class	Seismic Hazard		
	10% in 50 yrs.	5% in 50 yrs.	2% in 50 yrs.
CC-L & CC-M	N/A	N/A	Collapse Prevention Structural Performance Life Safety Non-structural Performance
CC-H (HC)	Immediate Occupancy Structural Performance Operational Non-structural Performance	N/A	Limited Life Safety Structural Performance Life Safety Non-structural Performance
CC-H (VHC)	N/A	Immediate Occupancy Structural Performance Operational Non-structural Performance	Life Safety Structural Performance Life Safety Non-structural Performance

- **Seismic Hazard Levels**

- 10% in 50 years
- 5% in 50 years
- 2% in 50 years (NBC Code Level)

- **Non-structural Performance Levels**

- Position Retention
- Life Safety

DEU: Exceptions

Same as Tier 3 Detailed Evaluation

With AHJ or building owner approval !!!

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
- 5% in 50 years
- 2% in 50 years (NBC Code Level)

• Non-structural Performance Levels

- Position Retention
- Life Safety

Seismic Hazard Values

DEU: Exceptic

User requested values

Code edition	NBC 2020
Site designation X_c	X_c
Latitude (°)	51.643
Longitude (°)	-121.296

Please select one of the tabs below.

NBC 2020 **Additional Values** Plots API Background Information

The NBC 5% damped spectral acceleration values can be viewed in the NBC tab. Additional hazard values for your site can be found below.

The 5%-damped spectral acceleration ($S_a(T)$, where T is the period, in s) and peak ground acceleration (PGA) values are given in units of acceleration due to gravity (g, 9.81 m/s²). Peak ground velocity (PGV) is given in m/s. Probability is expressed in terms of percent (%) exceedance in 50 years.

By default, all probabilities for the user-specified site designation are shown. Other site designations can be selected from the respective drop-down menu in the table. In low hazard regions, a minimum value of 0.001g for $T \leq 2.0s$ and of 0.0001g for $T > 2.0s$ is assigned. Further information on the calculation of seismic hazard is provided in the *Background Information* tab.

Site Designation	Probability	$S_a(0.05)$	$S_a(0.1)$	$S_a(0.2)$	$S_a(0.3)$	$S_a(0.5)$	$S_a(1.0)$	$S_a(2.0)$	$S_a(5.0)$	$S_a(10.0)$	PGA	PGV
X_c	2	0.103	0.159	0.191	0.178	0.145	0.0995	0.0753	0.0374	0.022	0.0851	0.135
X_c	2.5	0.0905	0.139	0.168	0.158	0.13	0.09	0.0673	0.0323	0.0185	0.075	0.121
X_c	3.5	0.0738	0.113	0.137	0.131	0.11	0.0766	0.0564	0.0258	0.014	0.0618	0.101
X_c	5	0.059	0.0902	0.11	0.107	0.0919	0.0641	0.046	0.02	0.0102	0.0498	0.0833
X_c	7	0.0474	0.072	0.0888	0.0876	0.0769	0.0536	0.0375	0.0156	0.00749	0.0404	0.0684
X_c	10	0.0371	0.056	0.0699	0.0704	0.0631	0.0438	0.0297	0.0118	0.00532	0.032	0.0546
X_c	14	0.0291	0.0434	0.055	0.0566	0.0516	0.0357	0.0235	0.00889	0.00375	0.0253	0.0435
X_c	20	0.0221	0.0324	0.0418	0.0441	0.041	0.0282	0.018	0.00634	0.00247	0.0195	0.0334
X_c	30	0.0155	0.0225	0.0297	0.0321	0.0305	0.0209	0.0129	0.00405	0.0014	0.0139	0.0237
X_c	40	0.0117	0.0167	0.0225	0.0247	0.0239	0.0163	0.00973	0.00281	0.000911	0.0106	0.0178

Consequence Class	20% in 50 yrs. ⁽¹⁾
CC-L & CC-M	Life Safety Structural Performance Life Safety Non-structural Performance
CC-H (HC)	Damage Control Structural Performance Position Retention Non-structural Performance
CC-H (VHC)	N/A

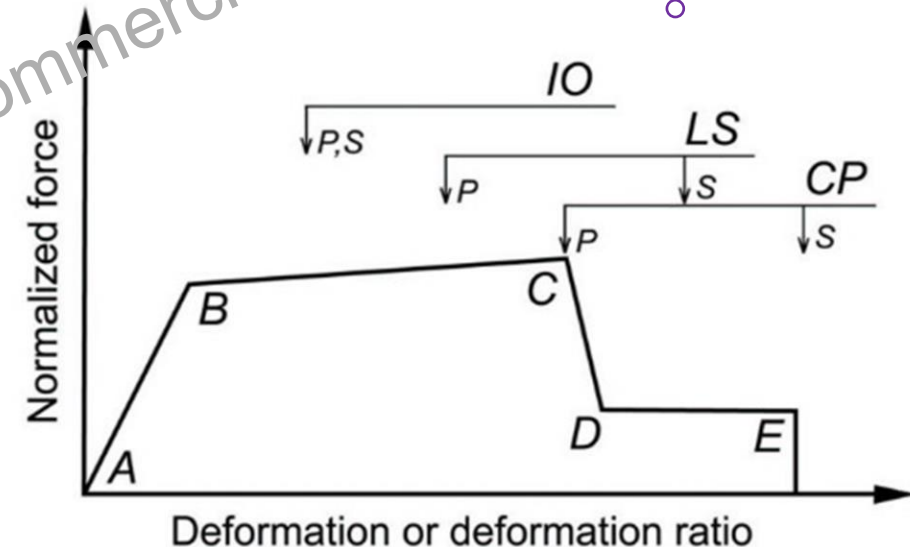
Download CSV

DEU: Non-linear Modelling Parameters (NDP) and Acceptance Criteria (AC)

Performance-based

- Non-linear analysis procedures
- Structural Performance Levels
 - Immediate Occupancy
 - Damage Control
 - Life Safety
 - Limited Life Safety
 - Collapse Prevention

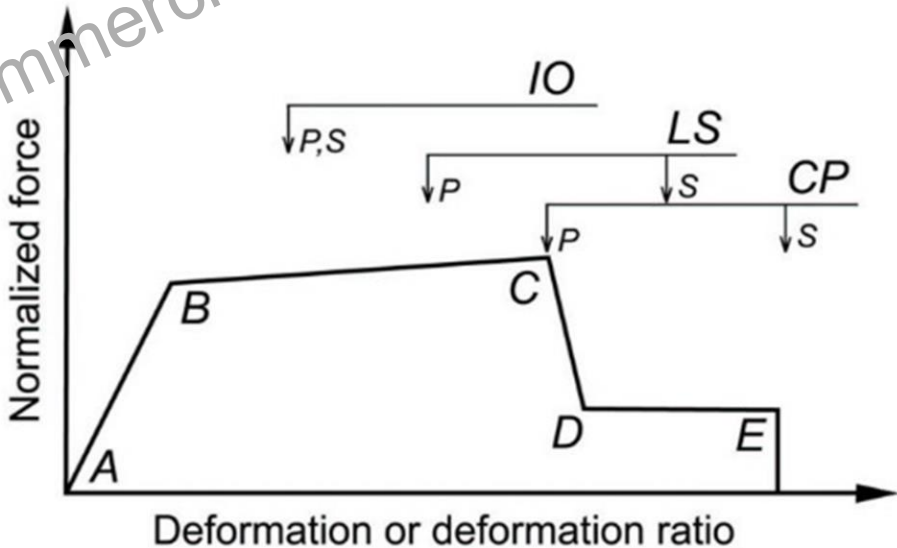
Investigation of the applicability of ASCE 41 to the Canadian context



Force-deformation relationship

DEU: NDP & AC

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



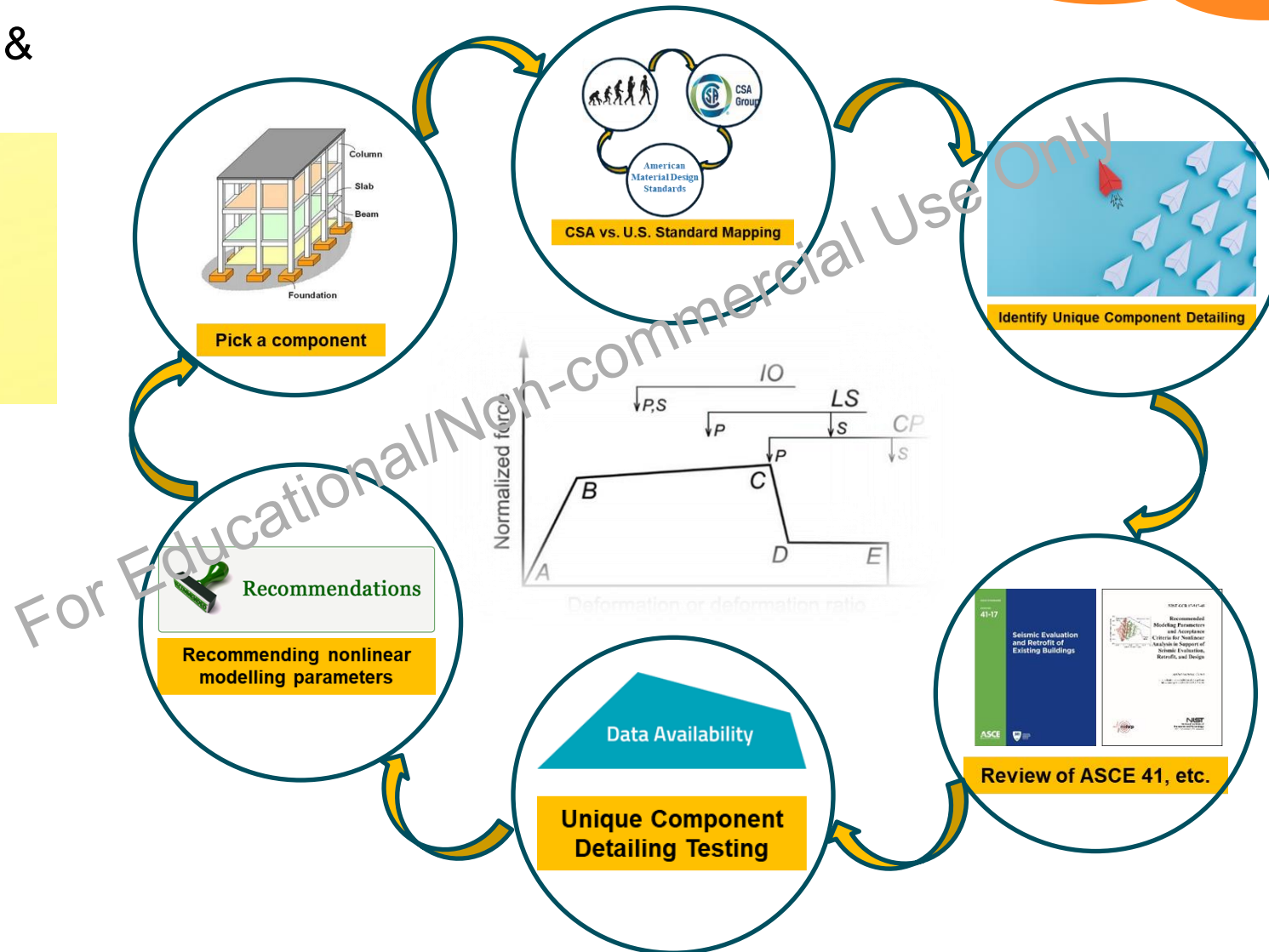
Force-deformation relationship

DEU: NDP & AC

Refer to Level 3 – SEG webinar & NRC's published studies for detailed information

American standards & guidelines

APPLICABILITY



DEU: 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;

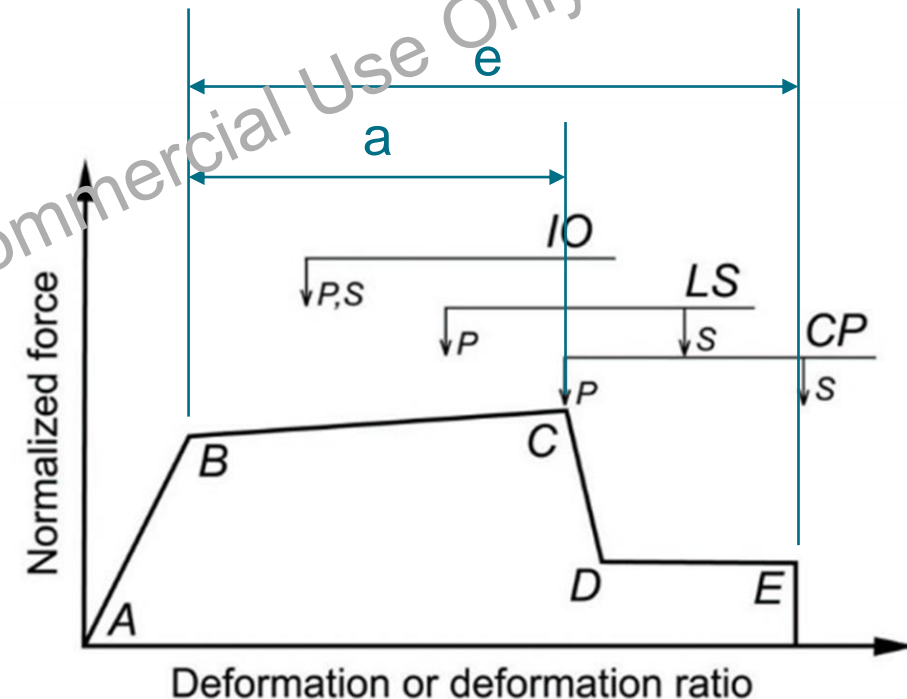
S_{ns} = Force demand from (non-seismic) gravity loads, kN;

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.

DEU: 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

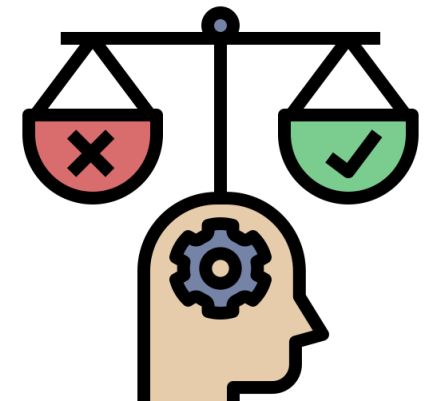
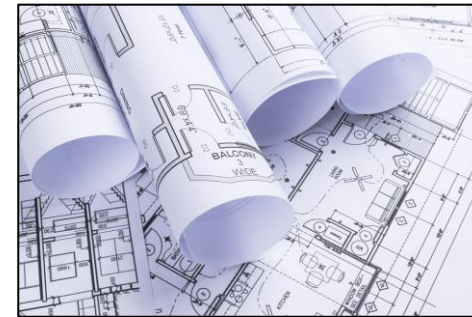


Force-deformation relationship

Upgrading Techniques

Intent and Scope

- Conventional and innovative upgrading techniques are covered
- Certain innovative solutions (e.g., shape-memory alloy) not covered
- Schematic details illustrate concepts only and not fully engineered
- Engineering design input required to develop project-specific details
- Upgrading design involves greater uncertainties and constraints than the design of new buildings; more engineering judgement is needed.



Development of Schematic Upgrading Details

Step 1: compile an inventory of upgrading details (> 470) from existing standards and guidelines



Techniques for the Seismic Rehabilitation of Existing Buildings
FEMA 547/2006 Edition
FEMA



Reducing the Risks of Nonstructural Earthquake Damage – A Practical Guide
FEMA E-74 / December 2012
FEMA



Seismic Retrofit Guidelines 3rd Edition
In Effect June 22, 2017
Please Note: This Guideline is only to be used by engineers who have participated in the SRG3 Training through APEGBC. If you have not participated in the training, please contact Tonya Hyde thyde@apeg.bc.ca to get more information about SRG3 training options.
~ 54 details
BRITISH COLUMBIA Ministry of Education, APEGBC Professional Engineers and Geoscientists of BC, UBC

CSA S832:14 (reaffirmed 2024)
CSA GROUP™
Seismic risk reduction of operational and functional components (OFCs) of buildings
4 details
Published by Institute for Research in Construction IRC

National Research Council Canada / Conseil national de recherches Canada
NRC-CNRC
Guideline for Seismic Upgrading of Building Structures
~ 38 details

Development of Schematic Upgrading Details

Step 2: critically review the details and identify applicable details (205 in total)



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160 structural + 45 non-structural
(based on most common deficiencies)

Development of Schematic Upgrading Details

Step 3: critically review the details and propose necessary modifications

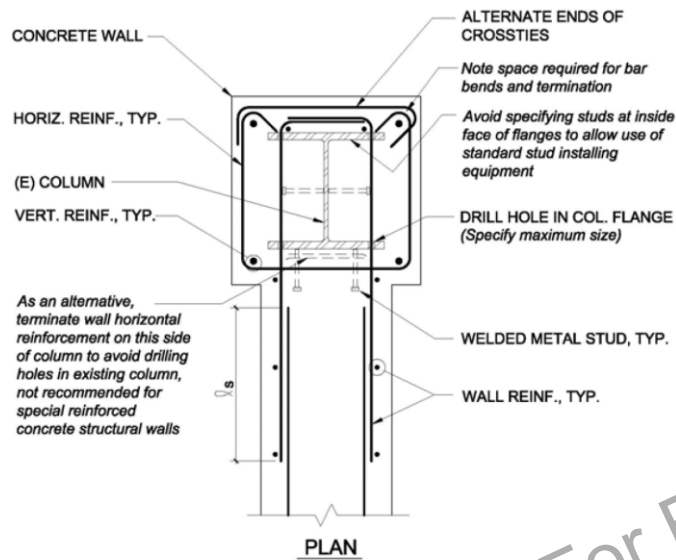


Figure 8.4.2-2: Cast-in-Place Concrete Wall Encasing Existing Column

FEMA 547

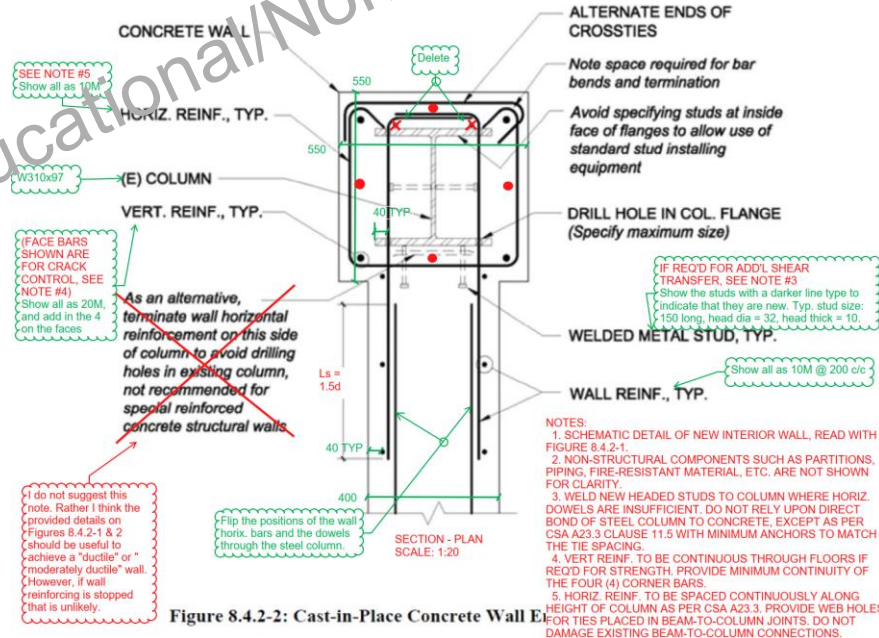
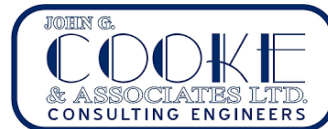


Figure 8.4.2-2: Cast-in-Place Concrete Wall Encasing Existing Column



Development of Schematic Upgrading Details

Step 4: discuss and finalize schematic details for SUG

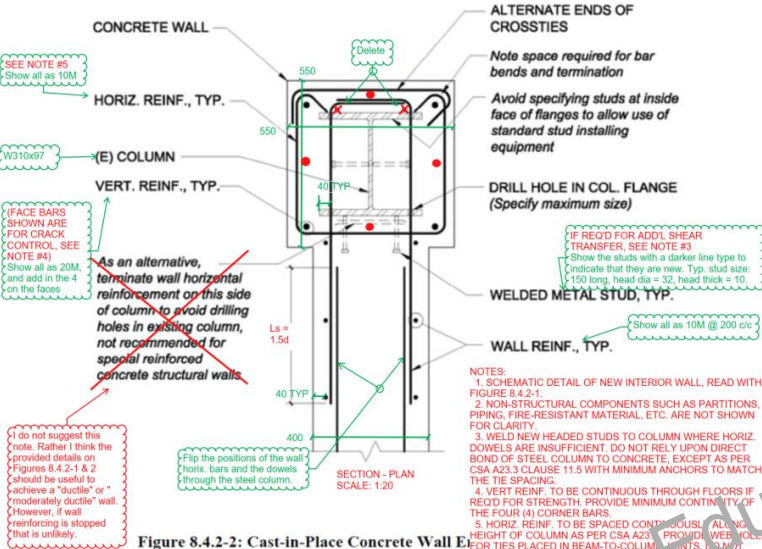


Figure 8.4.2-2: Cast-in-Place Concrete Wall Encasing Existing Column

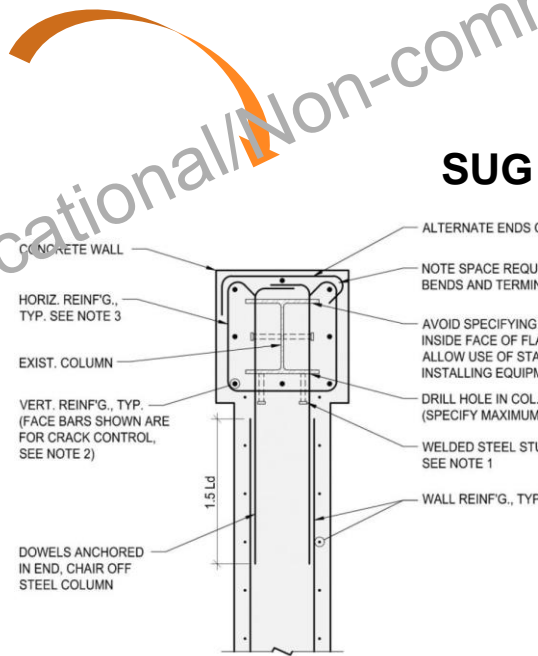
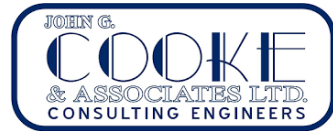


Figure 5.13: Connection of new concrete shear wall encasing existing concrete column (plan view)



- NOTES:**
1. WELD NEW HEADED STUDS TO COLUMN. DO NOT RELY UPON DIRECT BOND OF STEEL COLUMN TO CONCRETE, OR ONLY THE DOWELS THROUGH THE COLUMN THAT NEED TO DEVELOP THE HORIZ. REINF. IN THE WALL.
 2. VERT. REINF. TO BE CONTINUOUS THROUGH FLOORS IF REQ'D FOR STRENGTH. PROVIDE MINIMUM CONTINUITY OF THE FOUR (4) CORNER BARS.
 3. HORIZ. REINF. TO BE SPACED CONTINUOUSLY ALONG HEIGHT OF COLUMN AS PER CSA A23.3. PROVIDE WEB HOLES FOR TIES PLACED IN BEAM-TO-COLUMN JOINTS. DO NOT DAMAGE EXISTING BEAM-TO-COLUMN CONNECTIONS.
 4. FOR A DUCTILE OR MODERATELY DUCTILE SHEAR WALL THE PLASTIC HINGE REGION IS CRITICAL.

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Classification of Upgrading Techniques

- Concrete Construction
- Steel Construction
- Masonry Construction
- Wood Construction
- Diaphragms
- Structural Foundations
- Geologic Hazards
- Reduction of Seismic Demand
- Non-structural Components and Building Contents

5 Seismic upgrading techniques

This chapter describes *seismic upgrading* techniques for *existing buildings* including upgrading techniques using different materials (e.g., concrete, steel, masonry and wood construction) for specific elements such as diaphragms and foundations, using methods that reduce seismic demand, and upgrading techniques for *non-structural components* and building contents. The techniques are regrouped under major sections of this document based on their construction materials, which can be applied to buildings with different predominant construction materials (e.g., new concrete shear walls added to existing steel buildings). The upgrading design utilizing various upgrading techniques described in this section should comply with the upgrading design requirements outlined in Chapter 4.

When selecting upgrading techniques, there are many key considerations to keep in mind, as described in Section 3.3. For instance, it is important to note that applying these techniques often requires the removal of *non-structural components*, such as finishes or mechanical/electrical equipment, in most cases. The extent and impact of such removals should be considered during the technique selection and design process.

Many upgrading techniques for various types of construction involve installing anchors drilled into existing cast-in-place or precast concrete elements. When drilling into existing concrete, it is crucial to determine the location of all reinforcement or prestressing tendons by scanning the concrete beforehand to avoid damage. This scanning should be done before fabricating plates or brackets to ensure the desired anchor pattern can be used. The anchors and adhesives used are proprietary products with specific installation requirements. It is essential to ensure that the specified and installed anchors are rated for seismic use and have been tested to the appropriate standards. The quality of the installation significantly impacts the connection's capacity, so only qualified installers experienced with the product are permitted to perform the work. Inspection and proof load testing of the anchor installation should also be considered, following the requirements in CSA A23.3:24 (CSA, 2024a) and the technical advice of the anchor manufacturer.

Concrete Construction

Adding concrete or steel overlay to existing RC columns improves

- Shear capacity
- Axial compression
- Flexural plasticity hinge confinement
- Inadequate lap splices

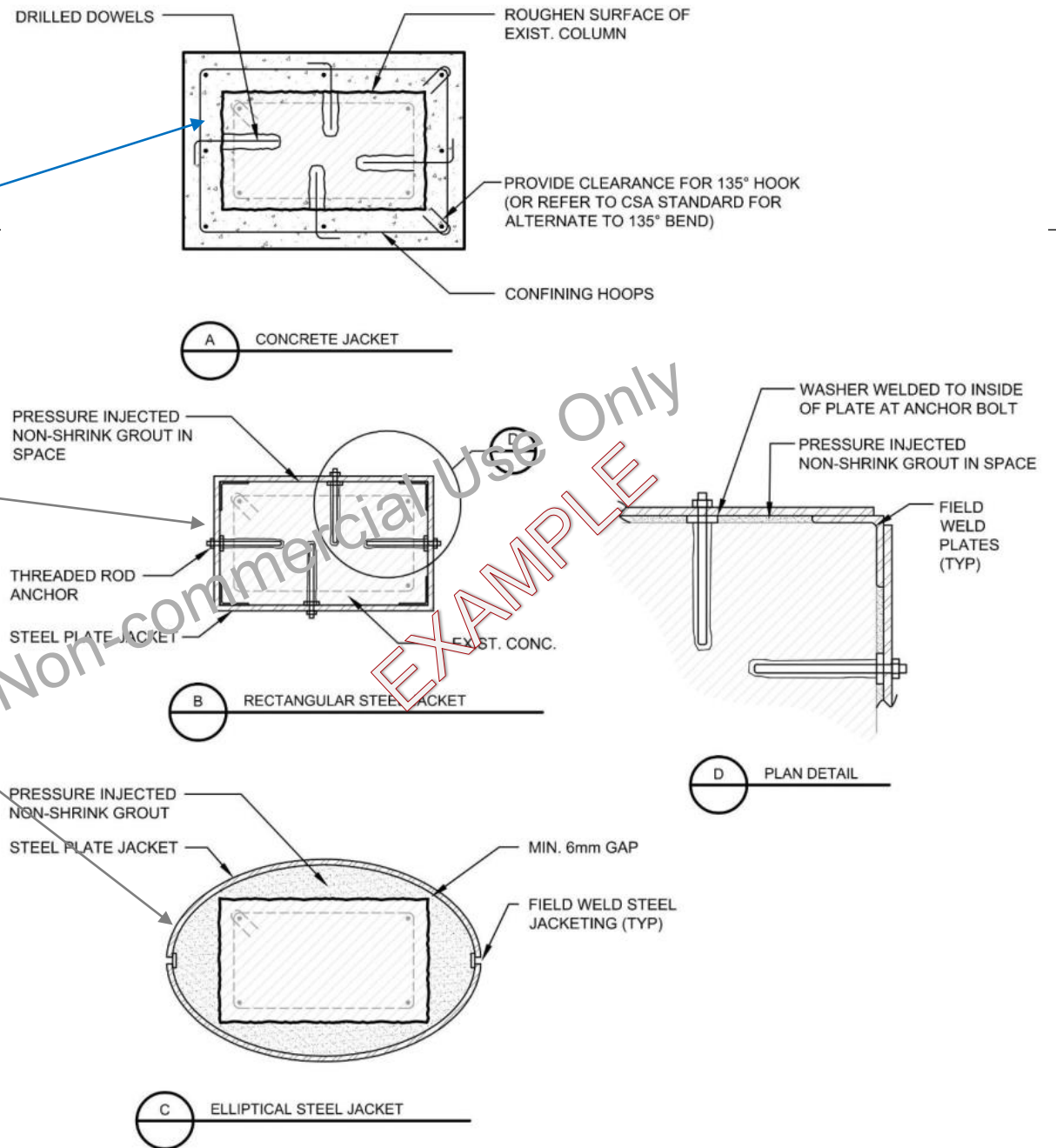


Figure 5.1: Concrete and steel overlay on concrete columns

Concrete Construction

Add new RC shear walls can

- Significantly **increase overall lateral strength and stiffness**
- **Reduce demands** on existing shear walls or diaphragms



Compatibility must be confirmed if new shear walls are designed to act together with existing SFRS

New shear walls

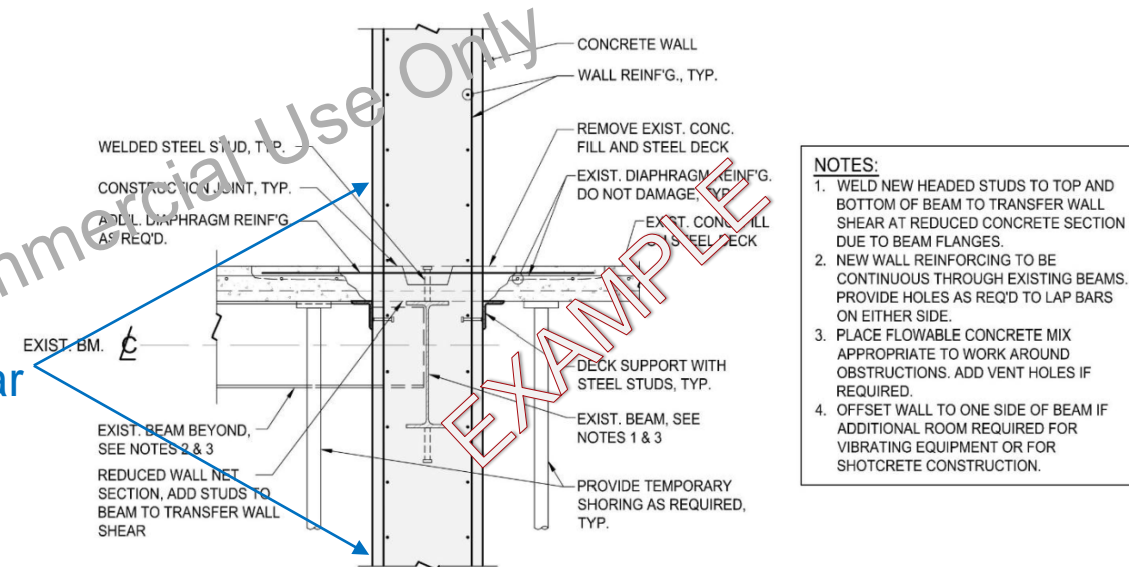


Figure 5.12: Connection of new concrete shear wall at existing steel beam

Concrete Construction

Add new RC coupling beam can

- Significantly **increase overall lateral strength**
- **Provide additional ductility**

New Coupling Beam

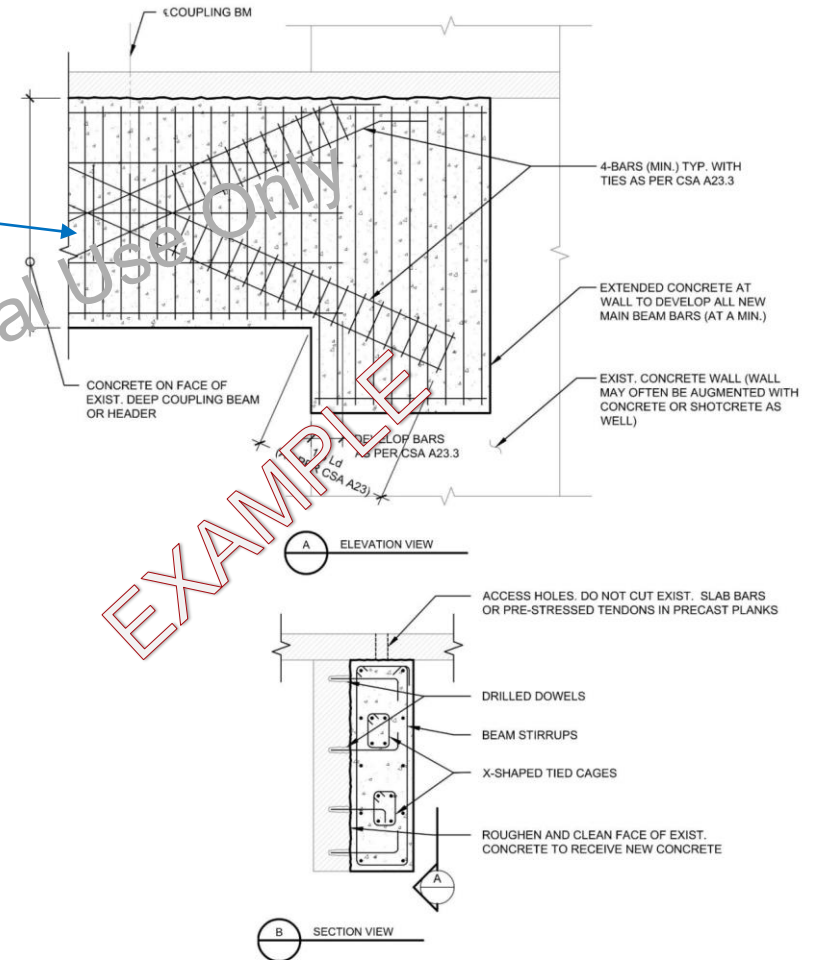


Figure 5.6: Enlargement of the existing deep concrete coupling beam

Concrete Construction

Enhance existing connections

Address both bearing & shear deficiencies

Address shear deficiency only

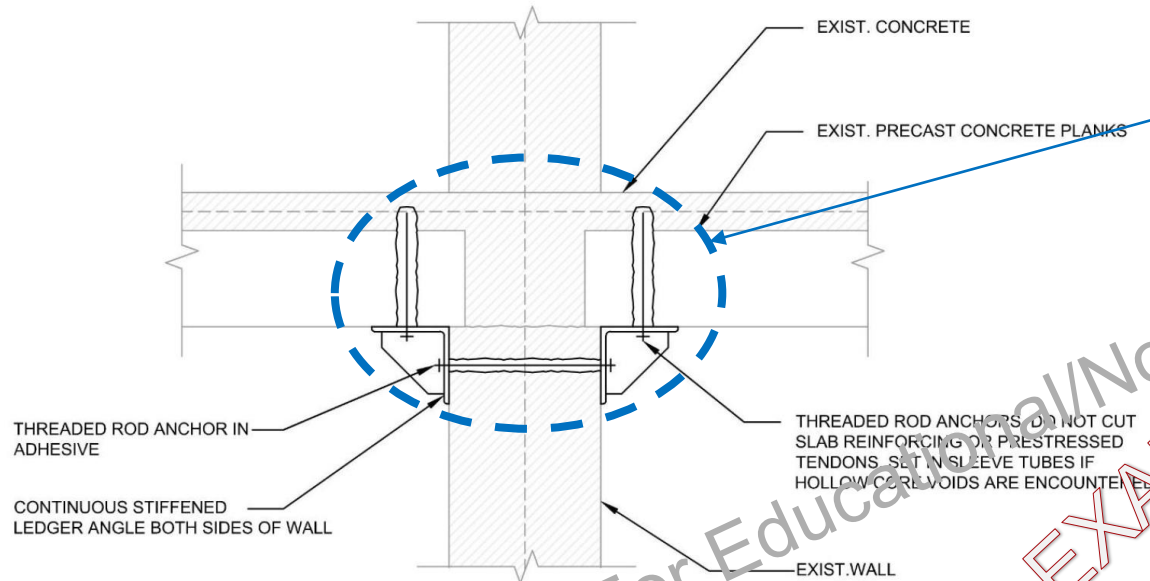


Figure 5.18: Steel ledger added at precast slab-wall joint

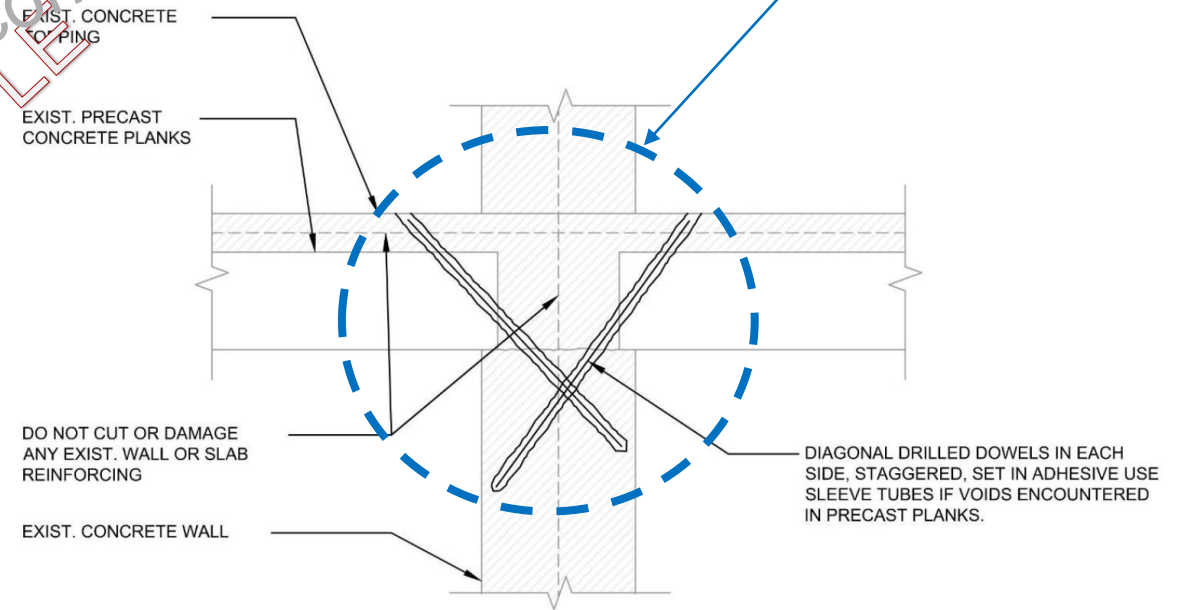


Figure 5.19: Diagonal dowels added at precast slab-wall joint

Steel Construction

Welding plates to existing W-section columns improves

- Axial capacity
- Shear capacity
- Flexural capacity

New plates

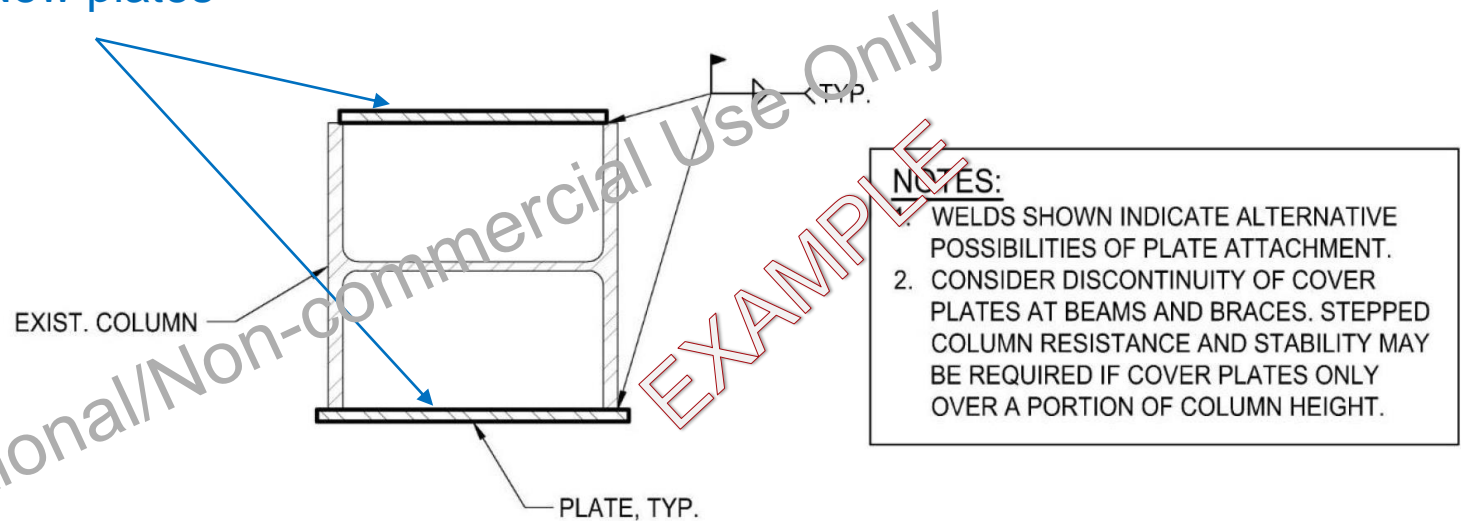


Figure 5.28: Addition of plates to sides of existing steel W-section column (plan view)

Steel Construction

Add new steel braces to

- Significantly **increase lateral stiffness & strength**
- **Reduce demands** on existing SFRS



The building should be analyzed for higher lateral and overturning forces due to the increase of lateral stiffness

New braces

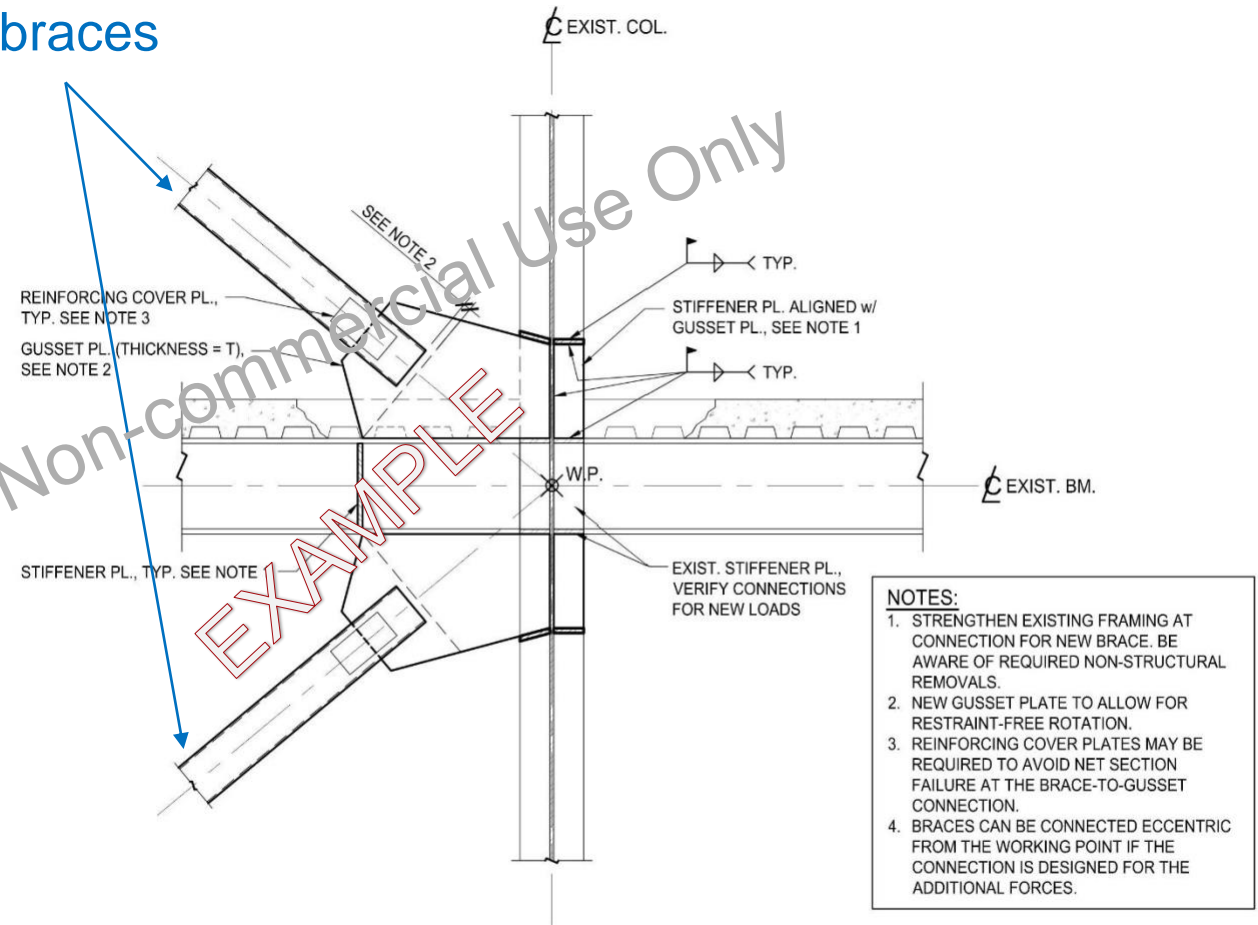


Figure 5.30: Connection of new steel brace to existing beam-column junction in moderately ductile CBF

Steel Construction

Adding a haunch to existing beam-column connection increases

- Connection strength
- Frame ductility

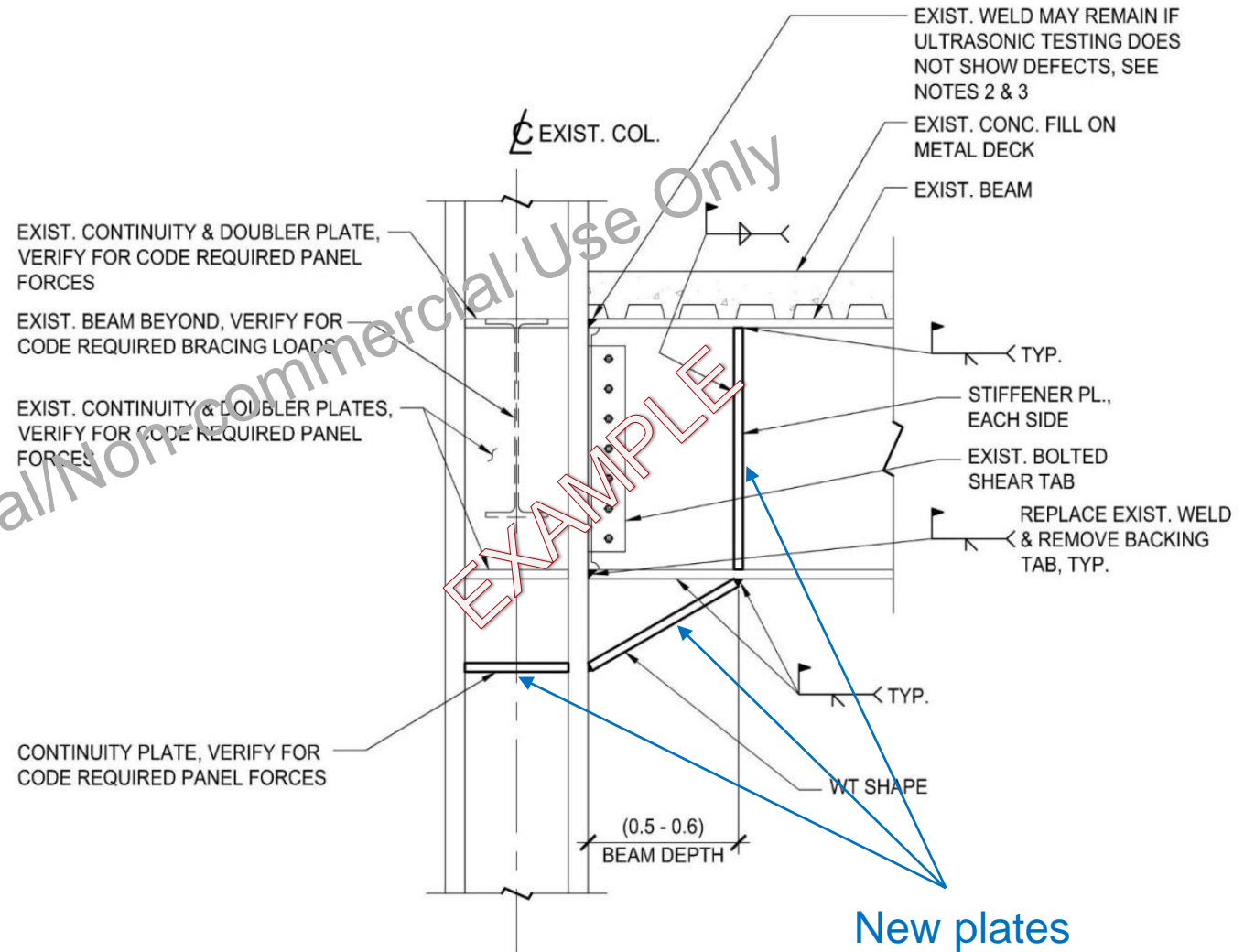


Figure 5.54: Welded haunch added to bottom flange of existing moment frame beam

Masonry Construction

Adding braces to existing URM walls to
improve out-of-plane capacity

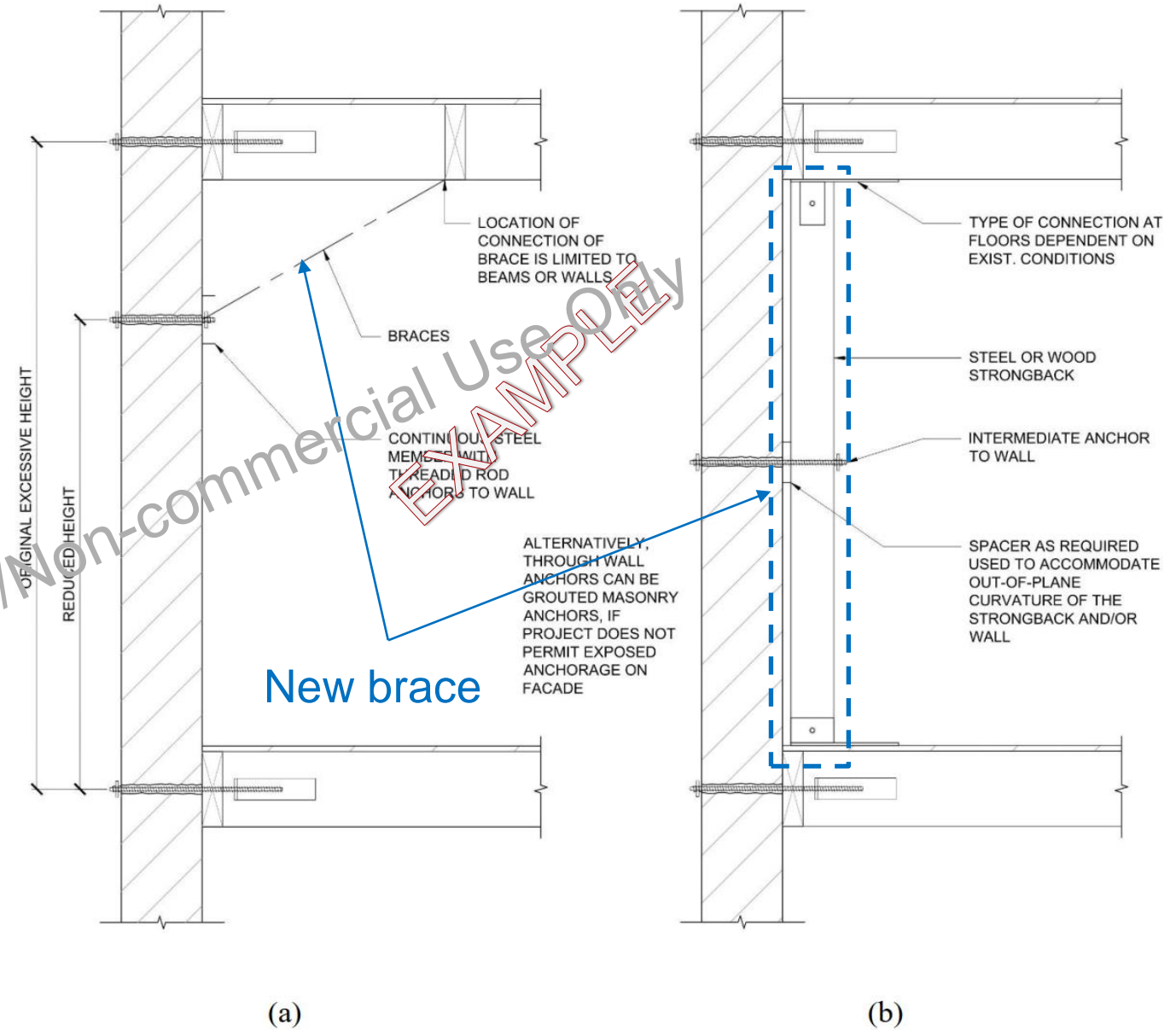


Figure 5.56: Addition of diagonal (a) and vertical (b) out-of-plane bracing to existing URM wall

Masonry Construction

Adding reinforced cores to existing URM walls increases

- In-plane capacity
- Out-of-plane capacity

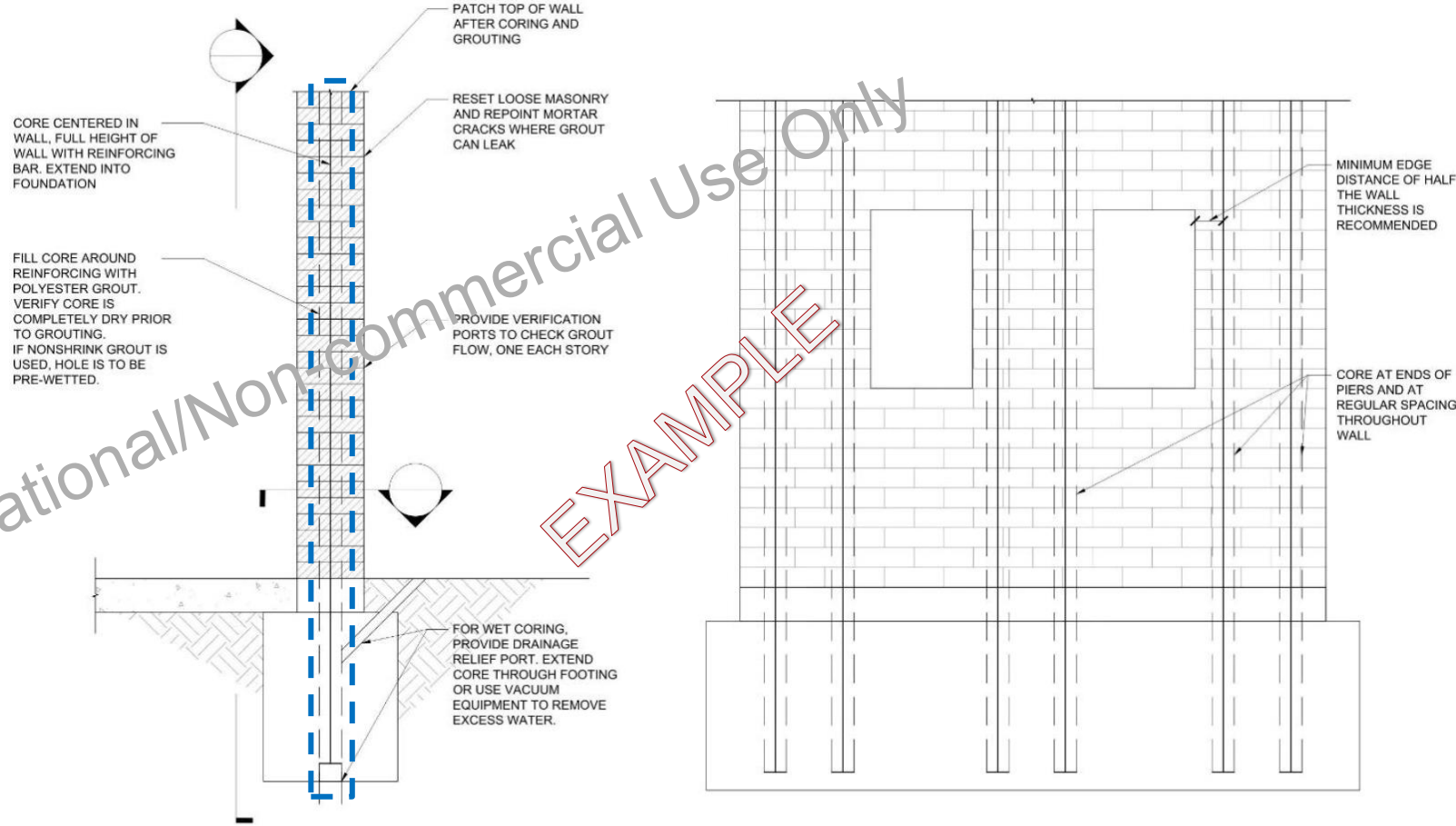


Figure 5.59: Addition of reinforced cores to URM wall

Masonry Construction

Adding FRP overlay to existing
URM walls

- Increases in-plane capacity
- Improves out-of-plane capacity

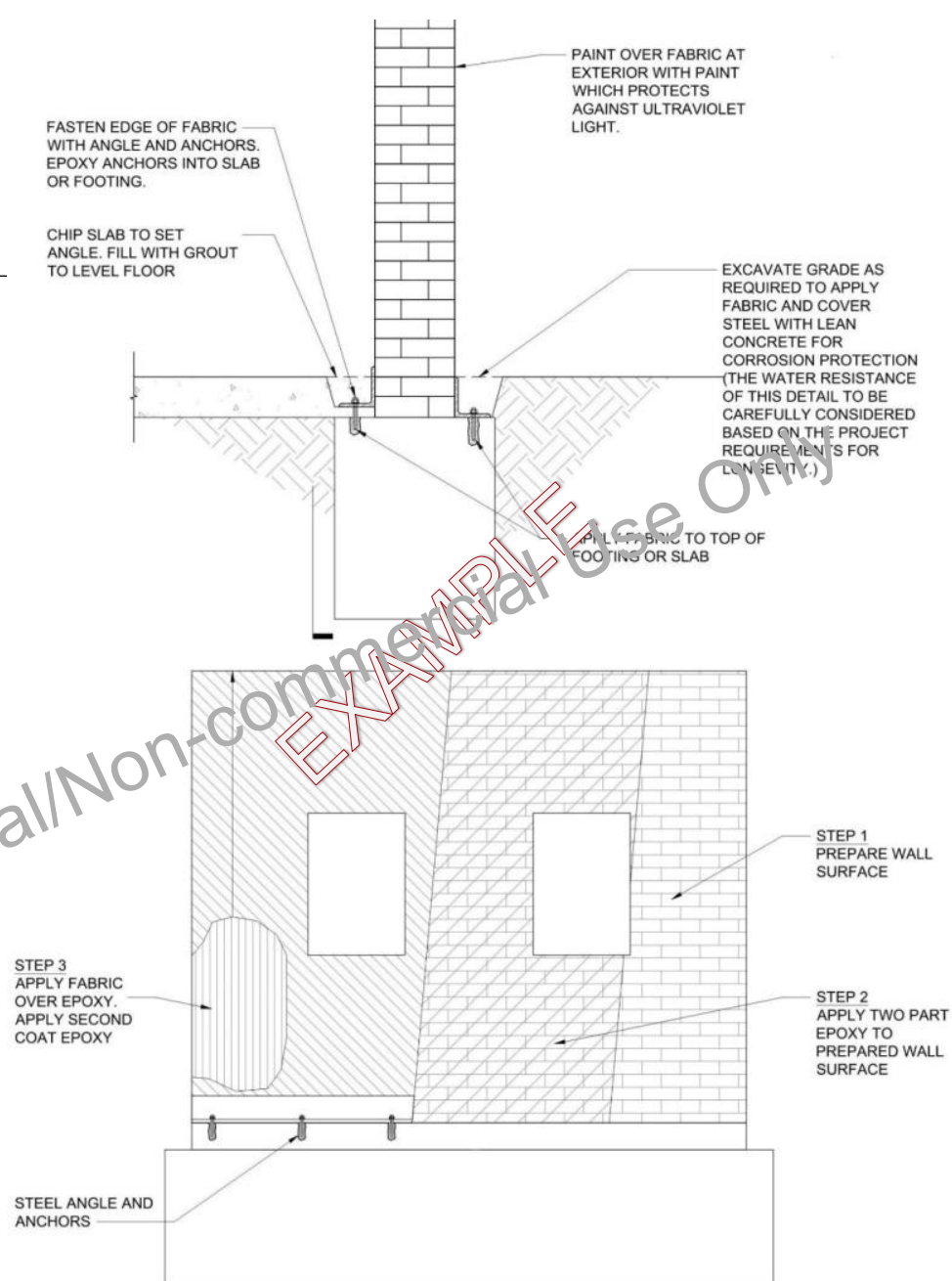


Figure 5.70: Addition of FRP overlay to URM wall

Masonry Construction

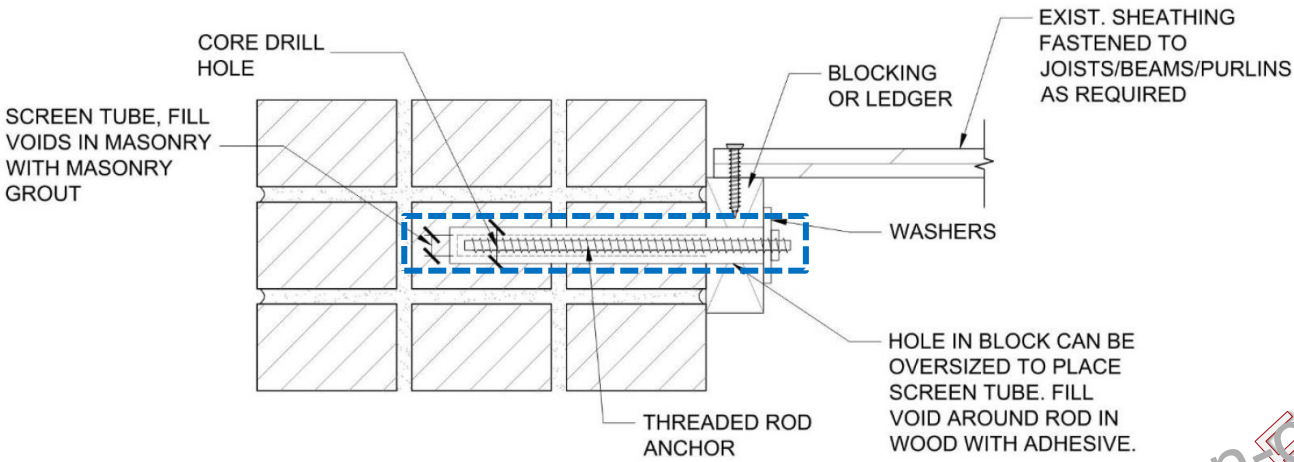


Figure 5.73: Drilled dowel connecting wood diaphragm to URM wall

Enhance existing connections

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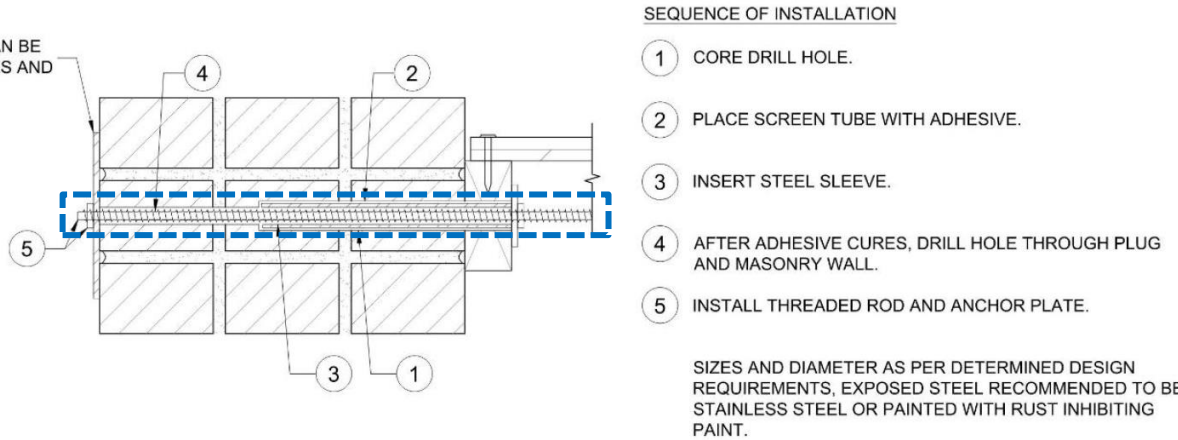


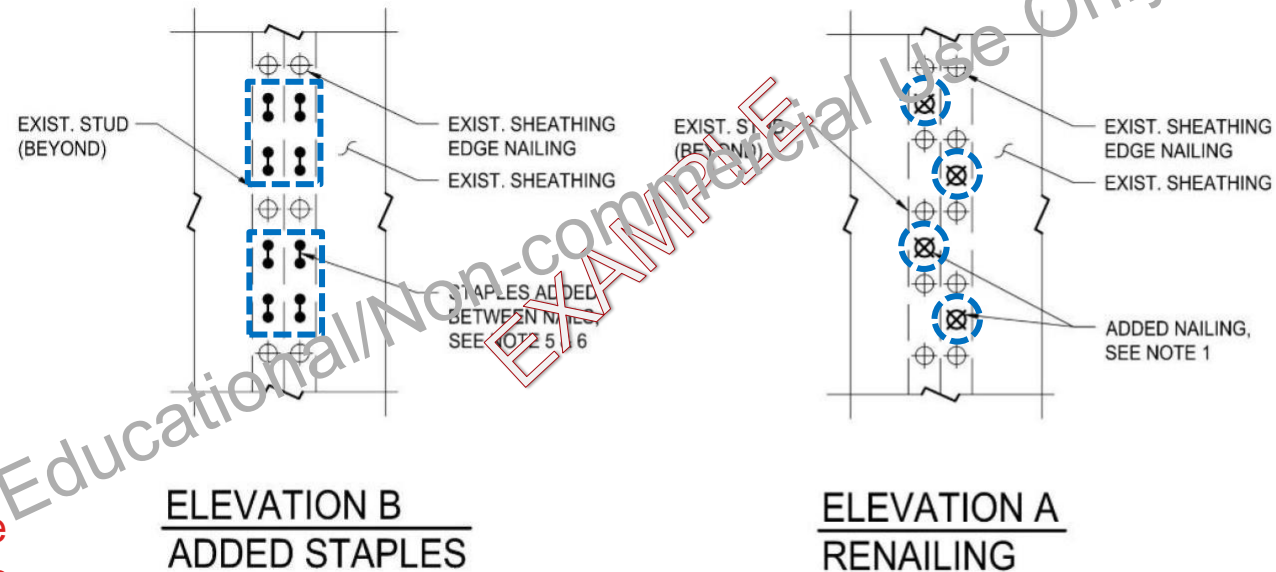
Figure 5.74: Through bolt anchor connection of wood diaphragm to URM wall

Wood Construction

Adding nails to existing
wall sheathing
increases wall capacity



Too many nails can
reduce sheathing
seismic performance
as it may prevent the
inelastic action of the
fasteners



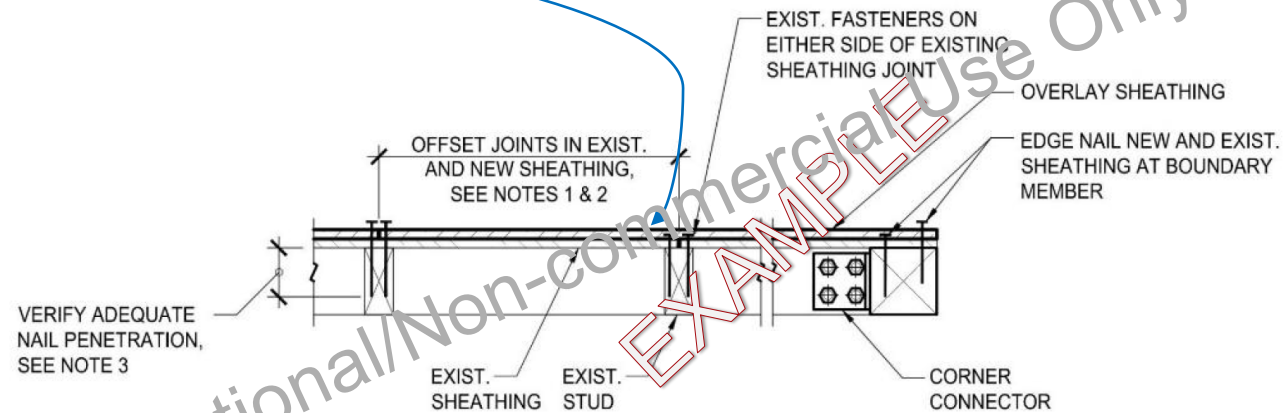
NOTES:

1. ADDED NAILING TO MEET REQUIRED SPACING WHEN AVERAGED OVER JOINT LENGTH. DISTRIBUTE AS EVENLY AS POSSIBLE.
2. ALL FASTENERS TO MEET LATEST EDITION OF THE NATIONAL BUILDING CODE OF CANADA.
3. INCREASED FASTENERS PROVIDE MODEST INCREASE IN SHEAR WALL CAPACITY WHERE OTHER DETAILING IS NOT REQUIRED.
4. UPGRADE MAY BE INCORPORATED WITH ADDITIONAL SHEAR WALL DETAILING FOR IMPROVED CAPACITY.
5. STAPLES TO BE ORIENTED PARALLEL TO STUD LENGTH. VERIFY SIZE AND EMBEDMENT REQUIREMENTS.
6. PROVIDE ENOUGH STAPLES TO CARRY FULL DESIGN SHEAR LOAD SUCH THAT NO SHEAR IS RESISTED BY THE EXISTING NAILS.

Figure 5.94: Addition sheathing fastening for wood shear wall

Wood Construction

Adding sheathing overlay to
existing wall sheathing
increases wall capacity



NOTES:

1. NEW FASTENERS TO BE STAGGERED WITH EXISTING AND HAVE ADEQUATE CAPACITY. REFER TO CSA O86 FOR FASTENING REQUIREMENTS.
2. OVERLAY SHEATHING MAY PREVENT NEED TO REMOVE EXISTING PANEL OR LUMBER SHEATHING; HOWEVER, NO CAPACITY SHOULD BE CONSIDERED FOR EXISTING LUMBER SHEATHING.
3. EXISTING FRAMING AND FASTENING MAY BE DIFFICULT TO VERIFY OR ADJUST IF EXISTING SHEATHING REMAINS IN PLACE.

PLAN DETAIL

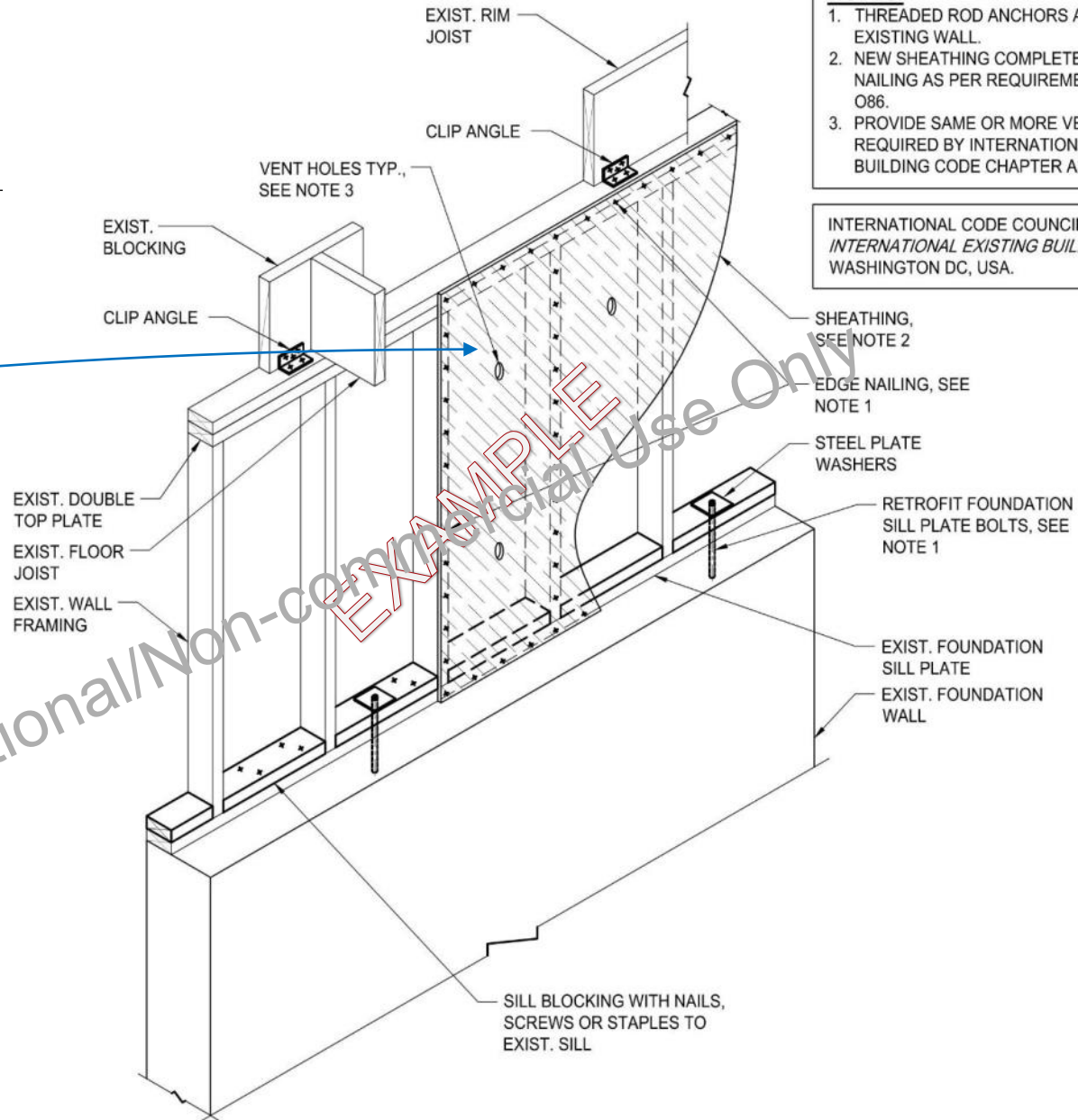
Figure 5.95: Addition of sheathing overlay on existing wood shear wall (plan view)

Wood Construction

Adding wall sheathing to existing cripple wall increases in-plane shear capacity of cripple wall



Care should be taken to protect cripple walls in areas susceptible to wood decay



NOTES:

1. THREADED ROD ANCHORS AT BASE OF EXISTING WALL.
2. NEW SHEATHING COMPLETE WITH EDGE NAILING AS PER REQUIREMENTS OF CSA 086.
3. PROVIDE SAME OR MORE VENTILATION AS REQUIRED BY INTERNATIONAL EXISTING BUILDING CODE CHAPTER A3.

INTERNATIONAL CODE COUNCIL, 2021,
INTERNATIONAL EXISTING BUILDING CODE,
WASHINGTON DC, USA.

Figure 5.108: Addition of sheathing to wood cripple wall

Wood Construction

Adding anchorage to existing wood shear wall to concrete foundation to improve shear transfer

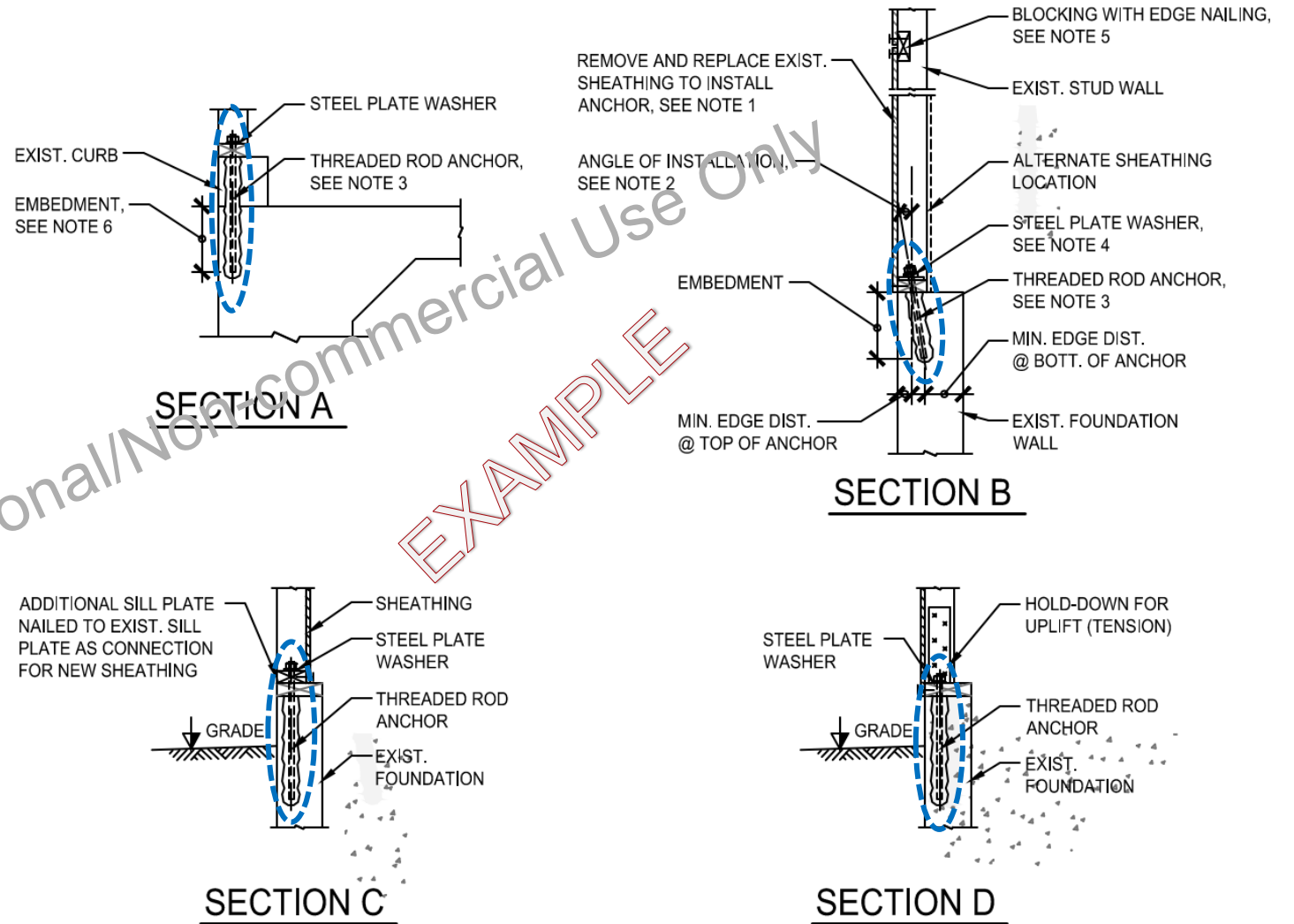
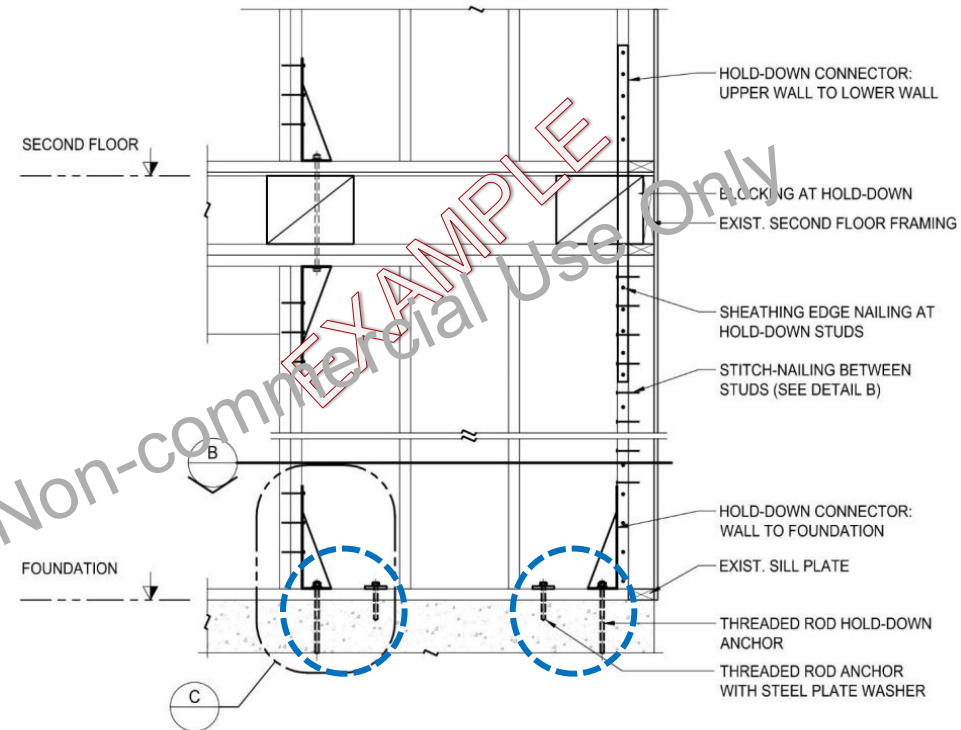


Figure 5.115: Additional anchorage of existing wood walls to concrete foundation

Wood Construction

Adding anchorage to existing wood shear wall to concrete foundation increases overturning capacity



A SHEAR WALL ELEVATION WITH ENHANCED OVERTURNING DETAILING

NOTES:

1. HOLD-DOWNS AND FASTENERS TO PROVIDE CLEAR AND CONTINUOUS LOAD PATH BETWEEN UPPER AND LOWER LEVELS DOWN TO FOUNDATION.
2. SHEATHING NOT SHOWN FOR CLARITY. NEW OR EXIST. SHEATHING ON ONE OR BOTH SIDES OF WALL, AS REQUIRED.
3. ALL FASTENERS TO MEET CSA O86.

Figure 5.119: Shear wall elevation with enhanced overturning detailing

Upgrading of Diaphragms

Infill existing diaphragm openings to improve shear transfer and chord capacity

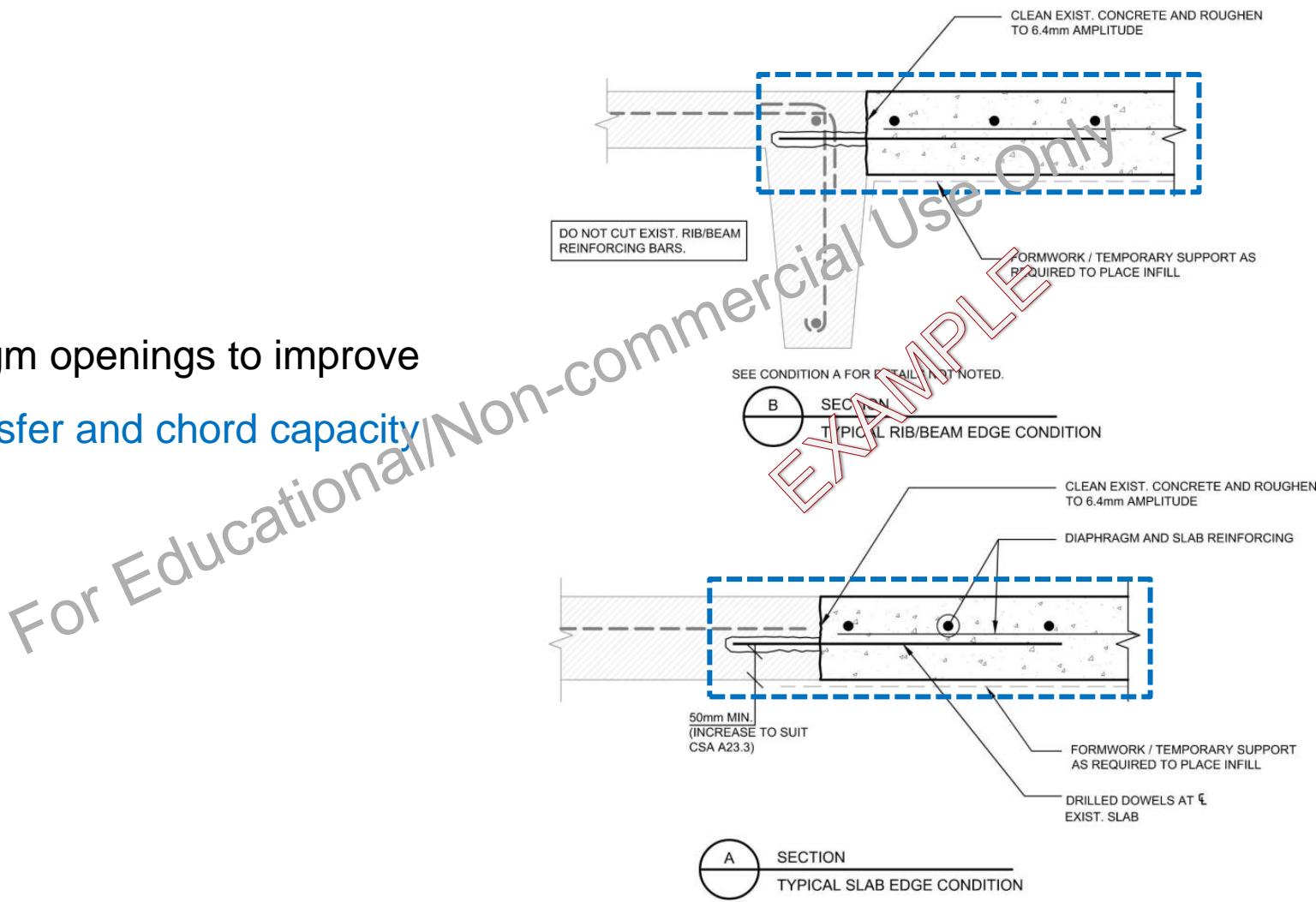


Figure 5.123: Infill existing opening in concrete diaphragm with reinforced concrete slab

Upgrading of Diaphragms

FRP overlay

Add FRP overlay to existing diaphragm to improve in-plane shear capacity

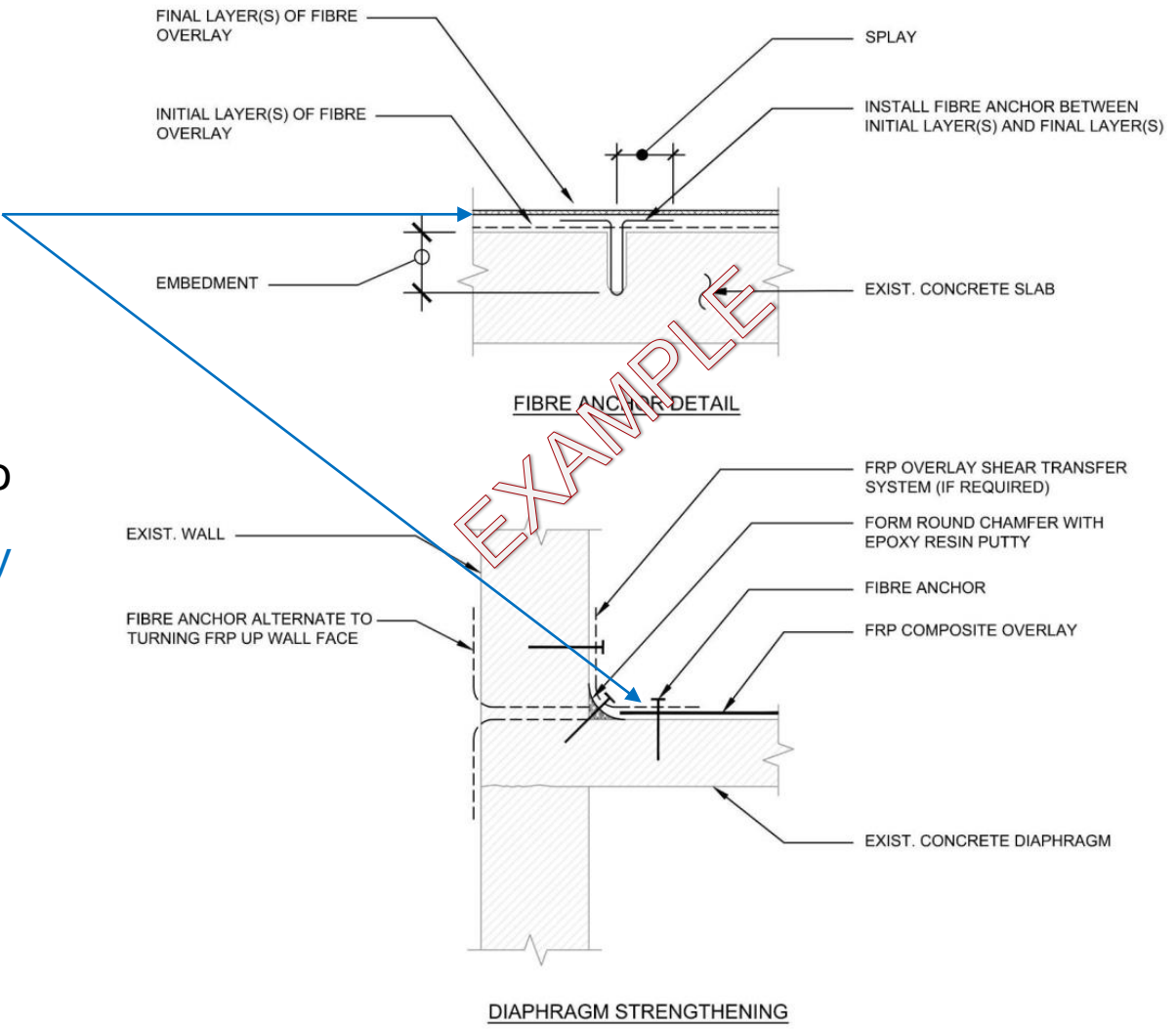


Figure 5.124: Addition of FRP overlay to concrete diaphragm

Upgrading of Diaphragms

Add new concrete collector at existing concrete beam to **improve shear transfer** from diaphragms to shear walls or braces

New collector

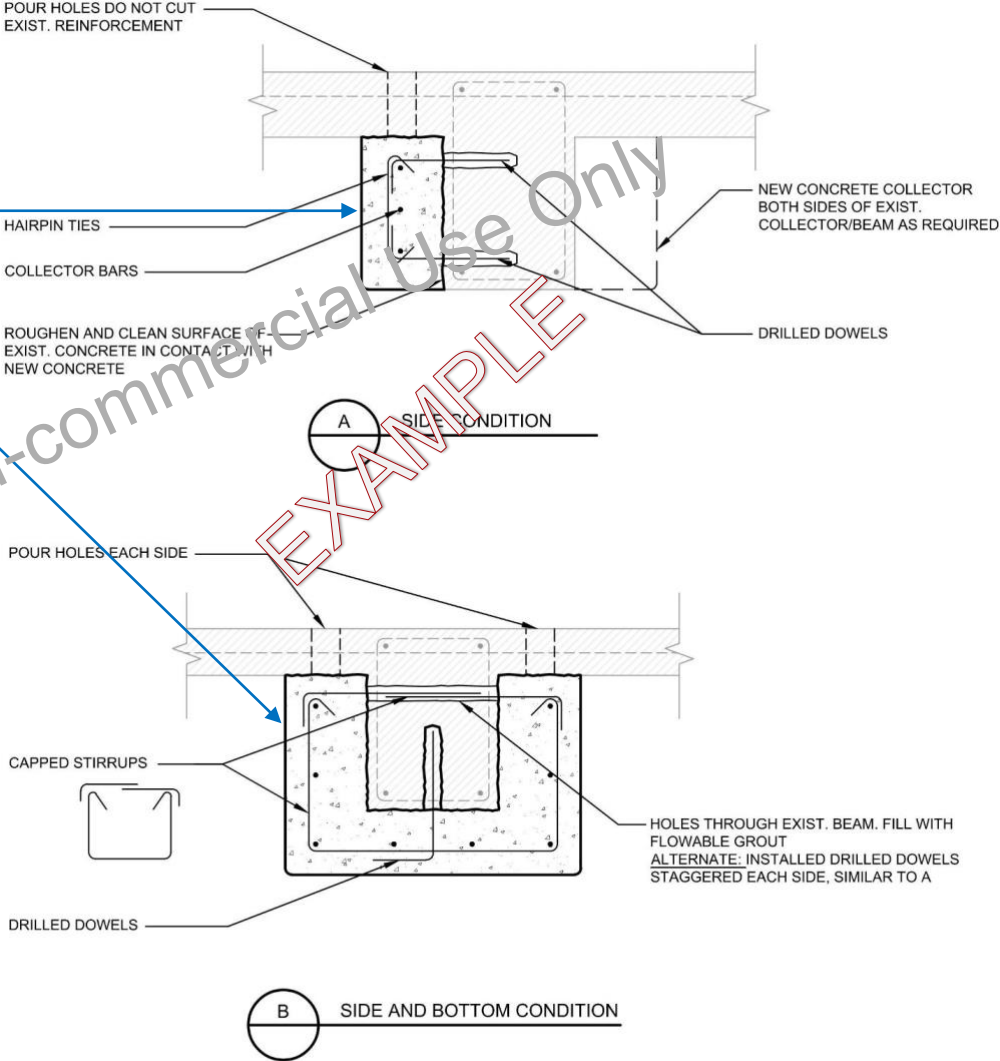


Figure 5.128: New concrete collector at existing concrete beam

Upgrading of Foundations

Enlarge existing spread footing to
 increase tension & compression capacity

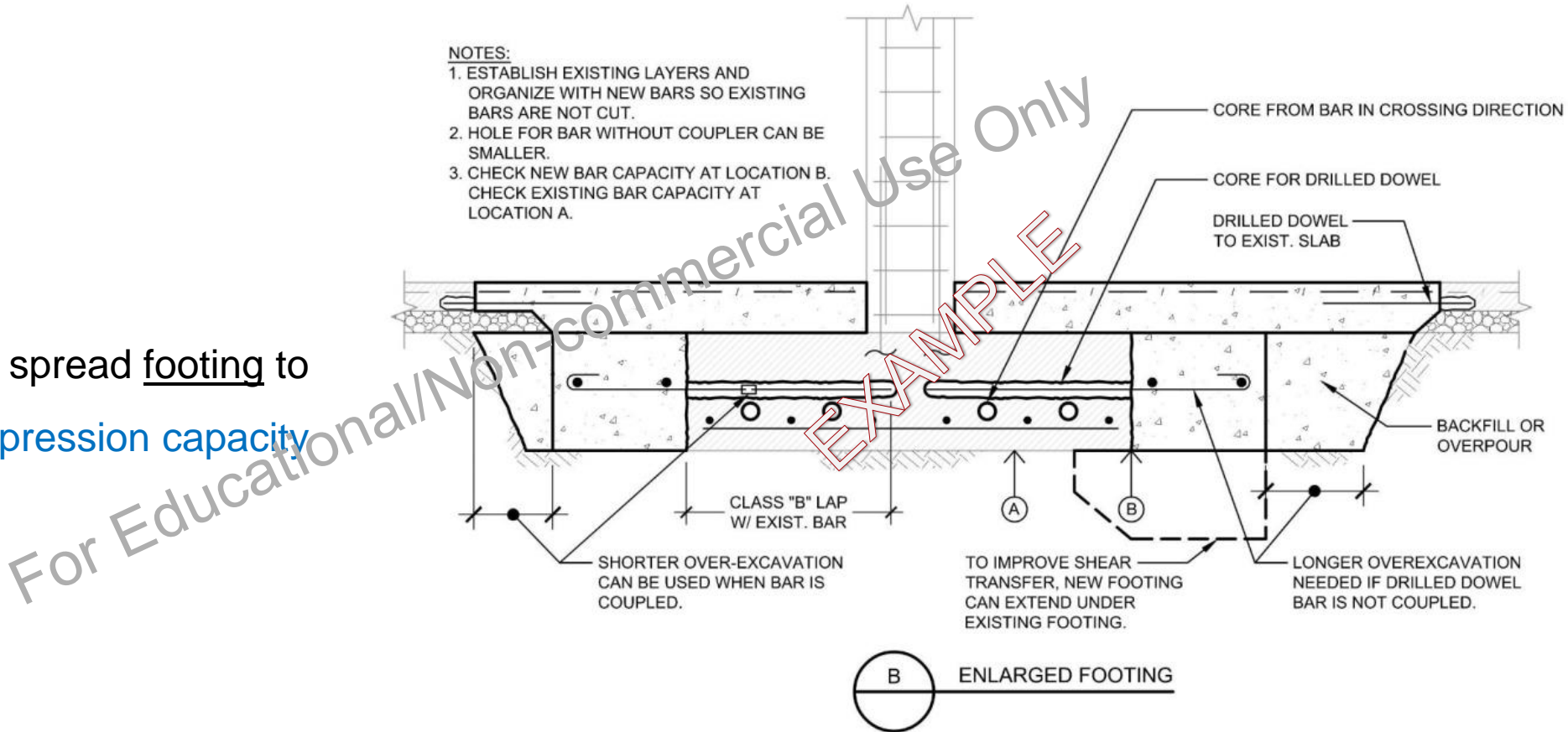


Figure 5.151: Enlargement of existing spread footing

Upgrading of Foundations

Add micropiles adjacent to existing spread footings to **increase tension & compression capacity**

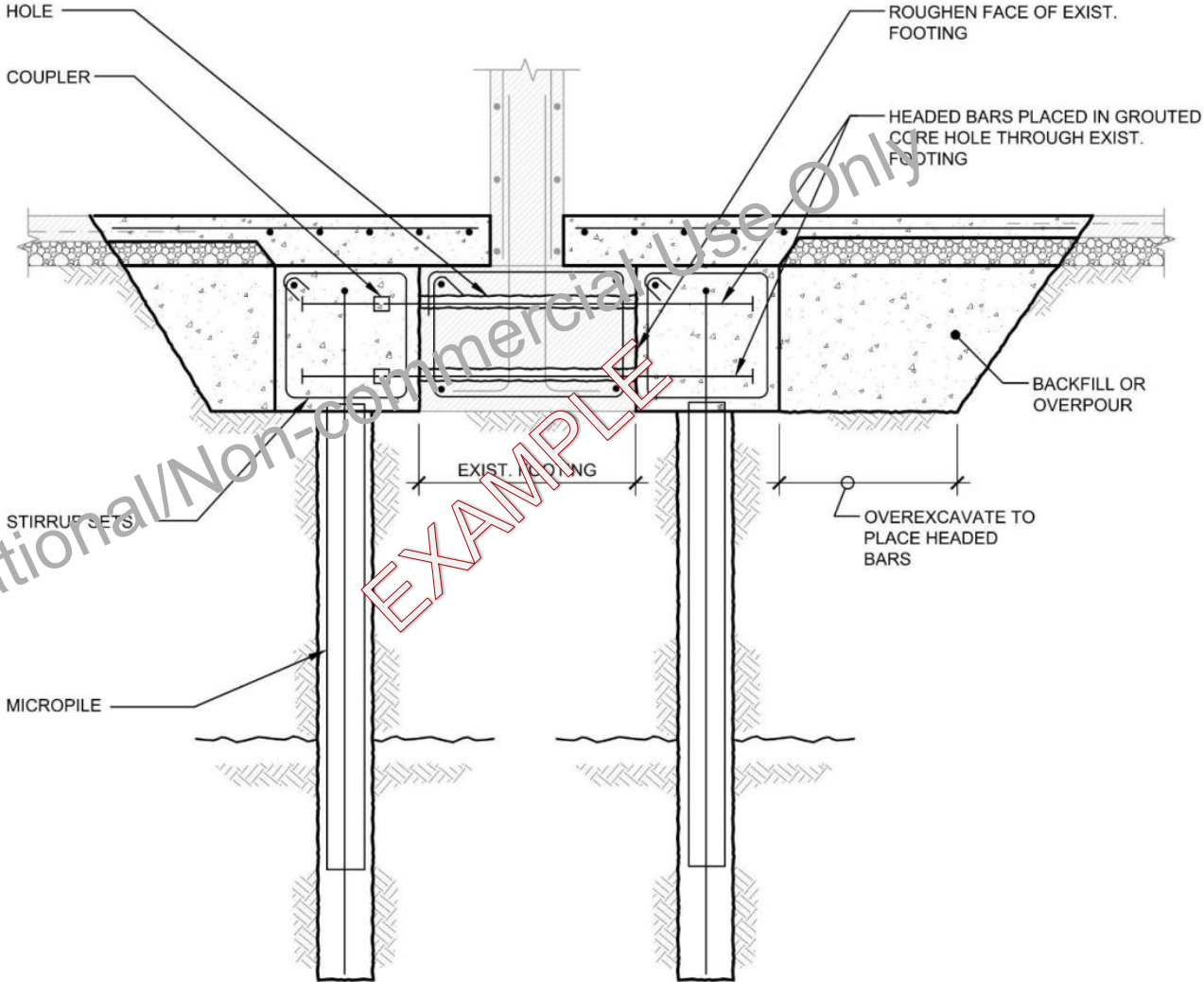


Figure 5.158: Addition of micropiles adjacent to existing strip footing

Upgrading of Foundations

Add micropiles adjacent to existing strip footings to **increase tension & compression capacity**

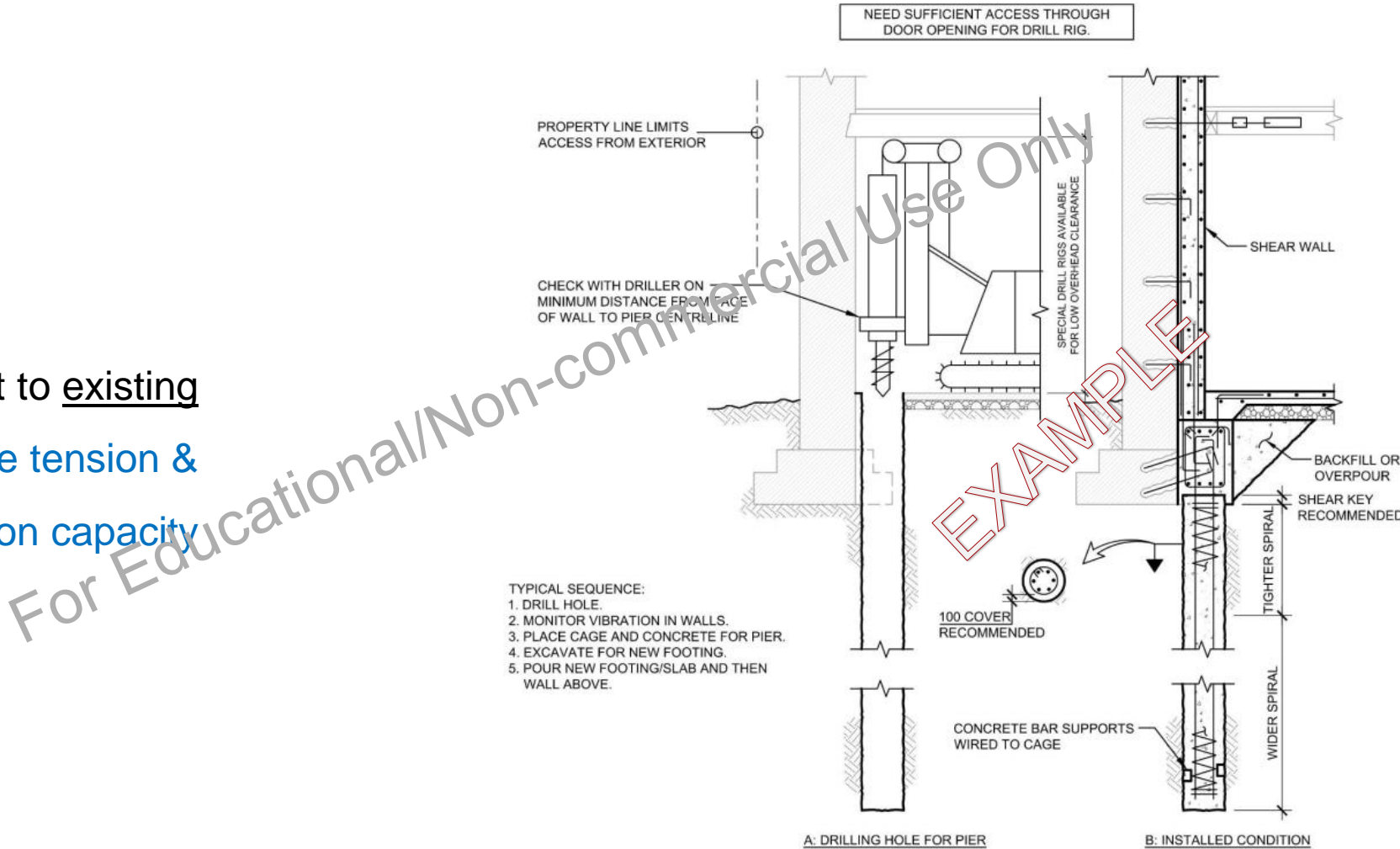


Figure 5.157: Addition of drilled piers next to existing strip footing

Upgrading of Foundations

Add top bars to existing pile cap to
increase uplift resistance

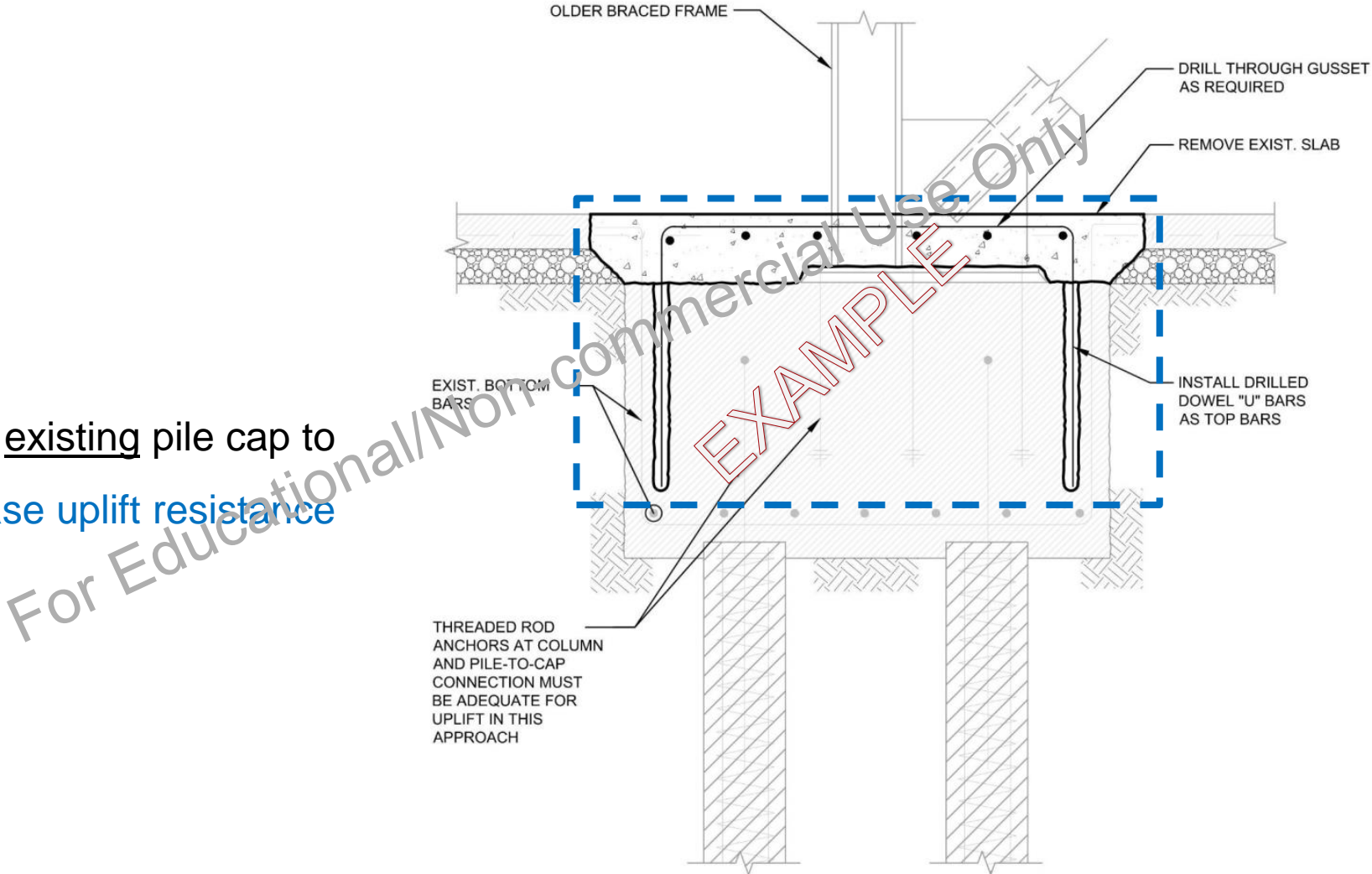


Figure 5.153: Addition of top bars to existing pile cap

Mitigation of Geologic Hazards

- Mitigation of liquefaction hazard
 - Lateral spreading
 - Densify or solidify existing liquefiable layer using compaction or permeation grouting or vibro-compaction
 - Installation of drainage and dewatering systems
 - Shallow foundation settlement
 - Underpin existing shallow foundation to transfer the superstructure loads to deeper, non-liquefiable layers
 - Use grade beams between isolated footings to increase foundation stiffness



Mitigation of Geologic Hazards

- Mitigation of landslide hazard
 - Modification of slope geometry (if possible)
 - Buttressing
 - Installation of drainage systems
 - Use of retaining walls
 - Soil nailing or anchor systems
 - Use of a debris wall
 - Soil modifications (e.g., grouting and densification for granular soils, and lime injection or electro-osmosis techniques for clayey soils)



Mitigation of Geologic Hazards

- Mitigation of fault rupture hazard
 - Move building away from the fault (if possible)
- Reduction of likelihood of severe damage
 - Strengthen structure and foundation using grade beams and/or reinforced slabs
 - Modify foundation to reduce angular distortion by distributing the effect of differential vertical movement over a larger foundation area



Reduction of Seismic Demand

- Reduction of seismic weight
 - Remove heavy roofing, flooring or equipment if only small reduction in seismic demand is required
 - Remove upper floors (if possible) if a large reduction in seismic demand is required
- Reduction of seismic demand
 - Install seismic isolation system and/or supplemental energy dissipation system



Mitigation of Non-structural Hazards

1. Exterior and Interior Walls (NBC 4.1.8.18 – Category 1)

Install steel angles tight to each side of existing heavy partition wall to **restrain out-of-plane movement**

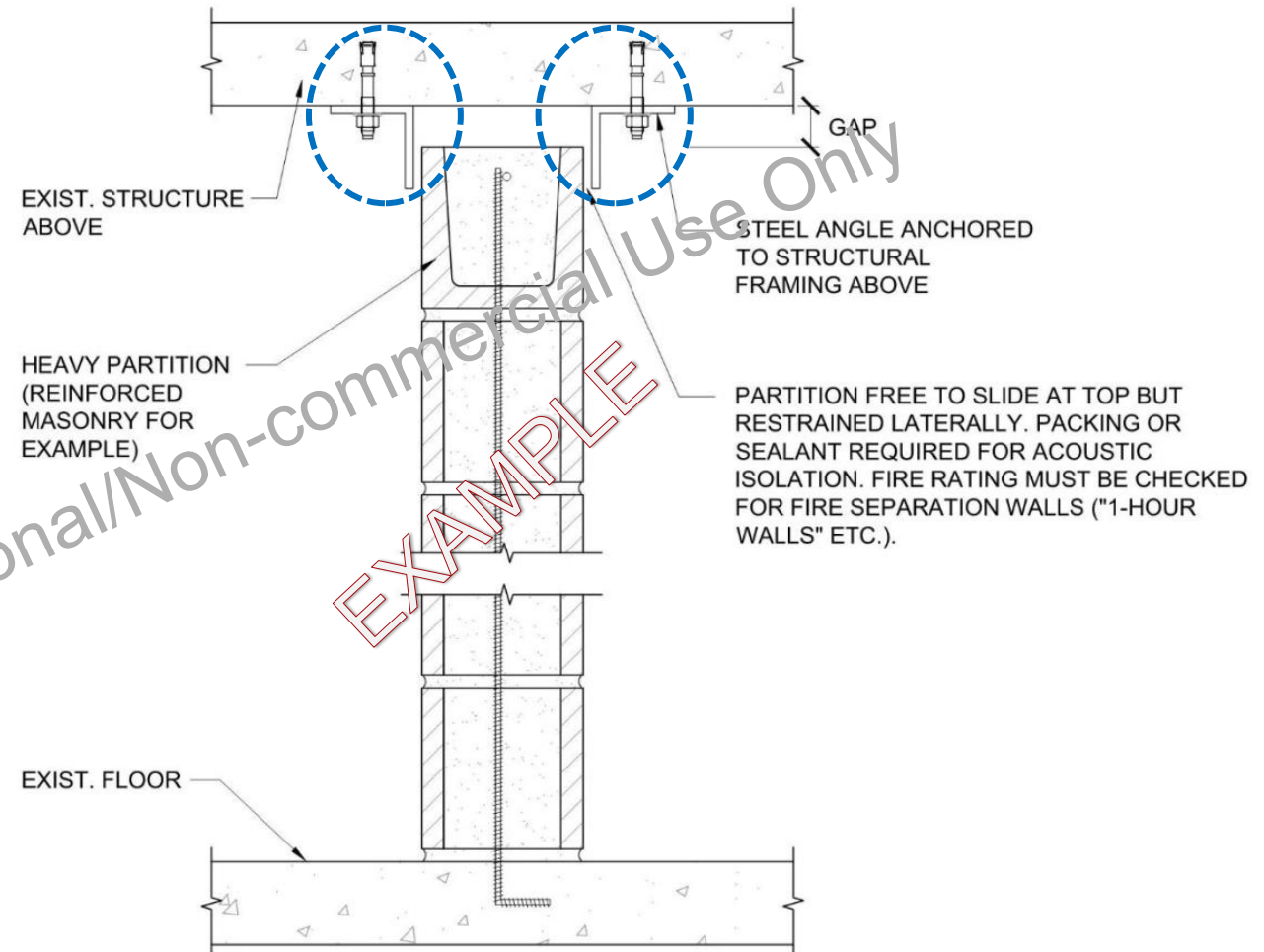


Figure 5.160: Out-of-plane bracing of existing full height heavy partition wall

Mitigation of Non-structural Hazards

2. Cantilever parapets and other cantilever walls (NBC 4.1.8.18 – Category 2)

Install vertical steel member to existing URM parapet to mitigate falling hazard

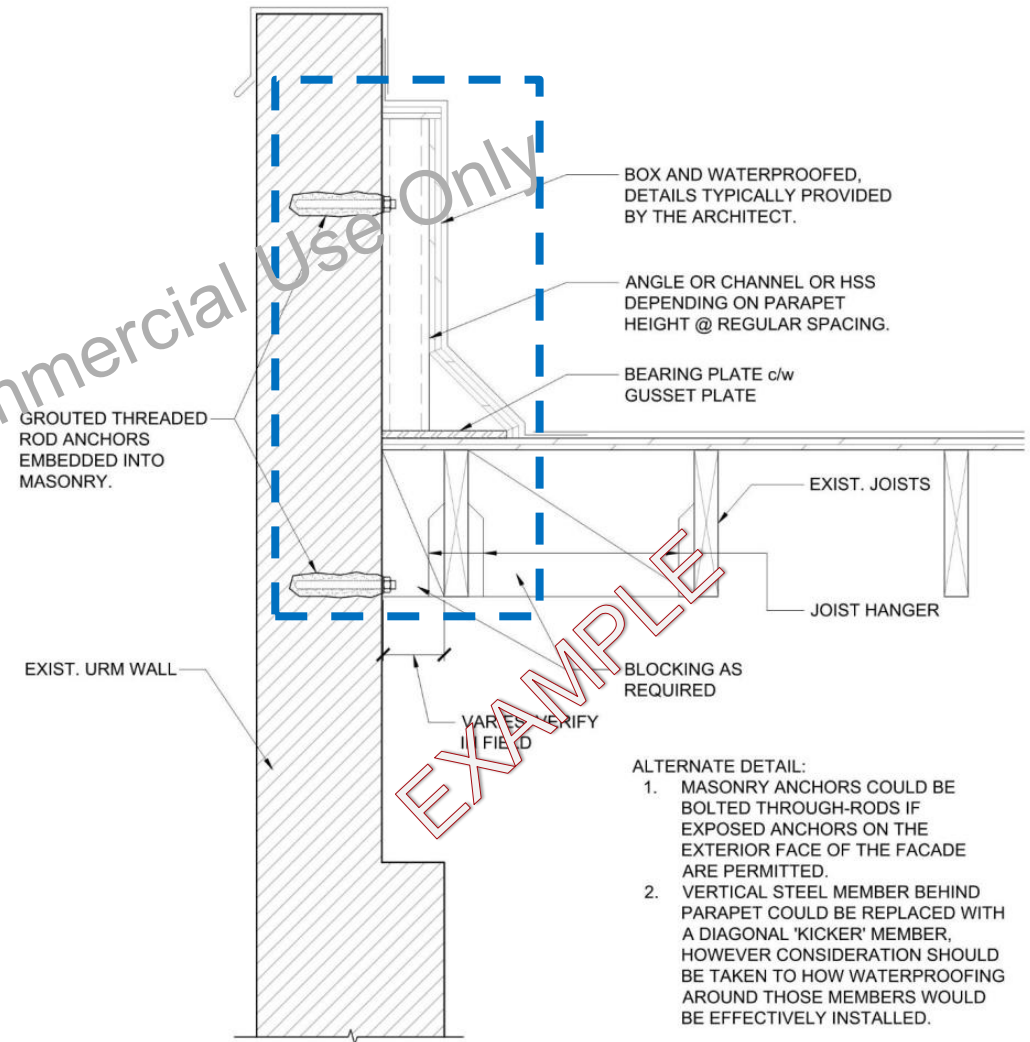


Figure 5.165: Out-of-plane bracing for URM parapet

Mitigation of Non-structural Hazards

3. Towers, chimneys, smokestacks and penthouses
(NBC 4.1.8.18 – Category 5)

Install steel straps to connect existing URM chimney to structure at roof level and each floor level to mitigate falling hazard

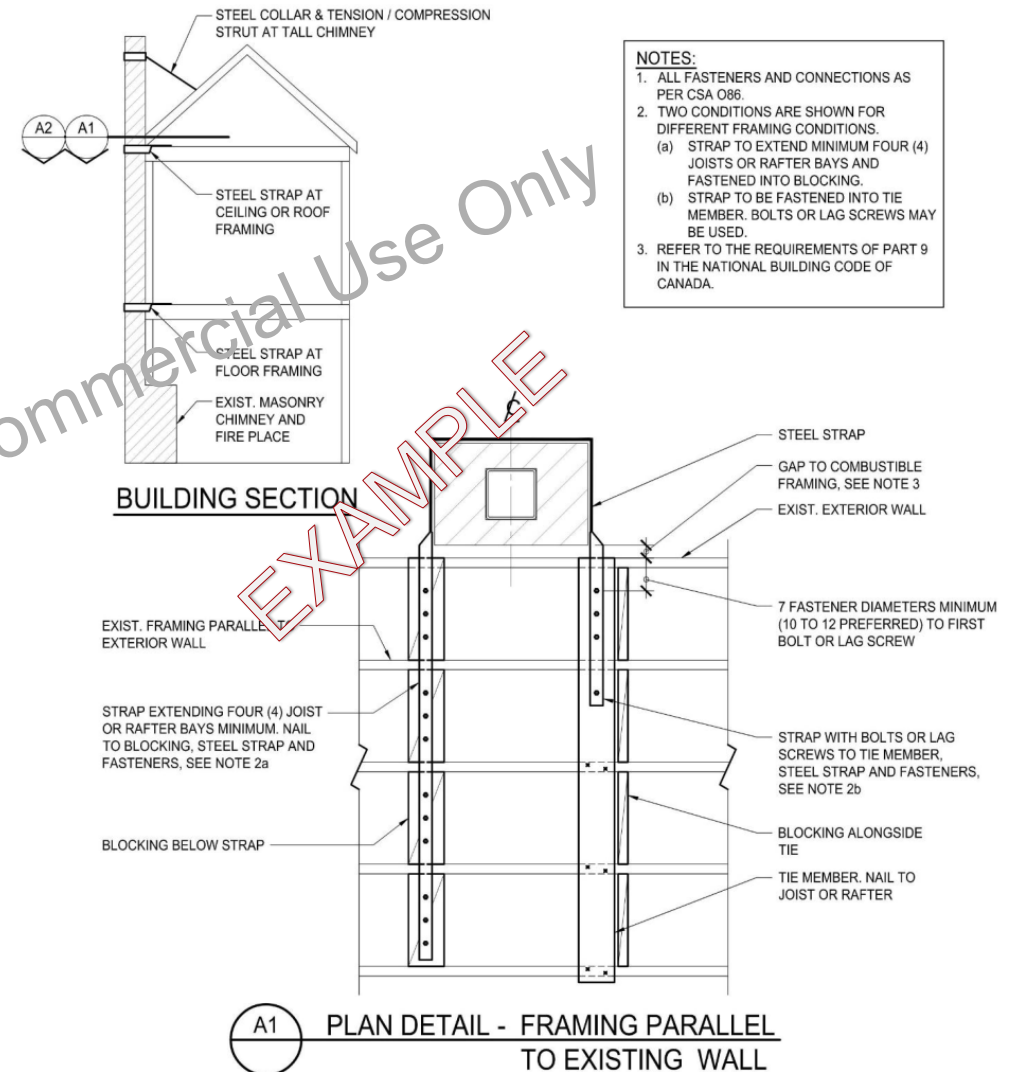


Figure 5.169: Bracing of URM chimney – framing parallel to wall

Mitigation of Non-structural Hazards

- Machinery, fixtures, equipment and tanks
(NBC 4.1.8.18 – Category 11)

Install cable/rigid brace to mitigate falling hazard

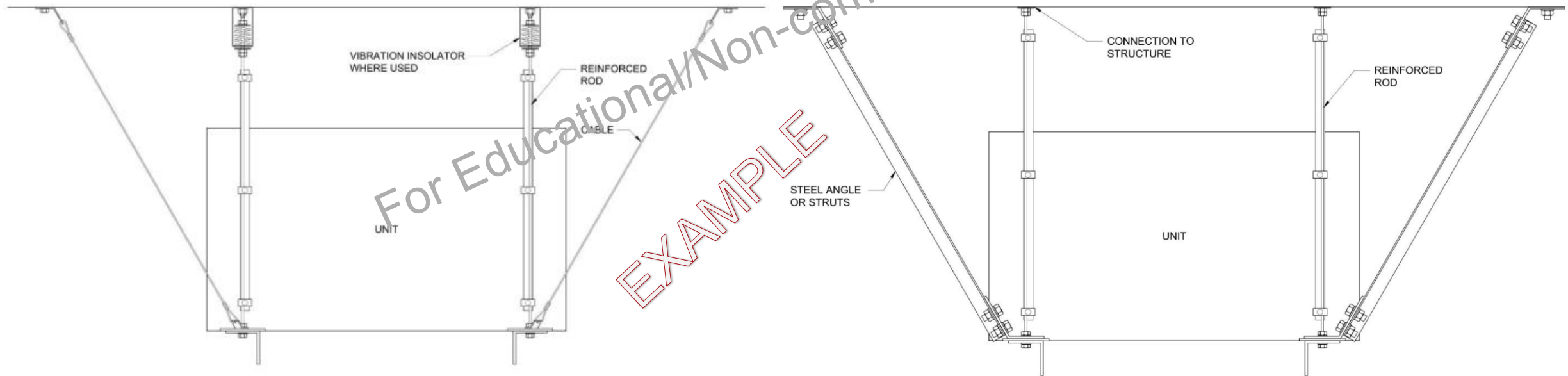


Figure 5.181: Bracing of suspended equipment with cable bracing

Figure 5.182: Bracing of suspended equipment with rigid bracing

Mitigation of Non-structural Hazards

5. Pipes and ducts containing toxic or explosive materials
(NBC 4.1.8.18 – Category 16)

Install bracing system to prevent the release of hazardous materials

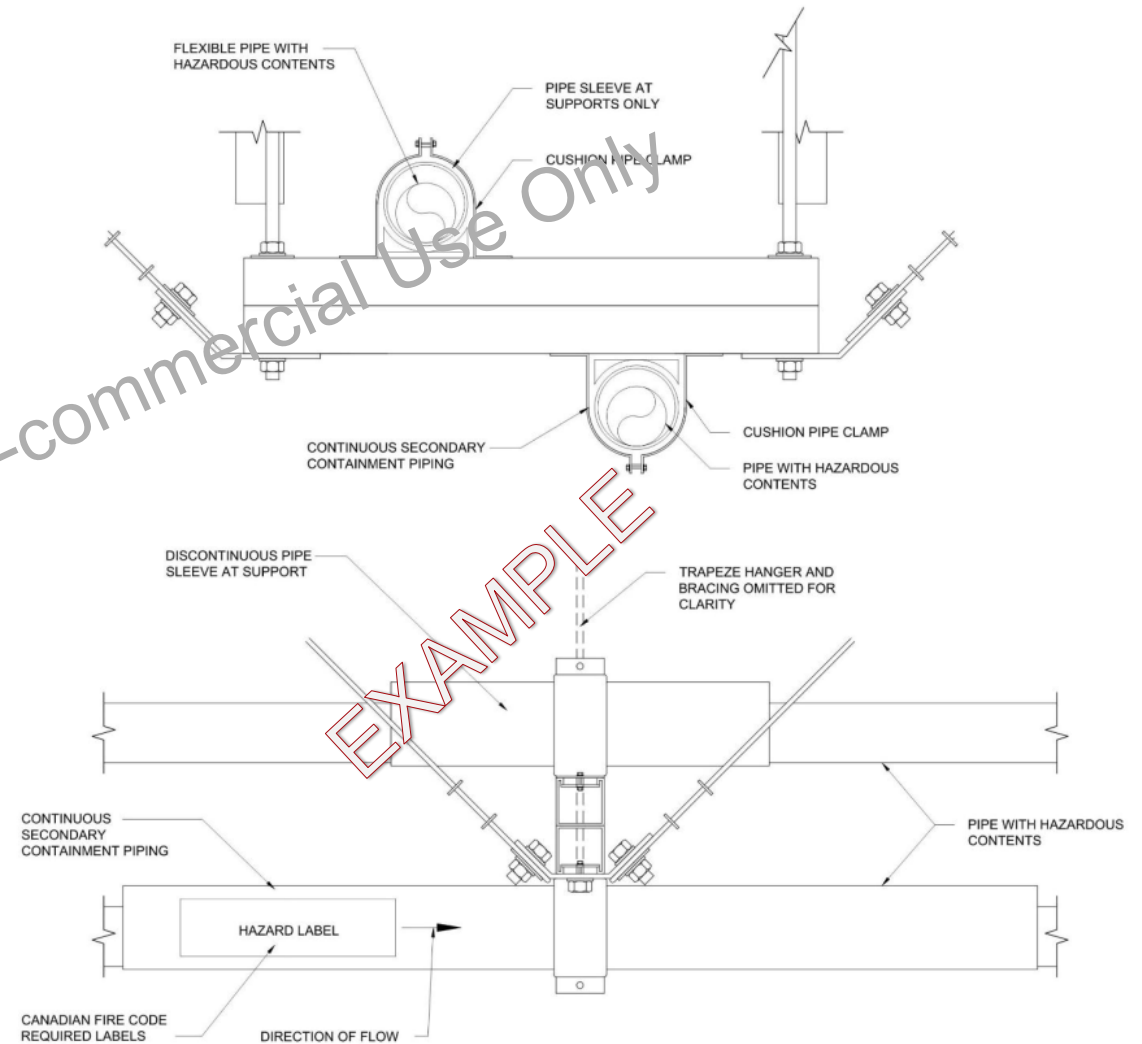
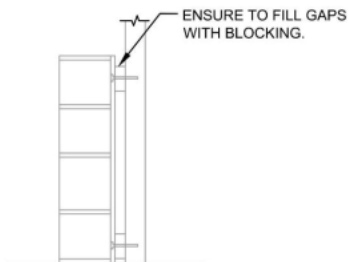
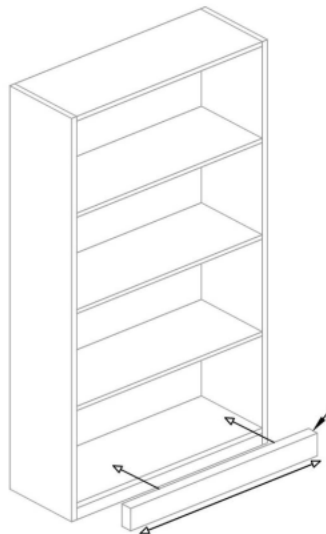


Figure 5.198: Bracing for hazardous piping

Anchorage/Bracing of Building Contents

NOTE:
ENGINEERING REQUIRED FOR ALL PERMANENT
FLOOR-SUPPORTED CABINETS OR SHELVING.

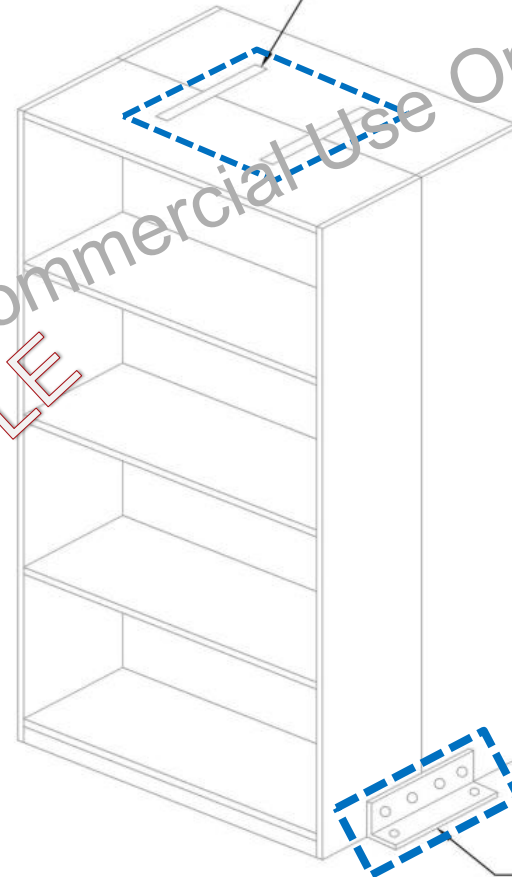
- TOP ANCHORAGE:
- ANGLE FRAMING ANCHORED TO STUDS/
SHELF OR STRUCTURAL WALL FRAMING.
 - FASTEN IN MIN. 2 LOCATIONS



- BASE ANCHORAGE:
- ANGLE FRAMING ANCHORED TO
FLOOR STRUCTURE.
 - FASTEN IN MIN. 2 LOCATIONS

NOTE:
ENGINEERING REQUIRED FOR ALL PERMANENT
FLOOR-SUPPORTED CABINETS OR SHELVING.

- TOP TIES:
- SECURE TOGETHER WITH STEEL PLATES
 - OPTION TO BOLT TOGETHER THROUGH BACKS
 - FASTEN IN MIN. 2 LOCATIONS



- BASE ANCHORAGE:
- GANG TOGETHER WITH ANGLE FRAMING
ANCHORED TO FLOOR STRUCTURE
 - FASTEN IN MIN. 2 LOCATIONS

Figure 5.202: Anchorage of bookshelf to existing wall

Figure 5.203: Anchorage of freestanding bookshelf

Summary

Key Takeaways

- Seismic upgrading principles (upgrading categories, upgrading techniques and key considerations)
- Seismic upgrading methodology (force-based + performance-based)
- Deficiency-Based Upgrading (linear analysis → address identified deficiencies + evaluate overall compliance)
- Detailed Upgrading (linear + non-linear analysis → evaluate all elements and components)
- Upgrading techniques (conventional & innovative, structural & non-structural)
- 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. (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 & 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

