Development of quick seismic evaluation procedure for existing buildings in Canada

By

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Abstract

The National Research Council Canada (NRC) is currently developing seismic evaluation and upgrading guidelines for existing buildings in Canada. The seismic evaluation guidelines consist of three tiers of seismic evaluation procedures, i.e., Tier 1 Quick Evaluation, Tier 2 Deficiency-Based Evaluation, and Tier 3 Detailed Evaluation. This paper presents the Tier 1 Quick Evaluation procedure, which aims to update the initial quick evaluation procedure in the existing seismic evaluation guidelines developed by the NRC in early 1990s. The proposed procedure covers seismic assessment of both structural and non-structural elements, and requires the review of construction documents, on-site inspection, and calculations. A set of checklists are contained to uncover potential key seismic deficiencies of the building under evaluation. The checklists are in the form of evaluation statements that relate to potential seismic deficiencies in the structural systems and non-structural components. The proposed procedure is demonstrated by conducting the seismic evaluation of an existing building that is part of a pilot study.

Keywords: seismic evaluation, quick evaluation, seismic deficiency, life safety objective, existing buildings.

1. Introduction

Earthquakes are one of the most disastrous natural phenomena that can cause significant casualties and monetary losses. Past major earthquakes have shown that buildings designed to conform to older seismic provisions may be inadequate to resist the seismic effects applied on them. Therefore, there has been a growing need to assess the seismic adequacy of existing buildings. To address this need, the National Research Council Canada (NRC) developed a series of technical guidelines for seismic screening (NRC 1993a), seismic evaluation (NRC 1993b), and seismic upgrading (NRC 1995a) of existing buildings, based on the 1990 edition of the National Building Code of Canada – NBC (NRC 1990). More than two decades later, the seismic requirements in the NBC 2015 (NRC 2015a) have become more stringent. There is a clear need to update these guidelines to be compatible with the NBC 2015. To this end, the NRC developed a multi-criteria and multi-level framework for seismic risk management of existing buildings in Canada (Lounis et al. 2016; Fathi-Fazl et al. 2020a), which includes three levels of seismic assessment: (i) Level 1 – Preliminary Seismic Risk Screening Tool (PST) (Fathi-Fazl et al. 2018; Fathi-Fazl et al. 2020b; Fathi-Fazl et al. 2020c), (ii) Level 2 – Semi-Quantitative Seismic Risk Screening Tool (SQST) (Fathi-Fazl et al. 2020d; Fathi-Fazl et al. 2020e; Cortés-Puentes et al. 2021; Fathi-Fazl et al. 2021a; Fathi-Fazl et al. 2022a), and (iii) Level 3 – Seismic Evaluation and Upgrading Guidelines (SEG) (currently under development). This framework ensures a consistent and acceptable seismic risk while minimizing the cost to perform seismic assessment of an inventory of buildings.

This paper presents an overview of the quick seismic evaluation procedure that is designed to be Tier 1 of the three-tired evaluation procedures in Level 3 – SEG. It is intended as an economical tool to identify potential key seismic deficiencies that require further seismic evaluation (i.e., Tier 2 Deficiency-Based Evaluation or Tier 3 Detailed Evaluation). Unlike Tier 2 (Fathi-Fazl et al.

2022c) and Tier 3 (currently under development) procedures that require comprehensive structural modelling and analysis, the Tier 1 Quick Evaluation procedure is limited to hand calculations using a set of quick checks. To facilitate the application of the Tier 1 procedure, the calculations of loads and resistances have been made compatible with the NBC 2015 and relevant CSA structural design standards. In the following sections, existing seismic evaluation methodologies around the world are reviewed first, after which the Tier 1 procedure is presented and demonstrated by applying it to an existing building that is part of a pilot study.

2. Review of existing seismic evaluation methodologies

The development of seismic evaluation methodologies dates back to the 1970s (GSA 1976; JBDPA 1977; Aoyama 1981; Hirosawa 1981; ATC-14 1987). Since then, substantial work has been done in the field of seismic evaluation of existing buildings (Priestley 1997; Holmes 2000; Lupoi et al. 2004). Many seismic evaluation standards and guidelines have been developed based on the state of the art and state of the practice (NRC 1993b; NRC 2015b; EGBC 2017; ASCE/SEI 41-17 2017; JBPDA 2001; NZSEE 2017) and applied to evaluate the seismic adequacy of existing buildings (Al-Washali et al. 2017; Balazadeh-Minouei et al. 2017; Harris and Speicher 2018). This section reviews several main seismic evaluation methodologies around the world and compares them with respect to several key aspects.

2.1. Canada

2.1.1. NRC Seismic Evaluation Guidelines

The 1993 NRC seismic evaluation guidelines (NRC 1993a) were developed based on "NEHRP Handbook for Seismic Evaluation of Existing Buildings" (FEMA 178 1992) and "A Handbook for

Seismic Evaluation of Existing Buildings (Preliminary)" (ATC-22 1989). The guidelines deal with life safety objectives and do not address other objectives more stringent than life safety. They are recommended as an alternative to the NBC 1995 Commentary K for seismic evaluation and upgrading of existing buildings (Allen and Rainer 1995).

The 1993 NRC seismic evaluation guidelines were made compatible with the NBC 1990 seismic provisions that were written for the design of new buildings. A reduction factor of 0.6 was applied to the lateral seismic forces on a building (including structure and non-structural components). The reduction is mainly due to economic and social factors (Allen 1991; Allen and Rainer 1995). Note that vertical seismic effects are not considered in the NBC 1990. To maintain the consistency with the NBC 1990, these effects are not considered in the guidelines. The methodology in the guidelines is centered on a set of questions that were designed to uncover the flaws and weaknesses of a building that could threaten life safety. The questions are in the form of positive evaluation statements that describe characteristics of the building type that are essential in avoiding the failures observed in past earthquakes. The evaluating engineer addresses each statement and determines whether it is true or false. "True" statements identify conditions that are acceptable, while "False" statements identify issues or concerns that need further investigation. The guidelines specify a procedure for dealing with false statements. A building is deemed seismically adequate if all applicable evaluation statements are satisfactorily answered.

2.1.2. NBC Commentary L

The first edition of the Commentary L was published in User's Guide – NBC 1995 Structural Commentaries (Part 4) (NRC 1995b) under section "Application of NBC Part 4 of Division B for the Structural Evaluation and Upgrading of Existing Buildings". In this commentary, different load factors were introduced for different load cases (i.e., dead, live, snow, wind, and earthquake) depending on applicable reliability levels (NRC 1995b). A single earthquake load factor of 0.6 (adopted from the 1993 NRC seismic evaluation guidelines) was introduced for all reliability levels and remained unchanged in the subsequent 2005 and 2010 editions (NRC 2005; 2010). The NBC 2015 Commentary L (NRC 2015b), however, provides new suggestions to perform the assessment/upgrading of existing buildings. A detailed review of the procedure in the NBC 2015 Commentary L can be found elsewhere (Fathi-Fazl et al. 2019). In this commentary, four levels of seismic hazards are defined for the renovation, evaluation, and upgrade of existing buildings:

- Level 1: This hazard level corresponds to 0.5 times the seismic hazards with 5% probability of exceedance (POE) in 50 years and is defined for minimum voluntary seismic upgrade of existing buildings not undergoing renovations/additions. Note that Commentary L does not provide POE of Level 1 seismic hazard.

- Level 2: This hazard level corresponds to seismic hazards with 10% POE in 50 years and is defined for significant renovation extending the life of a building or minor addition to it (either vertical or horizontal).

- Level 3: This hazard level corresponds to seismic hazards with 5% POE in 50 years and is defined for seismic upgrade of buildings that require significant renovation extending the life of a building or minor addition to it (either vertical or horizontal) but do not comply with Level 2 seismic hazard level.

- Code level: This hazard level corresponds to seismic hazards with 2% POE in 50 years and is defined for seismic upgrade of non-structural components.

Unlike the 1993 NRC seismic evaluation guidelines that provide a set of evaluation statements to assist evaluating engineers in identifying potential deficiencies in existing buildings, the NBC 2015 Commentary L requires comprehensive modelling and analysis to determine the seismic forces and drifts for the applicable hazad level.

Note that the NBC 2015 Commentary L does not provide information about the ratios of various seismic hazard levels to the Code level. Fathi-Fazl et al. (2019) conducted a study to investigate the ratio of each level of seismic hazard to the Code level. The ratios of the three levels of seismic hazards (i.e., Level 1 to Level 3 seismic hazards) to the Code level seismic hazards were calculated for 679 locations provided in Appendix C of Division B in the NBC 2015. The results showed that, on average, the three levels of seismic hazards in the NBC 2015 Commentary L corresponded to 30%, 40%, and 60% of the Code level seismic hazards, respectively. It is also found that 60% for Level 3 seismic hazard is equal to the earthquake load factor of 0.6 used in the 1993 NRC seismic evaluation guidelines and previous editions of Commentary L.

2.1.3. EGBC Seismic Retrofit Guidelines

Engineers and Geoscientists British Columbia (EGBC) published the first edition of Seismic Retrofit Guidelines (SRG) in 2011 (EGBC 2011) and revised it later in 2013 and 2017 (EGBC 2013; 2017). The SRG aims to reduce the overall seismic risk of low-rise school buildings in British Columbia.

The SRG adopts a rigorous probabilistic risk analysis methodology that assesses the seismic performance (i.e., probabilities of drift exceedance) of existing low-rise school buildings by combining the seismic hazard results from probabilistic seismic hazard analysis and conditional probability of drift exceedance results from incremental dynamic analyses.

2.2. United States

In 1987, the Applied Technical Council (ATC) developed the "Evaluating the Seismic Resistance of Existing Buildings" guidelines (ATC-14 1987) based on the state of the art and the state of the practice. It provides a consensus-based methodology, aiming to guide engineers throughout the U.S. in evaluating existing buildings to determine potential earthquake hazards and identify buildings or building components that present unacceptable risk to human lives.

Since the inception of the ATC-14 report, the methodology for seismic evaluation of existing buildings has evolved to become part of the current edition of "Seismic Evaluation and Retrofit of Existing Buildings" (ASCE/SEI 41-17 2017). It has been an integral part of ATC-22 (1989), FEMA 178 (1992), "Handbook for the Seismic Evaluation of Buildings – A Prestandard" (ASCE 1998), "Seismic Evaluation of Existing Buildings" (ASCE/SEI 31-03 2003), and "Seismic Evaluation and Retrofit of Existing Buildings" (ASCE/SEI 41-13 2013).

ASCE/SEI 41-17 adopts a performance-based methodology to evaluate the seismic performance of existing buildings. Specifically, it defines a matrix of structural and non-structural performance levels at specifically defined seismic hazard levels for buildings of different risk categories. The building performance is directly related to the extent of damage that would be sustained by the building and its systems in the seismic event. Two levels of seismic hazards, i.e., Basic Safety Earthquake-1 (BSE-1E) with 20% POE in 50 years and Basic Safety Earthquake-2 (BSE-2E) with 5% POE in 50 years, are defined for use with the Basic Performance Objective for Existing Buildings.

ASCE/SEI 41-17 includes three tiers of evaluation and retrofit procedures for existing buildings, including: (i) Tier 1 Screening, (ii) Tier 2 Deficiency-Based Evaluation and Retrofit, and (iii) Tier

3 Systematic Evaluation and Retrofit. Specifically, the Tier 1 Screening procedure contains a list of checklists that are completed by evaluating engineers. Each checklist includes a set of evaluation statements that identify potential key seismic deficiencies in existing buildings. A set of quick checks are included to assist evaluating engineers in calculating components' seismic demands and capacity. It should be noted that the Tier 1 Screening procedure adopts a displacement-based approach to calculate seismic demands, which is different from the force-based approach adopted by ASCE/SEI 7-16 (2016) for the design of new buildings. In addition, the Tier 1 Screening procedure takes resistance factors as 1.0 to calculate components' capacity.

2.3. Japan

The Japanese Building Disaster Prevention Association (JBDPA) published the first edition of "The Standard for Seismic Evaluation of Existing Reinforced Concrete Buildings" in 1977 (JBPDA 1977) and revised it later in 1990 and 2001 (JBPDA 1990; 2001). The JBDPA Standard aims to evaluate existing low-rise and mid-rise reinforced concrete buildings. The evaluation process consists of three levels of screening procedures, which may be used in accordance with the purpose of evaluation and the structural characteristics of the building.

The seismic performance of the structure is evaluated in terms of a qualitative seismic risk index of structure, I_S, which is determined as follows:

$$I_s = E_0 \cdot S_D \cdot T \tag{1}$$

where E_0 is the basic structural performance sub-index, S_D is the structural design of the building sub-index, and T is the time dependent deterioration of the building sub-index.

The I_S index is compared with a seismic demand index, I_{SO}, to judge the seismic safety of the building. I_{SO} is a function of the level of screening, the seismicity, the soil condition, and the occupancy of the building. The building is considered safe when $I_S \geq I_{SO}$.

2.4. New Zealand

In 2017, the New Zealand Society for Earthquake Engineering (NZSEE) published "The Seismic Assessment of Existing Buildings" guidelines (NZSEE 2017) to supersede the guidelines "Assessment and Improvement of the Structural Performance of Buildings in Earthquakes" that were released in 2006 (NZSEE 2006). The NZSEE 2017 guidelines consist of a qualitative Initial Seismic Assessment (ISA) method and a more extensive and quantitative Detailed Seismic Assessment (DSA) method.

The ISA method is intended to be the first step in the overall seismic assessment process to develop a holistic understanding of the building seismic performance. It includes an Initial Evaluation procedure that is completed by evaluating engineers based on the information collected in the office and on-site inspection and supplementary calculations as required. An earthquake rating %NBS [percentage achieved compared with requirements for a new building] is used to indicate the earthquake performance of an existing building. A building with a %NBS of less than 34 is identified as earthquake-prone. A %NBS of 34 or greater means that the building is outside the requirements of the earthquake-prone provisions. A %NBS of 67 or greater indicates that the building should not pose a significant earthquake risk.

The DSA method aims to provide a more reliable and consistent outcome in terms of %NBS by quantifying the strength and deformation capacities of the various structural elements and by checking the building structural integrity against the loads/deformations that would be used for the design of a similar building on the same site. The DSA can be performed with different levels of detail depending on the assessment scope and objectives. A building is identified as an earthquake risk building if its %NBS is less than 67.

2.5. Observation from existing seismic evaluation methodologies

Table 1 presents a comparison of existing seismic evaluation standards and guidelines reviewed in previous sections. The comparison aims to summarize the differences and similarities between existing seismic evaluation standards and guidelines with respect to several key aspects to be considered in the seismic evaluation. Note that the 1993 NRC seismic evaluation guidelines have never been updated. The NBC 2015 Commentary L suggests four seismic hazard levels for the seismic assessment and upgrading of existing buildings. The rationale for such suggestions, however, is not provided (Metten et al. 2019). In addition, it does not provide a cost-effective preliminary evaluation procedure that is comparable to the initial quick evaluation procedure in the 1993 NRC seismic evaluation guidelines. The EGBC SRG was developed for low-rise (one to three storeys) school buildings in British Columbia. This limits its potential to become nation-wide guidelines for all existing buildings in Canada. The Tier 1 Screening procedure in ASCE/SEI 41-17 adopts a performance-based approach that is different from the prescribed force-based approach in ASCE/SEI 7-16 and the NBC 2015 and thus does not directly apply to the Canadian context. Nevertheless, it is beneficial to make use of its organization of checklists to develop the checklists in the proposed procedure presented in this paper. The JBDPA standard adopts a qualitative index approach to evaluate the adequacy of existing buildings, which is more appropriate to be used in the screening phase. The IEP procedure in ISA of NZSEE 2017 guidelines also adopts a qualitative approach to determine the percentage new building standard (%NBS), which is not considered in the development of the proposed procedure that is to be based on a quantitative approach.

Based on the review of existing seismic evaluation methodologies, it is judged more appropriate to update the initial quick evaluation procedure in the 1993 NRC seismic evaluation guidelines to be compatible with the NBC 2015 seismic provisions and relevant CSA structural design standards and to incorporate beneficial features from more recent seismic evaluation methodologies.

3. Highlights of the Quick Evaluation procedure

The Quick Evaluation procedure presented in this paper aims to update the initial quick evaluation procedure of the 1993 NRC seismic evaluation guidelines. The proposed procedure is designed to provide evaluating engineers with an economic tool to identify potential key seismic deficiencies that require further seismic evaluation (i.e., Tier 2 Deficiency-Based Evaluation or Tier 3 Detailed Evaluation). The main differences and updates with respect to the initial quick evaluation procedure are summarized as follows:

- The limit states criteria have been made consistent with the NBC 2015 and relevant CSA structural design standards.
- Building seismic categories are defined to describe various seismicity levels.
- A list of conditions that trigger Tier 3 Detailed Evaluation are introduced.
- Benchmark NBC editions are introduced to identify post-benchmark buildings that are eligible to be exempted from structural seismic evaluation.
- A set of earthquake load factor matrices are proposed to determine reduced seismic base shear demands for seismic evaluation.
- A remaining occupancy time factor is introduced to account for the smaller probability in experiencing a Code level earthquake for buildings with remaining occupancy times not greate than 10 years.
- An additional step is introduced to assist evaluating engineers in selecting appropriate Quick Evaluation checklists based on the calculated estimated minimum seismic base shear capacity (V_E) and reduced seismic base shear demand for seismic evaluation (V_{QE}).

- A guidance is included to assist evaluating engineers in calculating V_E.
- The organization of evaluation statements has been modified based on a critical review of the Tier 1 Screening checklists in ASCE/SEI 41-17 (2017).
- The limits and thresholds that define the acceptance criteria in the evaluation statements associated with building configuration, seismic-force-resisting systems, connections, diaphragms, and non-structural components, have been updated based on a comprehensive review of the seismic requirements in the NBC 2015, the 1993 NRC seismic evaluation guidelines, CSA structural design and assessment standards, U.S. standards and guidelines, and other relevant studies.

4. Quick Evaluation procedure

The Quick Evaluation procedure is based on a set of checklists that are designed to identify potential key seismic deficiencies that require further seismic evaluation. The checklists are in the form of evaluation statements that relate to potential seismic deficiencies in the structural systems and non-structural components. The details of the checklists can be found elsewhere (Fathi-Fazl et al. 2021c). Evaluating engineers should address each statement in the applicable checklists and choose one of the following conditions: compliant (C), non-compliant (NC), not applicable (N/A), or unknown (U). Compliant statements identify the conditions that conform to the life safety objective, whereas non-compliant statements identify issues or concerns that could jeopardize it. A non-compliant statement does not necessarily imply that a complete structural or non-structural component evaluation is necessary, or that the building is automatically deficient; it simply flags an area of concern for the evaluating engineer and implies that a life safety hazard may exist. Non-applicable statements indicate conditions that do not exist in the building under evaluation. Unknown statements indicate conditions whose compliance cannot be identified due to a lack of information or a lack of building access. A follow-up site visit is recommended. A seismic deficiency is considered present if an evaluation statement is judged to be non-compliant or unknown.

The proposed procedure also contains a set of quick checks to assist evaluating engineers in determining demand parameters (e.g., axial stress and shear stress) and components' capacity. It should be noted that these quick checks are limited to hand calculations without involving comprehensive structural modeling and analysis.

A building is deemed compliant with the life safety objective if it is not found deficient through the proposed procedure. Building that are potentially deficient are flagged for further seismic evaluation (i.e., Tier 2 Deficiency-Based Evaluation or Tier 3 Detailed Evaluation). Note that the Tier 2 procedure has been recently developed by NRC (Fathi-Fazl et al. 2022b) and the Tier 3 procedure is currently under development by NRC.

The authors acknowledge that the content provided in this paper is not sufficient to guide the potential end users to conduct a quick evaluation. The intent of this paper is to provide an overview of the key elements of the proposed procedure and to illustrate the steps for conducting a quick evaluation. The detailed instructions for conducting a quick evaluation are provided in the guidelines recently developed by NRC (Fathi-Fazl et al. 2021c). In the following subsections, key elements and steps of the proposed procedure are presented and discussed.

4.1. Life safety objective

Life safety is one of the objectives defined in the NBC 2015. In the proposed procedure, the life safety objective is deemed non-compliant if one or more of the following occur during a seismic event: (1) the entire building collapses, (2) portions of the building collapse, (3) non-structural components that can pose life safety hazards fail and fall, and (4) means of egress is blocked, preventing the evacuation and rescue of the occupants.

The proposed procedure deals with the life safety objective and does not address other objectives more stringent than life safety. A building expected to achieve objectives more stringent than life safety (e.g., a post-disaster building or a building with a federal heritage designation) is still eligible for seismic evaluation using the proposed procedure, but only to determine whether the life safety objective is met or not.

4.2. Limit states criteria

The NBC and CSA structural design standards have introduced limit states design procedures for structural design since the 1970s. The criterion of the limit states design is expressed as the factored resistance is greater than or equal to the effect of factored loads, or

$$\phi R \geq \Sigma \alpha_i S_i \tag{2}$$

where ϕ is the resistance factor, R is the structural resistance, α_i is the load factor, and S_i represents the effect of a particular load.

4.2.1. Loads

The NBC 2015 adopts a force-based approach to quantify the effect of the earthquake load (E) based on seismic design base shear demand (V_N). The calculated V_N value is checked against the minimum and maximum limits prescribed in the NBC to obtain the minimum V_N value for design.

In the proposed procedure, a reduced seismic base shear demand for seismic evaluation, V_{QE}, is used to evaluate existing buildings, and is calculated as follows:

$$V_{QE} = \kappa \alpha_{QE} V_N \quad (3)$$

where κ is a remaining occupancy time factor accounting for the reduction in the probability of experiencing a Code level earthquake for a building with a remaining occupancy time not greter than 10 years. For remaining occupancy times of 5 years and 10 years, the values of κ are equal to 0.31 and 0.46, respectively. More technical details on the determination of κ values can be found in Fathi-Fazl et al. (2018; 2020c; 2020e). α_{QE} is reduced earthquake load factor for seismic evaluation. More details about the derivation of α_{QE} can be found in Lounis et al. (2016). The α_{QE} values range from 0.3 to 1.0 depending on the redundancy degree, inspection quality level, and consequence class. Greater α_{QE} values indicate less reduction of seismic base shear demands. α_{QE} should be taken as 1.0 when the building is used to provide post-disaster services, disregarding its redundancy degree, inspection quality level, and consequence class. It should be noted that the determination of α_{QE} as a function of redundancy degree, inspection quality, and consequence class is a unique feature in the proposed procedure.

4.2.2. Resistances

Resistances depend on material properties and dimensions of structural components. To maintain consistency with the CSA structural design standards, nominal material properties and resistance factors are used to determine structural resistances in the proposed procedure. The material properties may be obtained from one or more of the following sources: default values, structural drawings, or material tests. Default values are permitted to be used when there are structural drawings but material properties are unavailable in existing documentation. These values are mainly adopted from structural design standards and handbooks for construction in Canada. If structural drawings are unavailable, material testing must be undertaken to determine the material properties.

4.3. Limitations on the use of the proposed procedure

The proposed procedure is developed as a cost-effective tool to evaluate the potential key seismic deficiencies in existing buildings. The equivalent static force procedure in the NBC 2015 is adopted to calculate the seismic base shear demands. For that reason, some limitations are imposed where assessing seismic deficiencies requires detailed evaluation. The use of the proposed procedure is not recommended if any of the following conditions apply:

- **Building Defects and Deterioration**: In the proposed procedure, certain patterns of defects and deterioration as well as thresholds are developed based on similar restrictions in ASCE/SEI 41-17 (2017) for the use of Tier 1 analysis (Fathi-Fazl et al. 2021c). For these specific patterns, the use of the proposed procedure is not recommended.
- **Unknown Model Building Type**: When the model building type is not known, or the building is constructed using materials or systems not listed in Table 2, the use of the proposed procedure is not recommended. The model building types in Table 2 are mainly based on the 1993 NRC seismic evaluation guidelines (NRC 1993b).
- **Base Isolated Buildings or Buildings with Additional Damping**: The use of the proposed procedure is not recommended for these buildings as they dissipate energy through a mechanism with much higher damping than the 5% damping used in the proposed procedure.

- **Buildings Located on Site Class F**: Since the structural analysis of buildings located on Site Class F requires a site-specific seismic hazard analysis, the use of the proposed procedure is not appropriate.

- **Buildings Located on Sites with Geological Hazards**: Geological hazards such as fault rupture, liquefiable soils, or sloping sites pose site-specific demands on building structures. These demands require site-specific seismic hazard analysis. Therefore, the application of the proposed procedure is not appropriate.

Despite of the limitations above, building owners may still use the proposed procedure as a starting point to gain a better understanding of the potential key seismic deficiencies in their buildings.

4.4. Quick Evaluation process

The process for Quick Evaluation is shown in Figure 1, where the steps and terminology are explained in detail in the following sub-sections.

4.4.1. Building information collection

This Quick Evalution process starts with the collection of information about the building, including the characteristics of the building and the site where it is located. The information is collected by reviewing available documentation and other records and by conducting a site visit. The site visit is intended to verify the general conformance of existing conditions to those described in available documents, identify the material conditions, and collect the information needed to complete the applicable Quick Evaluation checklists.

4.4.2. Building exemption from Level 3 – SEG

In the absence of all the conditions that trigger Tier 3 Detailed Evaluation, the building site category (BSC) where the building is located is determined using Table 3. The BSC is defined in terms of the product of importance factor (I_E) and the design spectral response accelerations at short ($S(0.2)$) and long periods (S(1.0)). Consistent with Level 1 – PST and Level 2 – SQST, buildings located in BSC0 (very low seismicity) are exempted from further evaluation. This criterion has been validated by quantifying the life safety risk using Level 2 – SQST (Fathi-Fazl et al. 2018; Fathi-Fazl et al. 2020c; Fathi-Fazl et al. 2020e).

4.4.3. Building exemption from structural seismic evaluation

If a building is identified as a post-benchmark building, it is eligible to be exempted from structural seismic evaluation and only the Non-Structural Checklist needs to be completed. A post-benchmark building refers to a building which was designed or upgraded to an applicable benchmark NBC edition in which significantly improved seismic requirements were adopted and enforced (Fathi-Fazl et al. 2018; 2021b; 2022a). The benchmark NBC editions for the model building types in Table 2 can be found in Fathi-Fazl et al. (2021b; 2022a). The criterion of exempting post-benchmark buildings from structural seismic evaluation is consistent with Level 1 – PST and other seismic evaluation standards and guidelines such as ASCE/SEI 41-17 (2017) and NIST GCR 11-917-12 (2011).

4.4.4. Building height limits on the use of the proposed procedure

The proposed procedure was developed for buildings not exceeding certain building height limits as shown in Table 4. These building height limits do not apply to post-benchmark buildings because these buildings are exempted from structural seismic evaluation. The building height limits in Table 4 are primarily based on the building height limits applied to different Seismic Force Resisting Systems (SFRS) in the NBC, with the consideration of consequence class. It is noted that the definitions of model building types do not differentiate the level of ductility. For simplicity and practicality, the building height limits for buildings with Consequence Class – Low (CC-L) and – Medium (CC-M) are conservatively recommended based on the conventional design assumption. This recommendation is made as the existing buildings were constructed mostly based on older material standards with inadequate seismic detailing requirements compared to those in current standards. More stringent building height limits are applied to existing buildings with CC-H, expecting to achieve a higher level of accuracy when using the equivalent static force procedure.

4.4.5. Low Seismicity Checklist

For buildings with CC-L and CC-M located in BSC1 (low seismicity) as shown in Table 3, only the Low Seismicity Checklist needs to be completed. The Low Seismicity Checklist only checks for the existence of a clear defined load path for lateral loads, and anchorage of concrete or masonry walls to diaphragms for out-of-plane forces, as these two are major seismic deficiencies that can pose life safety hazards in existing buildings located in low seismicity areas. The out-of-plane force is calculated as follows:

$$T_c = \psi \alpha_{QE} S(0.2) w_p A_p \qquad (4)$$

Where ψ equals 1.0 for buildings of CC-L or CC-M and 1.3 for buildings of CC-H, α_{QE} is the reduced earthquake load factor, $S(0.2)$ is the design spectral response acceleration at short period (0.2 seconds), w_p is the unit weight (kN/m^2) of the wall, and A_p is the area (m^2) of the wall tributary to the connection.

4.4.6. Existing building capacity

In the proposed procedure, the estimated minimum seismic base shear capacity (V_E) of the building is determined based on the requirements of the NBC edition used for the design or upgrade of the building. This calculation is conservative because the building should have higher seismic base shear capacity due to the conservatism embedded in the design procedure. V_E is determined according to the following equation:

$$V_E = \alpha_Q V_D \tag{5}$$

Where α_Q is the adjusted earthquake load factor which corresponds to the NBC edition that was used to design or upgrade the building (see Table 5), and V_D is the minimum seismic design base shear as per the NBC to which the building was originally designed or fully upgraded.

4.4.7. Selection of appropriate Quick Evaluation checklists

The proposed procedure provides a guidance on selecting appropriate Quick Evaluation checklists to be completed. This is a unique feature of the proposed procedure compared with existing seismic evaluation standards and guidelines. The selection is based on comparing the existing building capacity (V_E) with seismnic demands. The Quick Evaluation checklists are selected according to the following scenarios:

- For cases where $V_E < 0.3\kappa V_N$, flag the building for Tier 3 Detailed Evaluation without completing the Quick Evaluation checklists.
- For cases where $0.3\kappa V_N \leq V_E < V_{QE}$, select and complete all applicable Quick Evaluation checklists.
- For cases where $V_E \geq V_{QE}$, select and complete the Basic Configuration Checklist and the Non-Structural Checklist only.

$V_E < 0.3\kappa V_N$ implies that V_E is very low and is unable to resist V_{QE} (see Eq. (3)) for the best case scenario (i.e., high redundancy degree, high inspection quality level, and low consequence class). As a result, the building is unlikely to comply with the acceptance criteria for axial, shear, and flexural resistances in applicable Quick Evaluation checklists.

$V_E \geq V_{QE}$ implies that the building structure has adequate capacity to resist V_{QE} provided that no major building configuration deficiencies such as the discontinuous load path and building irregularities are present. The Structural Checklists are thus not required to be checked given that the statements in these checklists are intended to verify if the structure (including SFRS elements, diaphragms, and connections) has adequate capacity to resist V_{QE}. It is recognized that localized failures such as brace buckling may occur, but these failures are unlikely to cause partial or complete building collapse that threaten life safety. The Basic Configuration Checklist and Non-Structural Checklist are still required to be completed to identify potential building configuration deficiencies and non-structural life safety hazards.

Buildings with $0.3\kappa V_N \leq V_E < V_{QE}$ require comprehensive checks as V_E lies between Scenario 1 and Scenario 2. All applicable Quick Evaluation checklists are required to be completed to identify potential key seismic deficiencies.

4.4.8. Basic Configuration Checklist

The Basic Configuration Checklist applies to buildings with CC-L, CC-M, and CC-H in different Building Site Categories (BSC). This checklist was developed for evaluating potential deficiencies in the building system and configuration (e.g., discontineous load path, adjacent buildings, building irregularities, inadequate ties between foundation elements, and geologic hazards) in buildings with CC-L and CC-M. For buildings with CC-H, the evaluating statements for one level higher seismicity should be checked. This is intended to reduce the likelihood of missing potential building deficiencies, which in turn implicitly reduces the probabilities of structural failure of such buildings. The limits and thresholds that define the acceptance criteria in the evaluation statements (e.g., minimum building separation, maximum distance between the storey centre of mass and storey centre of rigidity, and minimum base-to-height ratio that avoids foundation overturning) were based on a comprehensive review of the seismic requirements in the NBC 2015, 1993 NRC seismic evaluation guidelines, U.S. standards and guidelines (ASCE/SEI 31-03 2003; ASCE/SEI 41-13 2013; ASCE/SEI 7-16 2016; ASCE/SEI 41-17 2017; FEMA 178 1992; FEMA 310 1998), and relevant studies (Florin and Ivanov 1961; Humar et al. 2003; Seed and Idriss 1971). The completion of the evaluation statements in this checklist is limited to hand calculations without involving structural modelling and analysis. For example, the presence of torsional irregularity is determined by comparing the estimated distance between the storey centre of mass and the storey centre of rigidity based on hand calculations. The torsional irregularity is considered present if the estimated distance is equal to or greater than 20% of the building width in either direction. More detailed information on this checklis is provided elsewhere (Fathi-Fazl et al. 2021c).

4.4.9. Structural Checklists

Seventeen Structural Checklists were developed for existing buildings with CC-L, CC-M, and CC-H in different BSCs. In the proposed procedure, Structural Checklists were developed for evaluating structural components in buildings with CC-L and CC-M. For buildings with CC-H, the evaluating statements for one level higher seismicity should be checked. Each Structural Checklist includes more stringent checks for buildings located in higher BSCs. The evaluation statements in each Structural Checklist were mainly based on the 1993 NRC seismic evaluation guidelines. Additional evaluation statements were adapted from the Tier 1 Screening Structural

Checklists in ASCE/SEI 41-17 (2017). The limits and thresholds that define the acceptance criteria in the evaluation statements (e.g., maximum shear stress in concrete columns, maximum aspect ratio in unblocked wood structural panel diaphragms, and maximum height-to-thickness ratio in unreinforced infill walls) were based on a comprehensive review of the seismic requirements in the NBC 2015, 1993 NRC seismic evaluation guidelines, CSA structural design standards (CSA S16 2014, 2019; CSA S136 2016; CSA A23.3 2014, 2019; CSA S304 2014, 2019; CSA O86 2014, 2019; CWC 2017), U.S. standards and guidelines (ACI 318 2014, 2019; ANSI/AISC 341 2016; ANSI/AISC 360 2016; ASCE/SEI 31-03 2003; ASCE/SEI 41-13 2013; ASCE/SEI 7-16 2016; ASCE/SEI 41-17 2017; FEMA 178 1992; FEMA 310 1998; SDPWS-2015 2015; TMS 402/602-16 2016), and relevant studies (Lew et al. 1971; Soltis 1984; Falk and Soltis 1988; Khajehdehi and Panahshahi 2016; Khajehdehi et al. 2018).

In the Structural Checklists, there are evaluation statements that require hand calculations to estimate certain demand parameters (e.g., shear stress, axial stress, and flexural stress) on principal components of the SFRS. In the proposed procedure, simple and, in some cases, empirical equations are similar to the quick checks in the 1993 NRC seismic evaluation guidelines. These quick checks are intended to provide evaluating engineers with a quick estimate of the demands on certain structural components to be able to compare with the limits and thresholds in the evaluation statements. For illustrative purposes, the shear stress, v_j^{avg}, in columns of concrete frames is calculated as follows:

$$v_j^{avg} = \frac{n_c}{n_c - n_f}\left(\frac{V_j}{A_c}\right) \tag{6}$$

Where n_c is the total number of frame columns at the level j, n_f is the total number of frames in the direction of loading at level j, V_j is the storey shear (kN) at level j, A_c is the summation of the cross-section area (m^2) of all columns in the storey under consideration.

More detailed information on the Structural Checklists is provided elsewhere (Fathi-Fazl et al. 2021c).

4.4.10. Non-Structural Checklist

The Non-Structural Checklist consists of evaluation statements for non-structural components located in buildings with different consequence classes and BSCs. BSC0 is not included since buildings in this BSC are exempt from seismic evaluation. The evaluation statements for non-structural components around means of egress are more stringent than those for non-structural components located elsewhere. This is in line with the NBC requirements, which aim to ensure that means of egress is not blocked during a seismic event. To maintain consistency with the NBC requirements, the evaluation statements for non-structural components around means of egress should be checked for CC-H regardless of the consequence class of the building. The Non-Structural Checklist was developed based on the non-structural categories identified in the 1993 NRC seismic evaluation guidelines and the Tier 1 Screening Non-Structural Checklist in ASCE/SEI 41-17 (2017). These categories were mapped with the non-structural component categories in the NBC 2015. Then a set of evaluation statements were developed for each non-structural component category, mainly based on the 1993 NRC seismic evaluation guidelines. Additional evaluation statements were adapted from the Tier 1 Screening Non-Structural Checklist in ASCE/SEI 41-17 (2017). The limits and thresholds that define the acceptance criteria in the evaluation statements (e.g., maximum height-to-thickness and length-to-thickness ratios in unreinforced masonry partitions, maximum height-to-thickness ratios in unreinforced masonry parapets, and maximum horizontal and vertical spacing of masonry veneer ties) were based on a comprehensive review of the seismic requirements in the NBC 2015, 1993 NRC seismic evaluation guidelines, CSA structural design and assessment standards (CSA A344.1-05/A344.2-05 2011; CSA A370-14 2014; CSA B-44-16 2016; CSA C282-19 2019; CSA S304 2014, 2019; CSA S832 2014, 2019), U.S. standards and guidelines (ANSI MH16.1-2012 2012; ASHRAE 2012; ASME A17.1 2016; ASTM C635/C635M-17 2017; ASTM C841-03 2018; ASTM E3090/E3090M 2020; CBSC 2019; FEMA E-74 2012; FEMA P-1050-1 2015; NFPA-13 2002; TMS 402/602-16 2016), and relevant studies (Ishiyama, 1983; Kariotis et al., 1985). More detailed information on the Non-Structural Checklist is provided elsewhere (Fathi-Fazl et al. 2021c).

4.4.11. Recommendation for further actions

In completing all applicable Quick Evaluation checklists, the evaluating engineer needs to address each statement in the applicable checklists. Further seismic evaluation (i.e., Tier 2 Deficiency-Based Evaluation or Tier 3 Detailed Evaluation) should be recommended for evaluating the potential key seismic deficiencies identified through the proposed procedure. If no deficiencies are found, the building is deemed to be compliant with the life safety objective and is thus exempted from further seismic evaluation.

4.4.12. Writing of seismic evaluation report

A seismic evaluation report should be prepared after performing the quick evaluation. The report should include, at a minimum, the following items:

1. Scope and intent.

2. Building description.
3. General building and site information.
4. List of existing documentation reviewed and the photos of the building taken during the site visit.
5. List of assumptions made to complete the applicable Quick Evaluation checklists.
6. Rationales for assessing each applicable evaluation statement in the applicable Quick Evaluation checklists.
7. Findings (e.g., a list of potential key seismic deficiencies, etc.).
8. Recommendations for further actions (i.e., no action, Tier 2 Deficiency-Based Evaluation, or Tier 3 Detailed Evaluation).

5. Application of the Quick Evaluation procedure

The NRC commissioned three consulting firms with experience and expertise in the areas of seismic design and analysis to conduct a pilot study on 12 existing Public Services and Procurement Canada buildings across the country. The objective was to collect feedback on the use of the proposed procedure and to assess its applicability to existing buildings across Canada. This section presents the application of the proposed procedure to one of the 12 buildings in order to demonstrate the proposed procedure and provide potential end users with a step-by-step guidance on conducting quick seismic evaluation. It is not meant to compare the proposed procedure with other seismic evaluation standards and guidelines due to different methodologies in different standards and guidelines. The evaluation of the building was conducted following the

Quick Evaluation process as shown in Figure 1 in conjunction with the guidelines developed by NRC (Fathi-Fazl et al. 2021c). Key steps to complete the evaluation are presented below.

Step 1: Collecting building information

The building under evaluation is an office building located on a site with spectral accelerations of $S_a(0.2)$ = 0.437 g, $S_a(0.5)$ = 0.236 g, $S_a(1.0)$ = 0.117 g at 0.2-, 0.5-, and 1.0-second periods, respectively, and peak ground acceleration (PGA) of 0.279 g. It consists of five storeys above grade, including the roof, and has a total floor area of approximately 4,800 m^2. Based on a review of existing structural drawings, the building was built in 1979 following the NBC 1975 (NRC 1975). The original building importance is identified as Normal based on the occupancy type of the building and the original design NBC. The foundation consists of reinforced concrete walls and footings bearing on bedrock (Site Class A per the NBC 2015). The floors consist of two-way slabs with concrete beams and columns; therefore, the model building type is identified as concrete moment frame (CMF). The building does not hold a federal heritage designation by checking the Directory of Federal Heritage Designations (https://www.pc.gc.ca/en/culture/dfhd). The consequence class is identified as Medium (CC-M) based on the occupancy type, number of storeys, and total floor area. The instructions for identifying consequence classes of existing buildings can be found elsewhere (Fathi-Fazl et al. 2020f; Fathi-Fazl et al. 2021c). The building has never been upgraded to improve its seismic performance. The building is not expected to be decommissioned in 10 years. There is no evidence of geological hazards near the site. The documentation reviewed is not included herein for confidentiality reasons advised by PSPC. Table 6 provides a summary of the information collected above.

Step 2: Identifying conditions triggering Tier 3 Detailed Evaluation

Based on the collected building information, none of the conditions triggering Tier 3 Detailed Evaluation apply to the building.

Step 3: Determining the building seismic category (BSC)

The BSC is identified as BSC2 (i.e., moderate seismicity) based on $I_E S(0.2)$, and BSC1 (i.e., low seismicity) based on $I_E S(1.0)$. The BSC is therefore selected as BSC2, which corresponds to a higher seismicity.

Step 4: Determining building exemption from seismic evaluation

The building is not eligible to be exempted from seismic evaluation as the BSC is other than BSC0.

Step 5: Determining building exemption from structural seismic evaluation

The building is not a post-benchmark building as the original design NBC (i.e., NBC 1975) is older than the benchmark NBC edition for CMF (NBC 2005); therefore, it is not eligible to be exempted from structural seismic evaluation.

Step 6: Determining conformity with building height limit

The building conforms to the building height limit for CMF corresponding to BSC2 and CC-M (see Table 4).

Step 7: Determining applicability of using Low Seismicity (BSC1) Checklist

Since the BSC of the building is identified as BSC2, the Low Seismicity (BSC1) Checklist does not apply and is thus not needed to be completed.

Step 8: Calculating estimated minimum seismic base shear capacity (V_E)

The minimum required seismic base shear demand (V_D) was calculated according to the NBC 1975. The values of parameters for calculating V_D are obtained from structural drawings. The estimated minimum seismic base shear capacity of the building (V_E) was calculated by Eq. (5) for both directions. α_Q is taken as 1.05 according to Table 5. V_E is calculated as 2,171 kN for both directions.

Step 9: Determining the reduced seismic base shear demand for seismic evaluation (V_{QE})

The reduced seismic base shear demand for seismic evaluation (V_{QE}) was calculated by Eq. (3). κ is equal to 1.0 since the remaining occupancy time is greater than 10 years. α_{QE} is equal to 0.5 for consequence class – medium (CC-M), high redundancy degree, and low inspection quality level. The instructions for identifying redundancy degrees and inspection quality levels can be found elsewhere (Fathi-Fazl et al. 2021c). V_N was calculated as 3,701 kN in accordance with the NBC 2015. V_{QE} was calculated as 1,850 kN by Eq. (3).

Step 10: Selecting the appropriate Quick Evaluation checklists

The estimated minimum seismic base shear capacity (V_E) in both orthogonal directions were compared with V_{QE} and V_N, respectively. For both directions, the V_E/V_{QE} ratios are 1.17. Given these ratios, the Basic Configuration Checklist and the Non-Structural Checklist were selected.

Step 11: Completing the applicable Quick Evaluation checklists

The evaluation statements in the Basic Configuration Checklist and the Non-Structural Checklist corresponding to BSC2 and CC-M were addressed. The evaluation statements for higher seismicity do not apply and thus are not needed to be completed.

A site visit was performed to verify the existing conditions to those described in the existing documentation, identify the material conditions, and collect the information as needed to complete the applicable Quick Evaluation checklists. The review was limited to readily visible components, and architectural finishes or ceilings were not removed.

Step 12: Summarizing potential key seismic deficiencies

The following potential structural deficiencies were identified:

- Insufficient separation distance between the building and its adjacent buildings.
- Vertical stiffness irregularity (soft storey).
- Weight (mass) irregularity.

The following potential non-structural deficiencies were identified:

- Nonexistent lateral support on the top of unreinforced masonry partitions.
- Unknown presence of flexible couplings for ducts and pipes containing hazardous materials.
- Equipment containing hazardous materials not positively connected to the building structure.
- Unrestrained breakable containers that hold hazardous materials, including gas cylinders.

Step 13: Recommendation for further actions

Given the absence of conditions that trigger Tier 3 Detailed Evaluation and the presence of potential key seismic deficiencies identified through the proposed procedure, a Tier 2 Deficiency-Based Evaluation is recommended for this building.

Step 14: Writing of seismic evaluation report

A seismic evaluation report was prepared following the requirement in the previous section.

6. Summary

The Quick Evaluation procedure presented in this paper aims to update the initial quick evaluation procedure in the 1993 NRC evaluation guidelines. It is designed to be an economical tool used as Tier 1 of the three-tired seismic evaluation guidelines currently under development by NRC. The Quick Evaluation methodology has been made compatible with the NBC 2015 and CSA structural design standards. A number of unique features have been incorporated to improve the state of the Canadian practice on the seismic evaluation of existing buildings. For example, a set of earthquake load factor matrices are introduced to calculate the reduced seismic base shear demands, and an additional step is included to assist evaluating engineers in selecting appropriate Quick Evaluation checklists.

The proposed procedure contains a set of checklists that are designed to uncover potential key seismic deficiencies in existing buildings that require further seismic assessment. The checklists are in the form of evaluation statements that relate to potential key seismic deficiencies in the structural systems and non-structural components. Evaluating engineers should address each statement in the applicable checklists. A follow-up site visit is recommended for assessing statements identified as unknown. A seismic deficiency is considered present if an evaluation statement is judged to be non-compliant or unknown. Through the proposed procedure, evaluating engineers are able to identify potential key seismic deficiencies and recommend further actions.

The proposed procedure deals with the life safety objective and does not address other objectives more stringent than life safety. Nevertheless, future research may be undertaken to extend this procedure to address more stringent objectives.

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Table 1: A comparison of existing seismic evaluation standards and guidelines around the world

Country	Standards and Guidelines	Evaluation Methodology		Analysis Procedure		Evaluation Phase				Objective	Seismic Hazards	Reduced earthquake load factor	Resistance	Checklists/Forms	Acceptance criteria in preliminary evaluation
		Force-based	Performance-based	Linear	Nonlinear	Structural		Non-Structural							
						Preliminary	Detailed	Preliminary	Detailed						
Canada	NRC Seismic Evaluation (1993b)	Y	N	Y	N	Y	Y	Y	Y	Life safety	Code level	Y	Factored	Y	All applicable questions are satisfactory answered
	NBC 2015 Commentary L (2015b)	Y	N	Y	Y	N	Y	N	Y	Life safety	Four levels	N	Factored	N	Demand ≤ Capacity
	EGBC SRG (2017)	N	Y	N	Y	N	Y	N	Y	Life safety	A range of seismic hazards	N	Factored	N	Probaability of drift exceedance ≤ 2%
United States	ASCE/SEI 41-17 (2017)	N	Y	Y	Y	Y	Y	Y	Y	A set of performance objectives	Four levels	N	Nominal	Y	All applicable statements are compliant
New Zealand	NZSEE (2017)	Y	N	Y	Y	Y	Y	Y	Y	Life safety	Code level	N	Factored	Y	%NBS ≥ 67
Japan	JBDPA (2001)	Y	N	Y	N	Y	Y	Y	Y	Life safety	Not explicitly defined	N	Factored	N	$I_S \geq I_{SO}$

Note: Y stands for Yes and N stands for No.

Table 2: Names of model building types in Level 3 – SEG

Model building types		Name
WLF-NE		Non-engineered Wood Light Frame buildings of 3 storeys or less, and having building area not exceeding 600 m^2
WLF		Engineered Wood Light Frame buildings of up to 6 storeys in building height, or having building area exceeding 600 m^2
WPB		Engineered Wood Post-and-Beam buildings which are covered by Part 4 of the NBC
SMF		Steel Moment Frames
SBF		Steel Braced Frames
SLF		Steel Light Frames
SCW		Steel frame with Concrete shear Walls
SIW		Steel frame with Infill masonry Walls
CMF		Concrete Moment Frame
CSW		Concrete Shear Walls
CIW		Concrete frame with Infill masonry Walls
PCW		Precast Concrete Walls
PCF	PCF1	Precast Concrete Frame with shear walls
	PCF2	Precast Concrete Frame without shear walls
RML		Reinforced Masonry bearing walls with Light wood or metal deck diaphragms
RMC		Reinforced Masonry bearing walls with Concrete diaphragms
URM		Un-Reinforced Masonry bearing wall buildings
CFS	CFS1	Cold-Formed Steel buildings with shear wall lateral system
	CFS2	Cold-Formed Steel buildings with strap-braced lateral wall system

Table 3: Building seismic categories in Level 3 – SEG

Building seismic category (BSC)		$I_E S(0.2)$		$I_E S(1.0)$	
		>	≤	>	≤
BSC0	Very Low Seismicity		0.10g		0.05g
BSC1	Low Seismicity	0.10g	0.20g	0.05g	0.10g
BSC2	Moderate Seismicity	0.20g	0.35g	0.10g	0.15g
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	

Table 4: Building height limits as a function of model building type, building seismic category, and consequence class

Model Building Types	Building Height Limit (m)							
	BSC1 (Low Seismicity)		BSC2 (Moderate Seismicity)		BSC3 (Moderately High Seismicity)		BSC4-5 (High and Very High Seismicity)	
	CC-L CC-M	CC-H	CC-L CC-M	CC-H	CC-L CC-M	CC-H	CC-L CC-M	CC-H
WLF-NE	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

Notes:
CC-L: Consequence Class – Low. CC-M: Consequence Class – Medium. CC-H: Consequence Class – High.
NL: No building height limit for Tier 1 Quick Evaluation and Tier 2 Deficiency-Based Evaluation.
NP: Not permitted for Tier 1 Quick Evaluation and Tier 2 Deficiency-Based Evaluation.

Table 5: Adjusted earthquake load factor (α_Q)

NBC edition	Adjusted earthquake load factor (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

Table 6: Summary of building information collected for conducting Quick Evaluation

Seismic data	$S_a(0.2) = 0.437$ g, $S_a(0.5) = 0.236$ g, $S_a(1.0) = 0.117$ g, PGA = 0.279 g
Occupancy type	Office
Number of storeys above grade	5
Total floor area (m^2)	4,800
Year built	1979
Original design NBC	NBC 1975
Original building importance	Normal
Federal heritage designation	No
Model building type	Concrete moment frame
Consequence class	Medium
Site class	A
Seismic upgrading	No
Remaining occupancy time	> 10 (years)
Geologic hazards	No

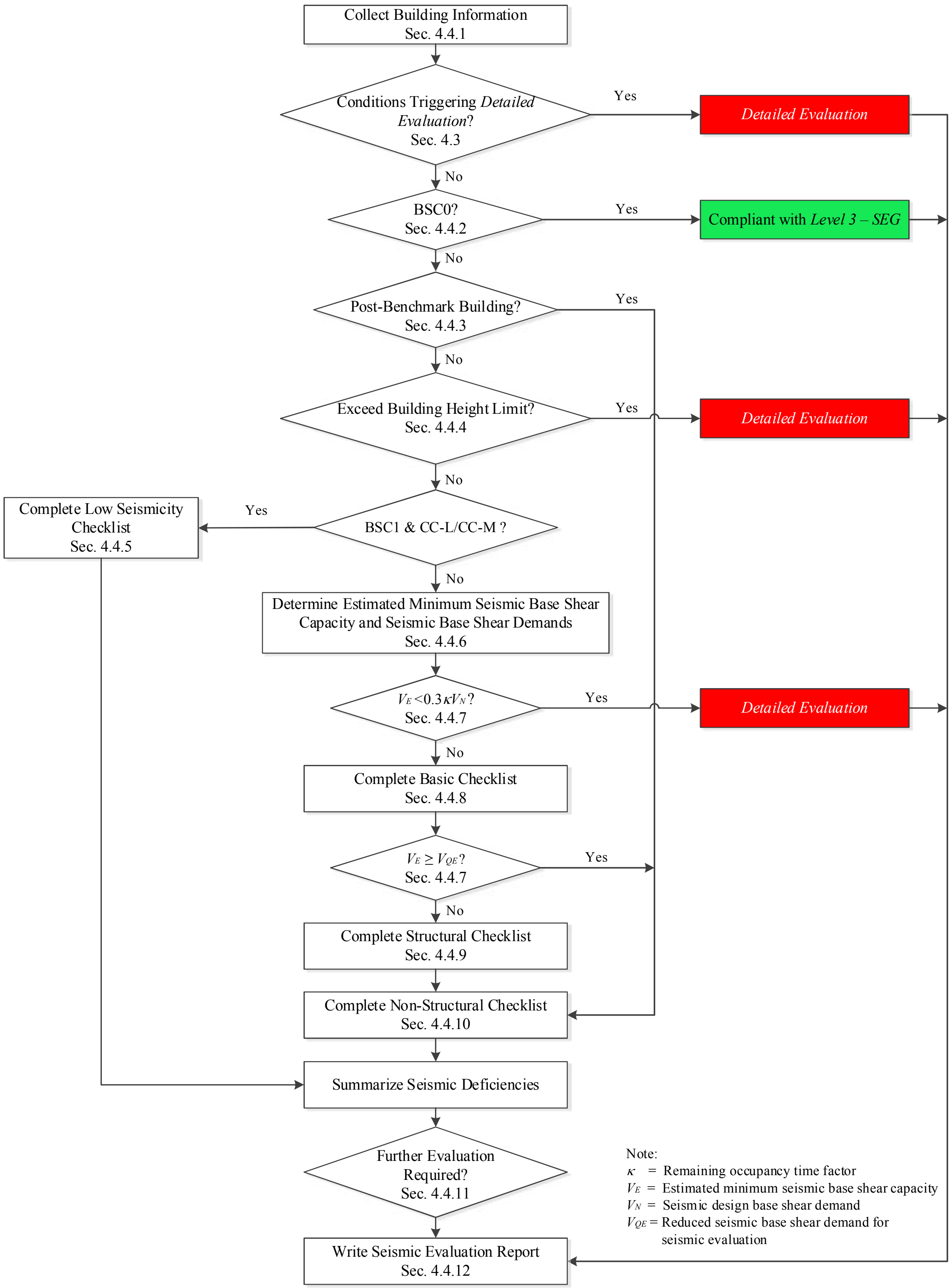

Figure 1: Quick Evaluation process