PROFESSIONAL PRACTICE GUIDELINES

BUILDINGS

STRUCTURAL CONDITION ASSESSMENT OF EXISTING BUILDINGS

VERSION 1.0
PUBLISHED DECEMBER 3, 2020

ENGINEERS & GEOSCIENTISTS
BRITISH COLUMBIA

ENDORSED BY:

STRUCTURAL ENGINEERS ASSOCIATION OF BRITISH COLUMBIA

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PREFACE

These *Professional Practice Guidelines – Structural Condition Assessment of Existing Buildings* were developed by Engineers and Geoscientists British Columbia (the Association), with the support of the Structural Engineers Association of British Columbia (SEABC). The purpose of these guidelines is to provide guidance on professional practice for Engineering Professionals who perform structural condition assessments of existing buildings in British Columbia (BC).

This document was prepared for the information of Engineering Professionals, statutory decisionmakers, regulators, the public, and other stakeholders who might be involved in, or have an interest in, the structural condition assessment of existing buildings.

These guidelines provide clarity on the expected level of effort, due diligence, and standard of practice when carrying out structural condition assessments of existing buildings. It is important to note that these guidelines are not intended to replace provisions of other applicable codes, such as the *National Building Code of Canada* (*NBC*) Structural Commentaries (User's Guide – NBC 2015: Part 4 of Division B), but to provide guidance in applying them.

These guidelines were prepared by a committee of SEABC members, and were reviewed by various committees and divisions of the Association and approved by the Association's Council.

These guidelines outline the appropriate standard of practice to be followed at the time that they were prepared. However, this is a living document that is to be revised and updated, as required in the future, to reflect the developing state of practice.

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ABBREVIATIONS

ABBREVIATION	TERM
BC	British Columbia
BCBC	*British Columbia Building Code*
CMU	concrete masonry units
NBC	*National Building Code of Canada*
OFC	Operational and Functional Component
R_d	ductility-related seismic force modification factor
R_o	overstrength-related seismic force modification factor
SER	Structural Engineer of Record
SFRS	Seismic Force Resisting System
SRG3	*Seismic Retrofitting Guidelines*, 3rd Edition
VBBL	Vancouver Building By-law
VLS	Vertical Load-Bearing System

DEFINED TERMS

The following definitions are specific to these guidelines. These words and terms are capitalized throughout the document.

TERM	DEFINITION
Act	*Engineers and Geoscientists Act* [RSBC 1996], Chapter 116.
Association	The Association of Professional Engineers and Geoscientists of the Province of British Columbia, also operating as Engineers and Geoscientists BC.
Authority Having Jurisdiction	The jurisdictional body (usually municipal) with the authority to administer and enforce the applicable Building Code, or the official or agency designated by that body to exercise such a function.
Bylaws	The Bylaws of the Association made under the *Act*.
Commentary L	Commentary L of the National Building Code of Canada (NBC), Structural Commentaries (User's Guide – NBC 2015: Part 4 of Division B).
Building Code	The *National Building Code of Canada*, the *British Columbia Building Code*, or the Vancouver Building By-Law, whichever applies in the jurisdiction in which the building being assessed is located.
Client	The individual or organization having responsibility or control over the building being assessed. Usually the Client is the building Owner but may also be an entity acting on behalf of the Owner, such as a property management firm.
Critical Members or Connections	A structural member or connection that, if it fails, is more likely to lead to collapse or global instability of the structure than a typical member or connection located elsewhere within the building or structure.
Deficiency (also, Deficiencies)	Any identified shortcoming in structural systems, members, or elements, compared to their relevant design or performance criteria.
Engineering Professional(s)	Professional engineers and licensees who are registered or licensed by the Association and entitled under the *Act* to engage in the practice of professional engineering in British Columbia.
Engineers and Geoscientists BC	The business name for the Association.
Geotechnical Engineer	An Engineering Professional engaged to perform the aspects of the structural condition assessment pertaining to the geotechnical discipline.
Immediate Action	Any measure required to mitigate an identified condition which, if left unaddressed, could pose a imminent risk to the safety or welfare of the public.
Lateral Force Resisting System	See definition of Seismic Force Resisting System below.
Operational and Functional Component(s)	Components within a building that are directly associated with the function and operation of the building. Operational and Functional Components consist of architectural components, building services components, and building contents.

TERM	DEFINITION
Owner	Any individual, firm, or corporation controlling the property under consideration during the period of application of the Building Code. The Owner when a building is being designed and constructed (e.g., the developer) is often different from the Owner after the building construction is complete and the property is being used for its intended purpose (e.g., a strata corporation).
Primary Structural Element	A beam, column, or other structural design element that, when combined with others, forms the Primary Structural System.
Primary Structural System	A combination of Primary Structural Elements that support a building's self-weight, superimposed dead loads, and applicable live loads based on occupancy, use of the space, and environmental loads such as wind, snow, and seismic forces.
Professional of Record	The Engineering Professional with the lowest level of direct professional responsibility for the engineering work and any related engineering documents produced.
Region of High Seismicity	A region in which the lateral design of the building or structure is governed by seismic demands. In the *National Building Code of Canada* (NRC 2015), such regions are identified by having $I_e F_a S_a(0.2) \geq 0.35$.
Seismic Force Resisting System	The part of the structural system identified to provide the required resistance to earthquake forces and effects (i.e., lateral demands). Sometimes referred to as the Lateral Force Resisting System.
Structural Engineer of Record	The Professional of Record who conducts the structural condition assessment.
Structural Integrity	The ability of a structure to absorb local failure without widespread collapse.
Structurally Adequate	A building or structural component is deemed Structurally Adequate provided it satisfies its prescribed evaluation criteria.
Structurally Safe	An existing Structurally Adequate building (or a specified part of the building) is deemed Structurally Safe provided: • it is maintained in its current condition; • it is not subjected to extreme weather conditions beyond those prescribed by the applicable Building Code; and • its Primary Structural Systems are, in the professional opinion of the Structural Engineer of Record, unlikely to collapse suddenly and without warning if subjected to the limiting weather conditions and load combinations imposed on their structural design by Part 4 of the Building Code.
Structurally Sound	A building or structure is deemed Structurally Sound provided it exhibits no evidence of defects, damage, deterioration, or distress that might impair its structural function or its present occupancy and use.
Structurally Sufficient	A building (or a specified part of the building) is deemed Structurally Sufficient provided it was designed and built to the minimum structural requirements of the applicable Building Code, in compliance with a valid building permit, and according to the design and general review requirements of the Building Code.
Vertical Load-Bearing System	The part of the structural system identified to provide the required resistance to vertical loads and that is not part of the Seismic Force Resisting System.

VERSION HISTORY

VERSION NUMBER	PUBLISHED DATE	DESCRIPTION OF CHANGES
1.0	December 3, 2020	Initial version.

1.0 INTRODUCTION

Engineers and Geoscientists British Columbia (the Association) is the regulatory and licensing body for the engineering and geoscience professions in British Columbia (BC). To protect the public, the Association establishes, maintains, and enforces standards for the qualifications and practice of its members and licensees.

The Association provides various practice resources to its members and licensees to assist them in meeting their professional and ethical obligations under the *Engineers and Geoscientists Act*. One of those resources are professional practice guidelines, which establish the standard of practice for specific professional activities. The Association works with experts in their fields to develop professional practice guidelines where additional guidance is beneficial or required.

These *Professional Practice Guidelines – Structural Condition Assessment of Existing Buildings* were first published in 2020 to provide guidance on professional practice for Engineering Professionals who perform structural condition assessments of existing buildings in BC.

Note that these guidelines are not intended to replace provisions of other applicable codes, such as the *National Building Code of Canada* (*NBC*) Structural Commentaries (User's Guide – NBC 2015: Part 4 of Division B), but are intended to provide guidance for applying them.

1.1 PURPOSE OF THESE GUIDELINES

This document provides guidance on professional practice to Engineering Professionals who are involved in structural condition assessments of existing buildings in BC. These guidelines provide a common approach for carrying out a range of professional activities related to such assessments.

Following are the specific objectives of these guidelines:

1. Describe the standard of practice that Engineering Professionals should follow when providing professional services related to these professional activities.
2. Specify the tasks and/or services that Engineering Professionals should complete to meet the appropriate standard of practice and fulfill their professional obligations under the *Act*. These obligations include the Engineering Professional's primary duty to protect the safety, health, and welfare of the public and the environment.
3. Describe the roles and responsibilities of the various participants/stakeholders involved in these professional activities. The document should assist in delineating the roles and responsibilities of the various participants/stakeholders, which may include the Professional of Record, Structural Engineer of Record, Owners, Authorities Having Jurisdiction, and contractors.
4. Define the skill sets that are consistent with the training and experience required to carry out these professional activities.
5. Provide guidance on the use of assurance documents, so the appropriate considerations have been addressed (both regulatory and technical) for the specific professional activities that were carried out.
6. Provide guidance on how to meet the quality management requirements under the *Act* and Bylaws when carrying out the professional activities identified in these professional practice guidelines.

1.2 ROLE OF ENGINEERS AND GEOSCIENTISTS BC

These guidelines were prepared by subject matter experts and reviewed at various stages by a formal review group. The final draft of the guidelines underwent a final consultation process with various committees and divisions of the Association. These guidelines were approved by the Association's Council and, prior to publication, underwent final legal and editorial reviews. These guidelines form part of Engineers and Geoscientists BC's ongoing commitment to maintaining the quality of professional services that Engineering Professionals provide to their clients and the public.

An Engineering Professional must exercise professional judgment when providing professional services; as such, application of these guidelines will vary depending on the circumstances, including where site-specific conditions need to be addressed or in the event that there are changes in legislation, regulations or the Building Code subsequent to the publication of these guidelines. Where an Engineering Professional intends to substantially deviate from following or applying these guidelines, the Engineering Professional should consider obtaining a second opinion on the merits of the deviation.

The Association supports the principle that appropriate financial, professional, and technical resources should be provided (i.e., by the Client and/or an employer) to support Engineering Professionals who are responsible for carrying out professional activities, so they can comply with the standard of practice provided in these guidelines. These guidelines may be used to assist in the level of service and terms of reference of an agreement between an Engineering Professional and the Client.

These guidelines are intended to assist Engineering Professionals in fulfilling their professional obligations, especially regarding the first principle of the Association's Code of Ethics, which is to "hold paramount the safety, health and welfare of the public, protection of the environment and promote health and safety in the workplace." Failure to meet the intent of these guidelines could be evidence of unprofessional conduct and lead to disciplinary proceedings by the Association.

1.3 INTRODUCTION OF TERMS

See the Defined Terms section at the front of the document for a full list of definitions specific to these guidelines.

1.4 SCOPE AND INTENT OF THESE GUIDELINES

The intent of these guidelines is to provide guidance and methodology for conducting structural condition assessments of existing buildings as defined in the Building Code. It does not cover other types of building assessments, such as code compliance reports, building envelope assessments, performance audits, reserve fund studies, and fire safety audits.

In many cases, the outcome of a structural condition assessment will be a recommendation for remediation or upgrade, or implementation of a maintenance and monitoring program. These guidelines only deal with the assessment stages, and remediation or upgrade of the structure is beyond the scope of this document.

1.5 APPLICABILITY OF THESE GUIDELINES

These guidelines provide guidance on professional practice for Engineering Professionals who carry out structural condition assessments of existing buildings. These guidelines are not intended to provide systematic instructions for how to carry out these activities; rather, these guidelines outline considerations to be aware of when carrying out these activities.

An Engineering Professional's decision not to follow one or more aspects of these guidelines does not necessarily mean a failure to meet his or her professional obligations. Such judgments and decisions depend upon weighing facts and circumstances to determine whether other reasonable and prudent Engineering Professionals, in similar situations, could have conducted themselves similarly.

1.6 ACKNOWLEDGEMENTS

These guidelines were prepared on behalf of the Association by a committee of Engineering Professionals who are also members of the Structural Engineers Association of BC (SEABC), including Nick Bevilacqua, P.Eng., Struct.Eng.; Patrick McGrath Ph.D., P.Eng.; Kevin Riederer P.Eng., P.E.; and Kenny Yip, P.Eng., P.E., S.E.

Engineers and Geoscientists BC thanks the authors and the SEABC for their contributions to these guidelines. This document was also reviewed by a group of technical experts, as well as by various committees and divisions of the Association.

Authorship and review of these guidelines does not necessarily indicate the individuals and/or their employers endorse everything in these guidelines.

The authors wish to acknowledge that content has been adopted and modified from other sources, including the Professional Engineers of Ontario (PEO) guideline titled *Structural Condition Assessment of Existing Buildings and Designated Structures Guideline* (PEO 2016), and the American Society of Civil Engineers (ASCE) standard titled SEI/ASCE 11-99 Guideline for Structural Condition Assessment of Existing Buildings (ASCE 2000). Sources have been cited and referenced accordingly (see Section 6.0 References and Related Documents).

2.0 ROLES AND RESPONSIBILITIES

2.1 COMMON FORMS OF PROJECT ORGANIZATION

Generally, the project organization for a structural condition assessment of an existing building is straightforward and it involves the Client, who is usually the Owner, contracting the engineering firm that undertakes the assessment. The contract should be put into writing and signed by both parties prior to the commencement of the project. Arrangements could become more complex when the Client is not the Owner.

The Structural Engineer of Record (SER) typically assumes a leadership role in project organization and works to establish the criteria for the project in consultation with the Client. See Section 3.1 Overview of Structural Condition Assessments for guidance on establishing the approach for the structural condition assessment to be completed.

2.2 RESPONSIBILITIES

2.2.1 CLIENT

Usually the Client is the building Owner but may also be an entity acting on behalf of the Owner, such as a property management firm. In some circumstances, the Client may not be directly controlled by or linked to the Owner. Such cases could include a leaseholder, prospective purchaser, insurer, or another individual or entity. The nature of the Client's responsibility depends, to some extent, on their relationship to the building.

In general, the Client has the following responsibilities:

- Enter into an appropriate services agreement with the Engineering Professional or engineering firm completing the structural condition assessment.
- Provide the requested information on the building. (See Section 3.2.1 Review of Record Documents.)
- Provide access to all areas of the building deemed necessary by the Engineering Professional to complete the assessment. This may include removing building finishes to expose structural elements or connections for review. (See Section 3.2.2 Field Evaluation.)
- Act on the recommendations of the assessment, especially in cases where there is an issue of public safety. In instances where the Client is not the Owner, the Client may have a duty to inform the Owner and the Authority Having Jurisdiction of the recommendations.

2.2.2 STRUCTURAL ENGINEER OF RECORD

The Structural Engineer of Record (SER) is the Engineering Professional who acts as the Professional of Record and takes overall responsibility for the structural condition assessment.

The SER is responsible for completing the scope of work as outlined in the services agreement. If the SER subsequently determines that work outside of the scope of the initial services agreement is needed, in order to perform an adequate assessment and protect public safety, the SER should request that the Client agree to an expanded or changed scope of work as deemed appropriate by the SER in the cirumstances. In doing so, the SER should bear in mind the SER's professional duty to hold paramount the safety, health, and welfare of the public, and report issues of structural concern to the appropriate authorities where that is necessary.

The detailed responsibilities of the SER in completing a structural condition assessment are described in Section 3.0 Guidelines for Professional Practice. In addition, the SER must adhere to the applicable quality management requirements during all phases of the work, in accordance with the Association's Bylaws (see Section 4.0 Quality Management in Professional Practice).

The SER should be aware of special duties and responsibilities related to public safety for existing buildings. This is particularly important where buildings may have deteriorated over time and structurally unsafe conditions may have developed. In some instances, the deteriorated conditions may be difficult to detect as they may be concealed within areas such as finished walls, ceilings, attics, and crawl spaces.

Where orders or requirements have been issued by any government body or regulatory authority, the SER should:

- develop an appropriate scope of work to deal with the order or requirement; and
- document the order or requirement in the scope of work and in all reports.

Engineering Professionals who discover a structural Deficiency during the course of a structural condition assessment that, in their professional opinion, poses a health or safety risk to the occupants, users, or the public, should take the following actions:

- If the Engineering Professional is not the SER for the structural condition assessment, he or she must immediately inform the SER of the nature of the Deficiency.
- In situations where, in the opinion of the SER, there is an imminent risk to the public, the SER or Engineering Professional must immediately contact the appropriate Authority Having Jurisdiction, so that the public safety issue may be immediately considered and dealt with by the Authority Having Jurisdiction. The Client and Owner must also be immediately made aware of the Deficiency.
- If the risk is not imminent, the SER or Engineering Professional must promptly provide a written report of the risk to the Client and request that, immediately or within a given timeframe appropriate in the circumstances, the Client provide a copy of the report to the Owner, occupants, and other interested parties or that the Client otherwise approve that a copy of the report be provided to those persons by the SER or Engineering Professional (the "Disclosure Request").
- If the SER or Engineering Professional is aware that the Client has not taken appropriate and timely action to satisfy the Disclosure Request, the SER or Engineering Professional is required by the Association's Code of Ethics to notify the appropriate Authorities Having Jurisdiction, including the chief building official.

3.0 GUIDELINES FOR PROFESSIONAL PRACTICE

This section outlines the services that should be provided when performing structural condition assessments of existing buildings. These guidelines may also help the Structural Engineer of Record (SER) explain services to a Client, whether the Client is an Owner, a person acting on behalf of the Owner, or a person not directly controlled by or linked to the Owner.

What is outlined in this section is not intended to be exhaustive and should not be interpreted as limiting the SER's responsibilities as discussed in the other sections of these guidelines, or what the SER ought to do based on the SER's exercise of good professional judgment in the circumstances of a particular assessment.

3.1 OVERVIEW OF STRUCTURAL CONDITION ASSESSMENTS

3.1.1 ASSESSMENT SCOPE

There are many reasons a structural condition assessment of an existing building may be undertaken; therefore, the scope and objective of the assessment will vary accordingly.

Reasons for undertaking an assessment include:

- to assess known or unknown life safety issues;
- to determine structural code compliance;
- to assess implications of change of use and occupancy;
- to assess structural damage caused by events such as accident, flood, or fire;
- to develop a performance report; and/or
- another specific objective.

Regardless of the objective, the scope of the assessment should be clearly defined in the services agreement and should generally include:

- the reason for the assessment;
- the assessment objectives;
- the methodology to be followed;
- a clear statement of whether seismic evaluation is part of the assessment;
- the limitations of the findings; and
- the deliverables.

3.1.2 ASSESSMENT APPROACH

The process of assessing the structural condition of an existing building consists of assembling and systematically analyzing information and data regarding the building, or portions of the building, in order to determine the structural adequacy. A general procedure for conducting a structural assessment of existing buildings is described in these guidelines.

A structural condition assessment of an existing building may require a significant and complex level of effort. In such cases, a multi-level, yet more manageable, assessment approach is recommended. The basic process entails conducting a preliminary assessment followed by a detailed assessment, if required.

The use of the term "preliminary" is not intended to imply that the preliminary assessment is incomplete or a precursor to a detailed assessment. Rather, the preliminary assessment is a stand-alone scope of work, and should include a conclusion as to whether a detailed assessment is recommended. If it has been predetermined that the building requires a detailed assessment, a preliminary assessment is not required.

In some instances, a review of the entire structure may not be required, and a limited scope assessment may be sufficient.

3.1.3 TYPES OF ASSESSMENTS

Three types of assessments may be undertaken during a structural condition assessment of existing buildings:

1. Preliminary assessments
2. Detailed assessments
3. Limited Scope assessments

3.1.3.1 Preliminary Assessments

Preliminary assessments (Section 3.2 below) are generally more qualitative rather than quantitative. The key elements of a preliminary assessment may include a combination of the following:

- Review of record documents
- Field evaluation
- Preliminary analysis
- Materials assessment

The preliminary assessment should also confirm whether a detailed assessment is recommended or further review is required to address specific issues.

3.1.3.2 Detailed Assessments

The process for detailed assessments (Section 3.3 below) is similar to that used for preliminary assessments, except it requires greater detail and more accuracy to increase the reliability of the resulting recommendations.

Since this assessment may require invasive investigation and extensive engineering work, which could demand significant investment by the Owner, the scope of a detailed assessment should be balanced against the probable risks to the public. As with a preliminary assessment, a detailed assessment may be limited to a specific area of the building, or it may focus on a specific structural aspect located throughout some or all of the building.

3.1.3.3 Limited Scope Assessments

Limited scope assessments (Section 3.4 below) are intended to address specific structural elements of a building. This may apply if the building was affected by a potential structurally compromising event, such as a fire, vehicle impact, or flooding, or if the request for the assessment is made due to a known structural concern, such as a failed or altered member, cracking, or settlement.

In such cases, the scope of the assessment may be limited to those structural elements of direct concern. A limited scope assessment may include some or all of the components of a preliminary assessment or a detailed assessment.

3.1.4 IMMEDIATE ACTIONS

If at any time during an assessment a condition is discovered that the SER considers a potentially imminent danger (i.e., a situation that endangers the safety or welfare of the public), the SER is obligated to promptly report (verbally and in writing) the condition and potential risk to someone who has authority or responsibility to take the appropriate action, and to the Authority Having Jurisdiction over the structure being assessed. The SER uses engineering judgment to assess what is considered a condition that poses a potentially imminent danger.

The report identifying such a condition will frequently state the need for Immediate Actions to mitigate the risk. Possible recommendations for Immediate Actions may include:

- installation of temporary shoring or bracing to prevent collapse;
- restriction of access to the building or a part of the building; or
- installation of a protective enclosure to minimize infiltration of the elements.

Due to the immediacy of these recommendations, such verbal and written notice should be provided before performing further assessment or preparing the assessment report.

3.1.5 REPORTING AND DELIVERABLES

A report must be produced at the completion of any preliminary, detailed, or limited scope assessment. The report should include a summary of the work and the key findings. An outline for the report is provided in Section 3.6 Reporting below.

The report should include a discussion about whether additional assessment is needed or recommended. A preliminary assessment report may recommend that a detailed assessment be undertaken. The SER must then clearly state the reasons for and timeframe of the detailed assessment, and should indicate the consequences of failing to undertake the assessment.

If the SER determines from the detailed assessment that there are significant life safety issues that need to be dealt with, then the SER must clearly state the actions required, including reasons and timeframe, and must indicate the consequences of failing to undertake the recommended actions.

The report must address any previously reported Immediate Actions and report the latest known status related to such actions, as noted in Section 3.1.4 above.

Any orders or requirements issued by any government body or regulatory authority must also be documented in the report.

3.2 PRELIMINARY ASSESSMENTS

Preliminary assessments are generally more qualitative rather than quantitative. This section describes the key elements of a preliminary assessment.

The preliminary assessment should also confirm whether a detailed assessment is recommended or further review is required to address specific issues.

3.2.1 REVIEW OF RECORD DOCUMENTS

Whenever possible, before visiting the building for observation, the SER conducting the preliminary assessment should review the relevant available documents (e.g., reports and drawings).

This review will assist the SER to:

- understand the building's layout and its Primary Structural Systems;
- understand the geotechnical and soil conditions encountered at the site;
- identify the originally specified design loads in relation to current loading and proposed usage;
- identify material specifications, such as strength and grade;
- identify if there have been any relevant additions or alterations;
- identify areas of interest for observation; and
- identify data that may be missing and should be obtained at the site.

The SER should request from the Client:

- original construction documents, including a geotechnical report;
- orders issued by an Authority Having Jurisdiction pertaining to structural adequacy;
- previous assessment reports;
- reports of chronic or new issues that typically could indicate a structural concern, such as
  - significant movement and/or displacements,
  - water leakage or damage,
  - fallen concrete (spalls or delamination),
  - cracks and deflections,
  - wood rot, or
  - steel corrosion; and
- records of ongoing maintenance and repairs.

3.2.2 FIELD EVALUATION

Before visiting the building, the SER should ask the Client to provide any available reports and information. Review of these record documents is important, as it may reveal a safety concern to the individuals involved in the field evaluation, such as designated substances or hazardous materials as defined by the *Occupational Health and Safety Regulation*. The field evaluation team should be aware of any site-specific safety rules or requirements and should, at minimum, follow all WorkSafeBC requirements while conducting the assessment, with particular attention to issues such as fall protection, confined spaces, ladders and scaffolds, and personal protective equipment (WorkSafeBC 2019).

The team involved in the field evaluation should include at least one Engineering Professional who is a structural engineer experienced in structural condition assessments of existing buildings in BC. When possible, an Engineering Professional performing a field evaluation should be accompanied by a building site representative or person familiar with the building who can provide access to various areas within the building and describe their uses; identify known areas of distress, corrosion, cracking, settlement, or water leakage; and provide a general building history. If Engineering Professionals other than the SER are involved in performing the field evaluation, their work must be sufficiently coordinated with the SER to ensure that the entire scope of assessment is covered consistently, and that the SER is able to ultimately take responsibility for the entire assessment (see Section 4.1.3 Direct Supervision).

The purpose of the field evaluation during a preliminary assessment is to:

- note the building information, such as
  - the general layout and type of construction, and
  - the vertical and lateral load-carrying systems;
- survey the condition of the building to
  - identify obvious, relevant, and significant instances where the construction may have been completed incorrectly or in substantial deviation from the structural drawings, and
  - determine obvious signs of structural damage, deterioration, distress, or deformations, including settlement or foundation problems;
- assess the use of the building to identify apparent deviations from intended use;
- look for additions, modifications, or alterations that may cause an adverse effect on the structure; and
- obtain the necessary information to complete the preliminary analysis and identify which structural members, if any, should be reviewed.

Difficulties may be encountered when conducting a field evaluation, if some of the main structural elements in a building are covered by finishes or are inaccessible due to height or other site constraints. It is therefore important that the Engineering Professional exercises professional judgment in determining which covered areas should be exposed for review. The Engineering Professional and Client may also agree to engage a contractor to attend the site assessment to remove any building finishes, as necessary to carry out the observations and repair the affected area.

While the field review is meant to be limited to visual observations, certain small tools may also be used in minimally invasive ways to quickly measure and determine certain conditions:

- Camera to photograph and document site visual conditions
- Tape measure to measure dimensions of interest
- Flashlight to illuminate dark spaces
- Small hammer to check materials, such as bonding of toppings, corrosion delamination, and cell grouting
- Leather awl or other sharp point to check for wood rot
- Hand-held moisture meter to check for trapped moisture in walls
- Pachometer to detect the presence of reinforcing steel in concrete or masonry elements

3.2.3 PRELIMINARY ANALYSIS

A preliminary analysis is not intended to be a comprehensive analysis of the building; however, engineering computation may be required to verify the adequacy of critical elements and/or structural systems. These calculations typically use approximate methods and should be focused on the suspect areas or elements of the building, to determine if the conditions identified in the document review or the field observations are cause for concern. These calculations can identify a need for Immediate Action or further investigation, or could provide satisfaction that a particular element is Structurally Adequate.

The following steps should be followed when performing a preliminary analysis:

1. Determine relevant loading and performance criteria.
2. Identify primary vertical and lateral load-carrying systems.
3. Estimate pertinent material properties.
4. Perform a preliminary structural analysis.
5. Review critical Operational and Functional Components (OFCs).

Guidance for each of these steps is provided in the following subsections. In some situations, not all the above steps are necessary to complete an appropriate preliminary assessment. For example, when assessing a building with no previously known or observed structural concerns and no anticipated change in loading or support conditions, based on professional judgment it may be determined that numerical structural analysis and estimates of material properties are not required as part of the preliminary assessment.

3.2.3.1 Analysis Criteria

In a Region of High Seismicity, seismic and non-seismic loading must be considered to ensure the Client has a complete and accurate representation of the state of the building. If a seismic assessment is not undertaken during the preliminary assessment stage, then this omission must be clearly stated in both the scope of work and any reporting to the Client, to ensure the Client or others using the report have the information they need to clearly understand the overall adequacy of the building.

Commentary L from the *National Building Code of Canada* (*NBC*) Structural Commentaries provides guidance for the appropriate assessment and retrofit design of existing structures, and includes specific guidance for earthquake loading as well as other environmental loading (NRC 2015). While those guidelines are summarized here, refer to Commentary L for more detailed information.

In addition to Commentary L, there are several other readily available seismic assessment standards and guidelines. Some commonly used resources include the following:

- *Seismic Retrofit Guidelines*, 3rd Edition (SRG3), developed by the Association specifically to address seismicity and construction practices in BC (Engineers and Geoscientists BC 2017a)
- ASCE/SEI 41 Seismic Evaluation and Retrofit of Existing Buildings (ASCE 2017)
- FEMA P-58 Seismic Performance Assessment of Buildings (FEMA 2018)

These resources and others may be used as guidance for seismic assessments, provided they meet the same life safety intent of the Building Code.

Non-Seismic Loading

The benchmark editions of the *NBC* provided in Commentary L are the earliest editions that provide a life safety level that satisfies the intent of current code requirements for various types of environmental loading. If a structural system or component was designed before adoption of the benchmark edition of the Building Code for a given loading type, then the assessments should use load factor methods from both the current edition of the Building Code and Commentary L. These load factors are intended to maintain the current Building Code's level of life safety and should be considered a minimum performance level, which, if not met, indicates the need for upgrading.

Alternatively, structural systems and components designed and built according to Building Code editions earlier than the benchmark editions can be considered to have demonstrated a satisfactory capacity to resist non-seismic loads when the following conditions are met:

- Careful examination did not reveal any evidence of significant damage, distress, or deterioration.
- The structural system was reviewed, and critical details were examined and checked for load paths.

- The building has demonstrated satisfactory performance for at least 30 years.
- No changes have been made within the past 30 years that could significantly increase the loads on the building or affect its durability, and no such changes are contemplated.

If a structural system or component was designed after the benchmark edition of the Building Code for a given loading type was adopted, then it can be assumed that the design of the system or component will meet the life safety intent of the current Building Code for that loading type. However, this determination alone does not mean the building is in acceptable structural condition; therefore, a field evaluation should still be carried out as part of the structural condition assessment.

Seismic Loading

As noted in Section 3.2.3.1 Analysis Criteria above, several guidelines and resources can be used to perform seismic assessments of existing structures, each containing their own loading and performance criteria. The approach outlined in the *NBC*, Commentary L is described below; when using alternative seismic assessment tools, Engineering Professionals should use their judgment to select appropriate demand levels and performance criteria that would result in similar seismic risk levels as those required by the Building Code.

During a seismic review of a building according to Commentary L, Engineering Professionals should review both the capacity of the Seismic Force Resisting System (SFRS) to carry seismic loads, and the ability of the structure (both the SFRS and the Vertical Load-Bearing System, or VLS) to accommodate deformations that the seismic loading will impose. For brittle structures, such as buildings with masonry and/or non-ductile concrete frame construction, drift requirements often govern. Consequently, the degree to which an existing building complies with code requirements is determined by considering both the strength (i.e. the lateral load-resisting capacity) and the drift capacity of the building.

The first step in the Commentary L seismic assessment procedure is to select a seismic event level for the assessment. Commentary L recommends the following assessment levels (described in more detail in Figure L-1 of Commentary L):

- **Level 1**: Applies to minor renovation projects, as well as voluntary seismic assessments and seismic upgrades, when no future renovation or addition work is anticipated
- **Level 2**: Applies to seismic assessments of renovation and minor addition projects
- **Level 3**: Used for seismic retrofits of renovation and minor addition projects, where required

As outlined in Figure L-1 of Commentary L, each event level prescribes a different response spectrum (and by extension different return period event and probability of exceedance) to be used with the seismic provisions in the Building Code when determining loading and performance criteria. When selecting an assessment level, the Engineering Professional should consider the objective of the building assessment being performed, as well as the age, use, and anticipated future use of the building.

In evaluating force capacity, the earthquake load at the assessment level and the strength of the building are determined using load factors (including RdRo values) and material factors from the Building Code and structural design standards. In evaluating drift compliance, the expected seismic drift of the building is calculated using the assessment levels mentioned above with the load and material factors from the Building Code and material design standards.

This drift demand is then compared to the drift capacity of the SFRS and the drift capacity of the VLS. To assist in determining drift capacities, the *SRG3* contains drift limits for SFRS and VLS systems that are commonly encountered in BC construction practice. Other seismic assessment standards and guidelines, such as ASCE/SEI 41, also contain drift capacities for various types of construction.

3.2.3.2 Vertical and Lateral Load Carrying Systems

Based on the review of documentation and results of the field evaluation, the Engineering Professional should identify the primary vertical and lateral load-resisting systems, along with the load paths that transfer the forces imposed on these systems into the foundations. Critical Members or Connections in the structural system should be identified, and the physical properties and details for these members and connections determined. Critical Members or Connections are those whose failure would either seriously reduce the capacity of the structure to resist the applied forces or result in partial collapse.

When identifying these Primary Structural Systems and their load paths, the Engineering Professional should qualitatively note any apparent major Deficiencies in these systems. For example, absence of an obvious SFRS in one (or both) of the primary lateral directions, undefined load paths, omission of connections between key structural components, or the lack of an appropriate foundation system should be clearly identified. Depending on the severity of these Deficiencies, Immediate Action may be recommended to ensure the life safety protection of the building users and occupants (see Section 3.1.3 Types of Assessments).

3.2.3.3 Material Properties

An estimate of the material properties is generally adequate for the preliminary assessment. If the preliminary assessment reveals that certain material properties have a significant impact on the building's structural adequacy, *in-situ* sampling and testing of these materials may be warranted in further assessments. Appropriate guidelines should be followed for the methods of *in-situ* sampling, (see Section 3.3 Detailed Assessments, under Section 3.3.3.3 Material Properties).

Structural Materials

In cases where numerical analyses of key building systems or individual structural elements are required as part of the preliminary assessment, estimates of the structural material properties of those systems or elements are required.

Initially, the Engineering Professional should review any available existing construction drawings and specifications, as these documents may contain information regarding the material properties used in the design. If no information exists, the material properties can be estimated based upon the design criteria and the types of structural materials commonly used at the time of design and construction. Several reference documents (e.g., ASCE/SEI 41) provide guidance on estimating material properties of common construction materials.

Geotechnical Parameters

When numerical analyses of key building systems or individual structural elements are required as part of the preliminary assessment, the Engineering Professional may need to obtain estimates for geotechnical parameters (e.g., design bearing pressures, seismic site classification) that are likely to be encountered at the project site. Initially, the Engineering Professional should review any existing construction drawings and specifications, as these documents may contain information on the geotechnical properties used in the design. If no information exists, the Engineering Professional may draw on available reference material, in order to make reasonable assumptions regarding the geotechnical properties likely to be encountered at the project site.

Examples of reference information that could be consulted include the following:

- Regional geological surveys, such as those published by Canadian Geoscience Education Network (CGEN), which provide some background information on the types of soils and their associated engineering properties likely to be encountered in locations across BC

- The Canadian Foundation Engineering Manual (Canadian Geotechnical Society 2006), which provides a range of preliminary design bearing pressures that can be used based on the predominant soil type encountered at the site
- The *SRG-3* (Engineers and Geoscientists BC 2017a), which provides maps outlining the seismic site class likely to be encountered in project sites on Vancouver Island and throughout the Lower Mainland
- Geotechnical information from nearby sites

If additional geotechnical input is required, the Engineering Professional should recommend that the Client engage a Geotechnical Engineer to provide an opinion on the geotechnical issues or provide input on the geotechnical parameters being considered.

3.2.3.4 Structural Analysis

Using the information above, the Engineering Professional performs a preliminary structural analysis of the Primary Structural Systems.

At this stage, the use of the term "preliminary" indicates that the goal is to develop a high-level understanding of the structural capacity of the existing building, so using approximate structural analysis techniques and methods is often sufficient. As mentioned in Section 3.2.3 Preliminary Analysis above, a structural analysis is not always required in a preliminary assessment. The SER should use professional judgment when determining whether numerical analyses are required for the assessment being undertaken.

If analyses are performed, the Critical Members or Connections in the structural system should be analyzed to determine their resistances. These resistances are then compared to the demands associated with the specified loading and performance criteria. In addition to these checks of Critical Members or Connections, when considering lateral loading, the overall lateral force resistance and drift capacity of the building are compared to the imposed lateral loading and expected lateral drifts, respectively.

Several standards and guidelines may be used for performing seismic screening and risk assessments, such as the *SRG-3* (Engineers and Geoscientists BC 2017a). Such guidelines provide an appropriate level of detail for the seismic-related analysis of the preliminary structural analysis, allowing the Engineering Professional to establish a fairly representative assessment of the seismic adequacy of an existing building while performing a limited number of calculations on the key components of the SFRS.

When following these guidelines, the Engineering Professional typically uses professional judgment to select the components of the SFRS that likely governs its behavior, so that these components can be focused on during the preliminary structural analysis.

Once the preliminary structural analysis has been performed, and the system and member checks have been completed, the Engineering Professional consolidates these results to determine an estimate of the overall structural adequacy of the building.

If the results of the preliminary analysis are marginal or unclear, a detailed assessment may be recommended (see Section 3.3 Detailed Assessments). If significant Deficiencies are identified, Immediate Action may be recommended to ensure the life safety protection of the building users and occupants (see Section 3.1.3 Types of Assessments).

3.2.3.5 Operational and Functional Components

Operational and Functional Components (OFC) include architectural components, building service components, and building contents. In the preliminary assessment, both the Primary Structural System and critical OFCs that can significantly impact the life safety of building users and occupants should be reviewed.

Guidance for the seismic review and risk reduction of OFCs is provided in the standard titled CAN/CSA-S832 Guideline for Seismic Risk Reduction of Operational and Functional Components (OFCs) of Buildings (CSA 2001).

When performing the OFC seismic review, particular emphasis should be placed on areas surrounding the egress routes for building users and occupants (e.g., corridors, stairwells, entry and exit points).

3.2.4 RECOMMENDATION FOR DETAILED ASSESSMENT

A preliminary assessment report may recommend that a detailed assessment be undertaken. The SER must then clearly state the reasons for and timeframe of the detailed assessment, and should indicate the consequences of failing to undertake the assessment.

3.3 DETAILED ASSESSMENTS

The process for detailed assessments is similar to that used for preliminary assessments, except it requires greater detail and more accuracy to increase the reliability of the resulting recommendations.

This section describes the key elements of a detailed assessment.

3.3.1 REVIEW OF RECORD DOCUMENTS

The document review work for a detailed assessment is similar to that for a preliminary assessment, as outlined in Section 3.2.1 above, with the following modifications:

- Additional effort may be required to obtain documents that were not readily available during the preliminary assessment stage. This may include researching alternative sources of information, such as municipal records and records of previous building owners or insurers, or interviewing design or construction professionals.
- Relevant information that is not available in the existing documents may be identified and determined by taking site measurements and using non-destructive or destructive investigation methods, if possible.
- Information or design parameters identified as being critical during the preliminary assessment may be verified on site.

3.3.2 FIELD EVALUATION

Field evaluation for a detailed assessment is similar to that for a preliminary assessment, as outlined in Section 3.2.2 above, with the following modifications:

- Critical areas of the building not observed during the preliminary assessment because they were covered by building finishes or were otherwise inaccessible may be observed.
- Where existing drawings are missing, unreliable, or insufficiently detailed, destructive or non-destructive surveys may be required of construction details. This portion of the field evaluation may be completed by the SER or by another qualified individual such as a materials engineer or a testing agency specialist.

Typical investigation items may include the following:

- Size, spacing, and concrete cover of reinforcing steel
- Geometry and dimensions, such as thickness of walls, slabs, and other structural members
- Shape and depth of footings
- Wood framing details (e.g., size, spacing, nailing, anchors)
- Presence of masonry reinforcing and cell grouting
- Changes, additions, and previous upgrades (e.g., previous plywood roof diaphragm upgrades)

3.3.3 DETAILED ANALYSIS

While the preliminary analysis is focused on Critical Members or Connections, the detailed analysis would, in general, encompass the structural systems and their interactions as a total structural system. Additionally, Critical Members or Connections found to be deficient or questionable in the preliminary analysis stage should be studied in greater detail at this stage.

3.3.3.1 Analysis Criteria

The analysis criteria used during a detailed assessment does not generally differ from what would be used during the preliminary assessment stage (see Section 3.2.3.1 above).

3.3.3.2 Vertical and Lateral Load Carrying Systems

To assess the adequacy of the existing structural systems, these systems should be holistically reviewed during the detailed assessment stage, paying careful attention to factors that could significantly impact the vertical and lateral load-carrying capacity of the existing structure.

The type and continuity of the existing structural system has a major effect on the performance of the building. Flexible buildings can undergo large deformations and relative movements; therefore, potential damage to non-structural elements and systems is greater. Stiff buildings will undergo smaller deformations, and the potential damage to non-structural elements and systems is less. Rigid diaphragms tend to reduce the effects of unsymmetrical form, when compared to flexible diaphragms.

Building geometry and configuration, such as irregularities, offsets, or discontinuities in the building's structural systems, also have a major influence on its performance. As a starting point, the Engineering Professional should refer to the list of structural irregularities provided in the Building Code (e.g., clause 4.1.8 of the *BCBC*).

The Engineering Professional should carefully evaluate the Structural Adequacy of the structural systems, paying particular attention to:

- load paths and connections between structural elements;
- physical condition of structural elements and connectors; and
- effects of unusual structural features.

Common problems include discontinuities with the vertical and lateral load-resisting systems, lack of ties and continuity, lack of connector elements, and nonredundant systems. Any Deficiencies identified in the vertical or lateral load path should be clearly identified in the assessment report and noted for potential future remediation.

3.3.3.3 Material Properties

A detailed investigation into the material properties, as-built construction details, and material condition of the structure may be required, particularly if the results would decide whether a structural element or system is acceptable in its existing state or requires a costly modification. The SER may need to retain qualified individuals with expertise in materials testing and investigation in such cases (see Section 3.5 Material Condition Assessments below).

The scope of this investigation depends on the:

- type and age of materials used for the building;
- issue, structural element, or system being investigated;
- availability and reliability of existing drawings and specifications;
- potential for material deterioration issues; and
- potential risks related to material property uncertainty.

Where member capacities need to be determined and the physical properties of the materials are not known, or cannot be conservatively estimated, destructive testing is often required. Typical material testing may include:

- extraction of concrete cores for compressive strength, possibly supplemented with calibrated non-destructive strength tests;
- extraction of reinforcing steel for tensile strength and elongation;
- extraction of coupons from structural steel for tensile strength, elongation, and chemical analysis; and
- visual checking for wood grade stamps.

The following resources can be used to guide the SER or specialist in the assessment of material properties:

- ASCE/SEI 41 Seismic Evaluation and Retrofit of Existing Buildings (ASCE 2017)
- SEI/ASCE 11-99 Structural Condition Assessment of Buildings (ASCE 2000)

- ACI 562-19 Code Requirements for Assessment, Repair, and Rehabilitation of Existing Concrete Structures and Commentary (ACI 2019)
- ACI 214.4R Guide for Obtaining Cores and Interpreting Compressive Strength Results (ACI 2010)
- Equivalent Specified Concrete Strength from Core Test Data (Bartlett and MacGregor 1995)

Care should be exercised when removing samples from existing elements, to ensure the Structural Integrity of the existing building is not compromised. Any damage caused to the structure or fire-rated assemblies may need to be restored.

3.3.3.4 Structural Analysis

Using the information above, the Engineering Professional performs a structural analysis of the Primary Structural Systems. While the preliminary analysis is focused on Critical Members or Connections, the detailed assessment, in general, encompasses the structural systems and their interactions as a total structural system. The intent of this analysis is to quantify the level of structural adequacy of the following aspects of the building:

- Primary vertical and lateral load-carrying systems
- Critical Members or Connections within these Primary Structural Systems
- Connections and elements that affect the load path continuity of these Primary Structural Systems

Additionally, any Critical Members or Connections or related systems found to be deficient or questionable in the preliminary analysis stage should be studied further at this stage. When performing the analysis, the structural elements described above should be analyzed to determine their resistances, which are subsequently compared to the demands associated with the specified loading and performance criteria.

As noted in Section 3.2.3.1 Analysis Criteria, several standards and guidelines are available for performing seismic assessments of existing buildings. Since the intent of the analysis undertaken at the detailed assessment stage is to review the adequacy of the existing structure as a whole, the Engineering Professional should use professional judgment to select an assessment tool that considers the seismic performance of the building to a sufficient level of detail; seismic screening or preliminary assessment tools such as those described in Section 3.2.3.4 above are not appropriate at the detailed assessment stage.

Once the detailed analysis is complete, the SER should conclude whether the building is Structurally Adequate or if further recommendations should be provided.

If significant Deficiencies are identified, Immediate Action may be recommended to ensure the life safety protection of the building users/occupants (see Section 3.1.3 Types of Assessments)

3.3.3.5 Operational and Functional Components

The review of OFCs during a detailed assessment does not generally differ from the review conducted during the preliminary assessment stage (see Section 3.2.3.5 above).

3.4 LIMITED SCOPE ASSESSMENTS

Limited scope assessments are intended to address specific structural elements of a building, so the scope of the assessment may be limited to those structural elements of direct concern.

A limited scope assessment may include some or all of the components of a preliminary assessment or a detailed assessment.

3.4.1 EXTENT OF SCOPE

A limited scope assessment often involves only a small part of a structure. The SER must exercise professional judgment to decide the extent to which the assessment should encompass other parts of the structure. Generally, it is acceptable to assess only the component of specific concern, provided this is properly noted in the scope of work.

However, where it is clear to the SER that other structural Deficiencies are present, then one of the following should occur, depending on the case:

- Any Immediate Actions recommended by the SER are completed
- The scope of work of the limited scope assessment is revised to include additional structural members and issues
- A preliminary assessment is recommended
- A detailed assessment is recommended

3.4.2 REVIEW OF RECORD DOCUMENTS

As outlined in Section 3.2.1 above, when possible, the Engineering Professional conducting the limited scope assessment should review the relevant or necessary documents that are available. Ideally, this would be completed before visiting the site, although that may not always be possible for various reasons. The extent of the document review may be limited to only the information pertaining to the area of focus in the limited scope assessment, and in some cases may not be required.

3.4.3 FIELD EVALUATION

The general process for the field evaluation of a limited scope assessment is like that of a preliminary assessment as outlined in Section 3.2.2 above. The extent of the field evaluation may be limited to only the area of focus of the limited scope assessment. When reporting on the field evaluation, it is also important to note what has and has not been reviewed so the extent of the evaluation is clear.

3.4.4 LIMITED SCOPE ANALYSIS

The analysis performed for a limited scope assessment, if required, will vary depending on the type of assessment. Situations where an analysis is not required may include either when observations alone are sufficient to provide an engineering opinion on the issue of concern, or when the original design of the structural member is not in question. In other cases, a process similar to that of the preliminary assessment analysis (see Section 3.2.3) may be sufficient, or a more detailed analysis (see Section 3.3.3) may be warranted.

When reporting on the analysis, it is also important to note what has and has not been evaluated, so the extent of the evaluation is clear.

3.5 MATERIAL CONDITION ASSESSMENTS

3.5.1 OVERVIEW

It is not the objective of a structural condition assessment to perform a detailed material condition assessment. Instead, readily visible or easily detected evidence of deteriorating material conditions should be noted and, where relevant, taken into consideration in the overall structural assessment.

The SER should be familiar with common types of material deterioration but need not be a specialist in the field. However, deterioration is sometimes observed that requires further investigation by a specialist.

Common types of material deterioration that could be encountered during the field evaluation are described in the following sections.

3.5.2 TYPES OF MATERIAL DETERIORATION

3.5.2.1 Concrete

Reinforcing Steel Corrosion

Corrosion of reinforcing steel is the most common type of material deterioration of concrete structures. It is typically caused by exposure to chlorides (e.g., de-icing salts) and results in expansive rust, which subsequently cracks the concrete around the reinforcement.

Readily visible or easily detected evidence for corrosion damage to reinforcing steel includes the following:

- Delamination (in-plane cracks below the surface, resulting in hollow sound when tapped)

- Spalls (loss of concrete) with rusting rebar exposed at the base of the spall
- Rust stains, often at cracks and joints
- Cracks, usually in a pattern sometimes related to the steel layout
- Existing concrete patches or repairs
- Evidence of lack of concrete cover (e.g., bars exposed on the surface)

Note that falling pieces of concrete dislodged by corrosion can, in some cases, pose a risk of injury to people or damage to property. If this deterioration is considered serious, it may call for Immediate Action (See Section 3.1.3 Types of Assessments).

Special attention should be paid to unbonded post-tension reinforcing, particularly in buildings constructed before the late 1980's. In poorly designed and constructed systems, water can enter and be trapped in the plastic sheath resulting in corrosion and failure of the tendon. Where such older systems are encountered, or if the Engineering Professional conducting the assessment suspects a problem, a specialist in post-tension condition assessment should be engaged to complete a review of the post-tension system.

Freezing and Thawing Damage

Cycles of freezing and thawing can damage concrete lacking adequate entrained air content, and also exposes the concrete to higher levels of water. This condition is not typically a problem for structural performance of buildings unless it is significantly advanced.

Readily visible or easily detected evidence for freezing and thawing damage includes the following:

- Scaling (loss of mass or surface layer, exposed aggregates)
- Extensive, deep, random pattern cracking
- Efflorescence (white crystal growth) and staining

Sulphate Attack

Sulphate attack can occur when concrete is exposed to elevated levels of sulfates. Sulphates can come from soil, groundwater, certain types of concrete aggregate (i.e., pyrite and pyrrhotite), fertilizers, and industrial waste. Sulphate reaction causes expansion, loss of strength, and eventually disintegration of the hardened cement paste.

Diagnosis of this type of deterioration should be completed by a materials specialist, but evidence for its occurrence that can be considered in a structural condition assessment includes the following:

- Expansion and cracking
- Disintegration
- Very soft, weak, surface layers
- Efflorescence and staining

Alkali Aggregate Reaction

Alkali aggregate reaction (AAR) is a relatively rare form of long-term expansion and cracking that occurs in concrete primarily due to the use of reactive aggregates. Typically, alkali in the cement and high levels of moisture exposure also contribute to AAR. The reaction can take many years to occur (e.g., 40 or more years).

Diagnosis of this type of deterioration should be completed by a materials specialist, but evidence for its occurrence that can be considered in a structural condition assessment includes the following:

- Large global expansions
- Pattern crack (network of random cracks)
- Efflorescence and stains

Excessive Cracks

Cracks are not a deterioration mechanism on their own but can be the result of deterioration (corrosion, freezing and thawing, sulphate attack, AAR). Cracks can also indicate structural overloading, settlement, or impact damage. Some cracks will usually be present due to shrinkage, thermal effects, and normal levels of stress.

It is therefore important to be able to distinguish between various types of cracks and their severity.

Typically, cracks are noted in a field survey only when they are judged to be significant in relation to the objectives of the structural condition assessment.

Types of cracks include the following:

- Load-induced: Noticeable at points of higher stress, such as at mid-span, over supports, or at high shear locations (inclined upward toward support); when combined with shrinkage, the cracks can pass through the element
- Early age shrinkage or plastic shrinkage: Typically occurs only in the slab top surface; random and meandering or oriented in a specified pattern (for example, parallel over reinforcing steel); varies from narrow to very wide at surfaces; discontinuous; does not penetrate through the section
- Drying shrinkage: Occurs mid-panel or mid-element, at points of restraint (for example, off column lines and restraint corners); generally linear and long
- Thermal stress: Typically random, deep, and narrow; associated with large block elements where heat of hydration can build up
- Cracks caused with reinforcing steel corrosion
- Cracks due to other forms of deterioration

When cracks are considered significant, the type of pattern, width, and frequency should be noted. Full mapping of cracks should generally not be necessary or productive, and would be done in a secondary detailed assessment.

3.5.2.2 Wood

Wood Decay and Fungal Attack

Wood decay is the most common form of deterioration that affects the structural performance of a wood structure. Wood decay or rot occurs when fungi attack the wood. For this to occur, there needs to be sufficient exposure to moisture. As the wood is attacked, it loses strength to the point where it can easily be crumbled by hand.

Readily visible evidence for wood decay includes the following:

- Unusual heavily cracked or damaged appearance
- Discoloration (black, brown, white)
- Mycelium (spidery white growth)
- Wood type mushrooms
- Mouldy or musty smell
- Conditions that suggest water ingress, including water stains and damaged drywall (drywall fasteners popping out)
- Reports of abundant carpenter ants
- Excessive deflections

Wood Creep

Wood structures will continue to creep and deform, particularly those that are under heavy loads for many years after construction.

Readily visible evidence of wood creep includes the following:

- Excessive deflections
- Bowing
- Related signs of cracks in finishes

Differential Shrinkage

Differential shrinkage can occur, particularly between wood structural components and non-wood components; e.g., between wood-framed floors and a wall with a concrete core. In some circumstances these conditions could be great enough to warrant a structural review.

Visual evidence of differential shrinkage includes the following:

- Uneven floors, particularly at places like elevator doors and other transitions between wood and other types of structures
- Cracks in finishes

Cracks [Checks]

In timber structures (large cross-section framing members) "checks" are cracks that commonly occur due to initial drying of the wood. Checks tend to cross the growth rings at right angles. They are generally not a structural concern until they affect a significant portion of the member's cross-section. They can also be an issue where they occur in wood with spiral grain where the crack travels across the member.

Special attention should be paid to cracks that occur at or near connections

Corrosion of Fasteners

Corrosion of fasteners can occur if they are exposed to moisture. Certain types of wood preservatives can also cause deterioration of fasteners if the fastener is not corrosion-resistant.

Insect Infestations

Infestations of termites (which are not common in BC) and carpenter ants can damage wood structures; the presence of these insects can also indicate that wood decay (rot) could be present.

3.5.2.3 Steel

Corrosion

Corrosion and section loss are the primary forms of deterioration of structural steel. Corrosion occurs in the presence of water, oxygen, electrical continuity, and an electrochemical driving force. Normal structural steel in buildings will corrode in the presence of water if not properly protected with paint or galvanizing. Exposure to chloride ions and industrial pollutants (e.g., hydrogen sulfide [H2S] gas) can greatly increase the rate of steel corrosion.

Special attention is needed to check for corrosion at structurally critical connections. Connection geometry can trap water, leading to more significant and sometimes less-easily observed corrosion. They may contain different types of metals that could result in increased corrosion rate.

The depth of corrosion can be quickly ascertained by simply scraping away the loose corroded layers and estimating the depth of surface loss, using a scraping tool such as a glazer's bar.

Visual evidence for steel corrosion includes the following:

- Surface rust and apparent loss of cross-section thickness
- Corrosion pitting (small, dark, pinhole-like pits on the surface)
- Staining or bleeding, indicating a corroded element that may not be visually exposed
- Peeling paint
- Evidence of water ingress

Fatigue Cracks

Fatigue cracks are a less-common type of deterioration in building structures but can be significant for certain types of steel structures.

Fatigue cracks occur from repeated cycles of loading. Brittle fatigue failure can occur with little or no signs of plastic deformation. These may not be easily seen in a typical visual inspection, as they may be small and covered from sight.

Conditions that would lead to fatigue cracks occurring can be considered for more detailed visual examination during a structural condition assessment; e.g., welded structural connections exposed to repeat heavy loading.

Fracture Cracks

Fracture cracks are brittle cracks that occur with little or no plastic deformation, and are caused by factors such as low temperature, stress concentration, and steel metallurgical characteristics. They can be the result of impact loading.

3.5.2.4 Masonry

Soft or Disintegrated Mortar

Softening or weakening of mortar and eventual disintegration can occur from long-term exposure to weather. Loss of section, strength, and bond can result.

Evidence of deteriorated mortar includes the following:

- Erosion
- Heavy efflorescence
- Mortar that can be scratched away with relative ease

Note that older or historic lime mortars are always very low in strength and can be easily scratched without being deteriorated. This does not necessarily mean they are deteriorated and non-functional. Strength (scratch resistance) in a protected area can be compared to an exposed area to judge deterioration level.

Brick, CMU, and Stone Deterioration

Poor-quality bricks and concrete masonry units (CMU) can soften and disintegrate from long-term exposure to weather. Softer, poorer quality stone (such as sandstone) will also experience deterioration.

Visual evidence for this deterioration may include the following:

- Surface erosion
- Shelling or spalling of the face

Reinforcement Corrosion

In CMU structures, corrosion damage can occur in both ladder-type joint reinforcements and in reinforcing steel in grouted cells and bond beams. Damage to ladder reinforcing wires can be difficult to detect, as the wires are often too small to burst the steel. Damage of this type is not common, and it likely only occurs under extreme environmental conditions (e.g., salt exposure, constant thorough wetting) and in combination with a large number of cracks. Similarly, bond beam and cell reinforcing steel is normally very well protected and is likely to corrode only under extreme conditions. Visible evidence of corroded reinforcement and delamination in CMU is similar to that of reinforced concrete.

Older masonry structures, such as stone structures and some solid brick structures, can have embedded steel bracing. Over years and particularly where exposed to water, steel bracing and other elements, such as cast-iron rods and bars, can become heavily corroded. It is difficult to see these elements and drawings are often lacking.

Cracks

Cracks commonly run through the joints of masonry structures. Excessively wide cracks may indicate that masonry is unreinforced, and this can be important relative to seismic performance. The extent of cracks should be documented when it is considered excessive and structurally significant.

3.6 REPORTING

3.6.1 GENERAL REQUIREMENTS

The SER must provide a written report to the Client following completion of the structural condition assessment. The content of the report will depend on the scope of work but it should generally include the items provided in the following sample report outline in Table 1 below.

The report should clearly note whether a preliminary, detailed, or limited scope assessment was conducted.

The report should contain enough information to allow a non-technical reader to clearly understand the conclusions and recommendations of the report and the implications of not following the recommendations. The report should also contain sufficient information for other structural engineers to understand the scope of work, methodology, and level and type of analysis.

The SER should sign and seal the report in accordance with the Association's requirements (see Section 4.0 Quality Management in Professional Practice).

3.6.2 SAMPLE REPORT OUTLINE

The following table outlines the minimum information required in a report for a structural condition assessment of existing buildings.

Table 1: Sample Report Outline for a Structural Condition Assessment

REPORT SECTION	REQUIRED CONTENT
Introduction	• A concise outline in simple language, describing the project in general • Typically includes the location, general type of building, and reason for the assessment • Does not typically include any results, conclusions, or recommendations – May include brief summary of serious concerns if applicable
Scope of Work	• A point-by-point description of what has been completed in the assessment • Refer to Section 3.1 Overview of Structural Condition Assessments
Building Description	• Should generally include the following: – Description of the structural systems and the building – Dates of construction, additions, major repairs – Current and/or proposed use, changes in use
Methodology	• Usually technical in nature • Describes the type of analyses, assumptions, performance levels, and similar methods upon which the assessment is based • Provides details on how codes, standards, and guidelines are used or relied upon in the assessment
Document Review	• Outlines all the existing building documents used in the assessment • Refer to the Review of Record Documents sections for each type of assessment in Sections 3.2.1, 3.3.1, and 3.4.2
Field Evaluation	• Describes the observations and data collected • Refer to the Field Evaluation sections for each type of assessment in Sections 3.2.2, 3.3.2, and 3.4.3 • Also include any material issues, as described in Section 3.5 Material Condition Assessments

REPORT SECTION	REQUIRED CONTENT
Analysis	• Presents the results of the structural analysis • Refer to Sections 3.2.3 Preliminary Analysis, 3.3.3 Detailed Analysis, and 3.4.4 Limited Scope Analysis
Discussion	• Provides more detailed explanation and interpretation of, or comments on, the assessment findings
Conclusions and Recommendations	• Includes a summary of the significant facts or findings of the assessment • Includes recommendations to address the structural concerns identified in the assessment, where appropriate • Clearly states any Immediate Actions and other requirements • Refer to Sections 3.1.3 Types of Assessments and 3.1.4 Immediate Actions
Appendices	• Can include relevant background documents, such as field sketches, photographs, data and evaluation results

4.0 QUALITY MANAGEMENT IN PROFESSIONAL PRACTICE

4.1 QUALITY MANAGEMENT REQUIREMENTS

Engineering Professionals must adhere to the applicable quality management requirements during all phases of the work, in accordance with the Association's Bylaws. It is also important to be aware of whether additional quality management requirements exist from Authorities Having Jurisdiction or through service contracts.

To meet the intent of the quality management requirements, Engineering Professionals must establish and maintain documented quality management processes for the following activities:

- The application of relevant professional practice guidelines
- Authentication of professional documents by the application of the professional seal
- Direct supervision of delegated professional engineering activities
- Retention of complete project documentation
- Regular, documented checks using a written quality control process
- Documented field reviews of engineering designs/recommendations during implementation or construction
- Where applicable, documented independent review of structural designs prior to construction

4.1.1 PROFESSIONAL PRACTICE GUIDELINES

In accordance with the *Act*, s.4(1) and Bylaw 11(e)(4)(h), Engineering Professionals are required to comply with the intent of any applicable professional practice guidelines related to the engineering work they undertake. One of the three objectives of the Association, as stated in the *Act* is "to establish, maintain, and enforce standards for the qualifications and practice of its members and licensees". Practice guidelines are one means by which the Association fulfills this obligation.

These professional practice guidelines establish the standard of practice for structural condition assessments of existing buildings. Engineering Professionals who carry out these activities are required to meet the intent of these guidelines.

4.1.2 USE OF SEAL

In accordance with the *Act*, s.20(9), Engineering Professionals are required to seal all professional engineering documents they prepare or deliver in their professional capacity to others who will rely on the information contained in the documents. This applies to documents that Engineering Professionals have personally prepared and those that others have prepared under their direct supervision.

Failure to seal these engineering documents is a breach of the *Act*.

As noted in Section 3.6 Reporting, the SER should seal assessment reports and other recommendations that result from the execution of structural condition assessments.

For more information, refer to *Quality Management Guidelines – Use of Seal* (Engineers and Geoscientists BC 2017b).

4.1.3 DIRECT SUPERVISION

In accordance with the *Act*, s.1(1) and 20(9), Engineering Professionals are required to directly supervise any engineering work they delegate. When working under the direct supervision of an Engineering Professional, unlicensed persons or non-members may assist in performing engineering work, but they may not assume responsibility for it. Engineering Professionals who are limited licensees may only directly supervise work within the scope of their license.

With regard to direct supervision, the Engineering Professional having overall responsibility should consider:

- the complexity of the project and the nature of the risks;
- which aspects of the work should be delegated;
- the training and experience of individuals to whom work is delegated; and
- the amount of instruction, supervision, and review required.

Careful consideration must be given to delegating field reviews. Due to the complex nature of field reviews, Engineering Professionals with overall responsibility should exercise judgment when relying on delegated field observations, and should conduct a sufficient level of review to have confidence in the quality and accuracy of the field observations. (See Section 4.1.6 Documented Field Reviews During Implementation or Construction.)

For more information, refer to *Quality Management Guidelines – Direct Supervision* (Engineers and Geoscientists BC 2018a).

4.1.4 RETENTION OF PROJECT DOCUMENTATION

In accordance with Bylaw 14(b)(1), Engineering Professionals are required to establish and maintain documented quality management processes that include retaining complete project documentation for a minimum of ten (10) years after the completion of a project or ten (10) years after engineering documentation is no longer in use.

These obligations apply to Engineering Professionals in all sectors. Project documentation in this context includes documentation related to any ongoing engineering work, which may not have a discrete start and end, and may occur in any sector.

Many Engineering Professionals are employed by organizations, which ultimately own the project documentation. Engineering Professionals are considered compliant with this quality management requirement when a complete set of project documentation is retained by the organizations that employ them using means and methods that are consistent with the Association's Bylaws and guidelines.

For more information, refer to *Quality Management Guidelines – Retention of Project Documentation* (Engineers and Geoscientists BC 2018b).

4.1.5 DOCUMENTED CHECKS OF ENGINEERING AND GEOSCIENCE WORK

In accordance with Bylaw 14(b)(2), Engineering Professionals are required to perform a documented quality checking process of engineering work, appropriate to the risk associated with that work.

Regardless of sector, Engineering Professionals must meet this quality management requirement. In this context, 'checking' means all professional deliverables must undergo a documented quality checking process before being finalized and delivered. This process would normally involve an internal check by another Engineering Professional within the same organization. Where an appropriate internal checker is not available, an external checker (i.e., one outside the organization) must be engaged. Where an internal or external check has been carried out, this must be documented.

Engineering Professionals are responsible for ensuring that the checks being performed are appropriate to the level of risk. Considerations for the level of checking should include the type of document and the complexity of the subject matter and underlying conditions; quality and reliability of background information, field data, and elements at risk; and the Engineering Professional's training and experience.

For more information, refer to *Quality Management Guidelines – Documented Checks of Engineering and Geoscience Work* (Engineers and Geoscientists BC 2018c).

4.1.6 DOCUMENTED FIELD REVIEWS DURING IMPLEMENTATION OR CONSTRUCTION

In accordance with Bylaw 14(b)(3), field reviews are reviews conducted at the site of the construction or implementation of the engineering work. They are carried out by an Engineering Professional or a subordinate acting under the Engineering Professional's direct supervision (see Section 4.1.3 Direct Supervision).

Field reviews enable the Engineering Professional to ascertain whether the construction or implementation of the work substantially complies in all material respects with the engineering concepts or intent reflected in the engineering documents prepared for the work.

For more information, refer to *Quality Management Guidelines – Documented Field Reviews during Implementation or Construction* (Engineers and Geoscientists BC 2018d).

4.1.7 DOCUMENTED INDEPENDENT REVIEW OF STRUCTURAL DESIGNS

Bylaw 14(b)(4) refers to an independent review in the context of structural engineering. An independent review is a documented evaluation of the structural design concept, details, and documentation based on a qualitative examination of the substantially complete structural design documents, which occurs before those documents are issued for construction. It is carried out by an experienced Engineering Professional qualified to practice structural engineering, who has not been involved in preparing the design.

Generally, structural design services are outside of the scope of a structural condition assessment. However, Engineering Professionals formulating designs concurrent with or based on the information contained in a structural condition assessment must ensure that such designs undergo an independent review.

For more information, refer to *Quality Management Guidelines – Documented Independent Review of Structural Designs* (Engineers and Geoscientists BC 2018e).

5.0 PROFESSIONAL REGISTRATION & EDUCATION, TRAINING, AND EXPERIENCE

5.1 PROFESSIONAL REGISTRATION

It is the responsibility of Engineering Professionals to determine whether they are qualified by training and/or experience to undertake and accept responsibility for carrying out structural condition assessment of buildings (Code of Ethics Principle 2).

5.2 EDUCATION, TRAINING, AND EXPERIENCE

Performing structural condition assessment of buildings, as described in these guidelines, requires minimum levels of education, training, and experience in many overlapping areas of engineering. The Engineering Professional taking responsibility must adhere to the Association's Code of Ethics (to undertake and accept responsibility for professional assignments only when qualified by training or experience) and, therefore, must evaluate his or her qualifications and must possess the appropriate education, training, and experience to provide the services.

The level of education, training, and experience required of the Engineering Professional should be adequate for the complexity of the project.

Typical qualifications for the Structural Engineer of Record or a team of professionals may include education and experience in the following areas:

- Registration as a P.Eng. with Engineers and Geoscientists BC in the discipline of structural engineering
- Previous experience on structural condition assessments of buildings under the supervision of a registered structural engineer practicing in this area
- Education, training, and experience for the type and location of building being assessed

The academic training for the above skill sets can be acquired by taking formal university or college courses or through continuing professional development. There may be some overlap in courses and specific courses may not correlate to specific skill sets. An Engineering Professional should also remain current with evolving topics, through continuing professional development. Continuing professional development can include taking formal courses; attending conferences, workshops, seminars, and technical talks; reading technical publications; doing web research; and participating in field trips.

It is the responsibility of the structural engineer to determine whether they are qualified by training and/or experience to undertake and accept responsibility for carrying out structural condition assessment of buildings.

Engineering Professionals undertaking a structural condition assessment of existing buildings should have knowledge and experience in:

- structural engineering as it applies to the building being assessed;
- failure mechanisms of structures and structural elements;
- statutes, regulations, standards, codes, bylaws, and rules that apply to the work being undertaken;
- properties, life expectancy, and durability of structural materials; and
- past and present methods of constructing buildings.

6.0 REFERENCES AND RELATED DOCUMENTS

Numerous technical documents have been published by recognized national and international authorities that focus on methods for assessing the strength, durability, and reliability of structural materials, assemblies, and systems in existing buildings. These documents are regularly revised, expanded, and enhanced to keep pace with scientific research and technological advances.

A number of these technical guidelines, standards, and other sources are cited in these guidelines and appear in Section 6.2 References below.

6.1 REGULATIONS

The following regulations are referenced in these guidelines:

Engineers and Geoscientists Act [RSBC 1996], Chapter 116.

Workers Compensation Act [RSBC 1996], Chapter 492.

Workers Compensation Act, Occupational Health and Safety Regulation, B.C. Reg. 296/97.

6.2 REFERENCES

The following documents are referenced in these guidelines:

American Concrete Institute (ACI). 2019. ACI 562-19 Code Requirements for Assessment, Repair, and Rehabilitation of Existing Concrete Structures and Commentary. Farmington Hills, MI: ACI.

ACI. 2010. 214.4R Guide for Obtaining Cores and Interpreting Compressive Strength Results. Farmington Hills, MI: ACI.

American Society of Civil Engineers (ASCE). 2000. SEI/ASCE 11-99 Guideline for Structural Condition Assessment of Existing Buildings. Reston, VA: ASCE.

ASCE. 2017. ASCE/SEI 41 Seismic Evaluation and Retrofit of Existing Buildings. Reston, VA: ASCE.

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City of Vancouver. 2019. City of Vancouver Building By-law 2019. Vancouver, BC: City of Vancouver. [accessed: 2020 May 06]. http://www.bccodes.ca/vancouver-bylaws.html.

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Engineers and Geoscientists BC. 2017a. Seismic Retrofit Guidelines, 3rd Edition (SRG-3). Burnaby, BC: Engineers and Geoscientists BC.

Engineers and Geoscientists BC. 2017b. Quality Management Guidelines: Use of Seal. Version 2.0. Burnaby, BC: Engineers and Geoscientists BC. [accessed: 2020 May 06]. https://www.egbc.ca/Practice-Resources/Quality-Management-Guidelines.

Federal Emergency Management Agency (FEMA). 2018. P-58 Seismic Performance Assessment of Buildings. Washington, DC: FEMA.

National Research Council Canada (NRC). 2015. National Building Code of Canada (NBC) 2015. Structural Commentaries (User's Guide - NBC 2015: Part 4 of Division B). Ottawa, ON: NRC.

Professional Engineers Ontario (PEO). 2016. Structural Condition Assessments of Existing Buildings and Designated Structures Guideline. November 2016. Toronto, ON: PEO. [accessed: 2020 May 06]. https://www.peo.on.ca/sites/default/files/2019-10/StructuralConditionAssessmentsGuideline.pdf.

WorkSafeBC. 2019. Occupational Health and Safety Regulation (OHSR). [website]. [accessed: 2020 May 06]. https://www.worksafebc.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation/ohsregulation.

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