

The Seismic Assessment of Existing Buildings

Technical Guidelines for Engineering Assessments

July 2017

Assessment Objectives and Principles

Part A



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- 2 Part B – Initial Seismic Assessment
- 3 Part C – Detailed Seismic Assessment

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Errata and other technical developments will be notified via www.building.govt.nz

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A1. Introduction

A1.1 General

The purpose of these engineering assessment guidelines is to assist engineers, building owners, territorial authorities (TAs) and building consent authorities (BCAs) responding to the challenges involved in understanding, managing and, over time, reducing seismic risk for people using existing buildings.

These guidelines provide engineers with the means to assess the seismic behaviour of existing buildings and building parts and to report the assessment results to building owners and agencies responsible for managing these. Such assessments can be for a range of purposes, including general property risk identification, change of use, and alterations.

These guidelines are also an integral part of the EPB methodology produced by the Ministry of Business, Innovation and Employment (MBIE) under section 133AV of the Building Act 2004 to identify earthquake-prone buildings.

This version of the guidelines is the result of an extensive revision by a Project Technical Group and incorporates research, knowledge and experience obtained from the significant New Zealand earthquakes between 2010 and 2016.

These guidelines are in three parts:

- Part A (this Part) provides assessment objectives and core principles to support detailed guidance on the Initial Seismic Assessment (ISA) method in Part B and the significantly more extensive Detailed Seismic Assessment method (DSA) in Part C. Part A also aims to provide an accessible reference for building owners and managers who need to understand the seismic assessment process.
- Part B covers the qualitative ISA method (including the Initial Evaluation Procedure, or IEP), which enables a broad indication of the earthquake rating of a building. It guides an engineer who is developing a holistic view of a building's structural weaknesses and assigning a qualitative earthquake rating to the building.
- Part C describes the more extensive, quantitative DSA method, which provides a more comprehensive assessment of the likely earthquake rating of a building.

An **Initial Seismic Assessment** procedure using Parts A and B together is essentially a qualitative procedure that observes building attributes, uses these to develop a holistic understanding of how the building would respond to an earthquake and provides an initial assessment of its earthquake rating. An ISA may include quantitative assessments of some elements if an engineer considers they are relatively easily carried out to improve the overall assessment.

An ISA is generally the first part of any seismic assessment because it provides a valuable 'first look' at the likely building performance and a valuable benchmark for comparison with buildings of similar age and other characteristics.

A **Detailed Seismic Assessment** using Parts A and C is a quantitative procedure that can take several forms. These have been developed specifically for assessing existing buildings and, it is important to note, are not simply a back calculation of the design process used for new buildings.

A DSA is used to confirm an earthquake rating for a building, particularly when a higher degree of reliability than considered available from a qualitative ISA rating is required. It can also be used to identify retrofit needs and provide a benchmark for proposed upgrading strategies to be tested against.

A1.2 Scope

These guidelines are specifically for the seismic assessment of existing buildings and apply to buildings of all eras and of all construction types and materials. They are also intended to be used for assessing existing building construction that is included in an upgrade of an existing building (e.g. seismic retrofit or alterations generally), or where a change of use is intended.

The assessment methods and criteria in these guidelines are not intended for use when designing new buildings (e.g. as justification for Building Code compliance), or for the design of new elements within an existing building that is being altered (e.g. retrofitted).

Note:

These guidelines are also not intended to be specifically applied to bridges, towers, masts, retaining walls, or building contents.

Although not intended for these types of structure, many of the approaches outlined and criteria presented may be helpful for this purpose if suitably adapted.

A1.3 Objectives

The objective of these guidelines is to provide engineers with a framework for assessing an existing building and the associated technical methods to:

- lead engineers toward understanding how that building might perform across a range of ground shaking levels
- provide an earthquake rating for the building based on the minimum expectations and requirements for a new building and with a level of conservatism that is appropriate for the level of detail available
- provide a level of assessment that is appropriate for the person commissioning the assessment, including appropriate information to help TAs determine whether or not a building is earthquake prone under the Building Act if the assessment is for that purpose, and
- produce consistent assessments by different engineers when based on the same information and briefing.

These guidelines aim to provide engineers with the communication tools to:

- effectively and consistently communicate the outcomes of assessments, and
- enable building owners to understand and be able to improve the seismic safety of their buildings and, where necessary, prioritise any mitigation works.

Note:

The guidelines also support the wider objective of reducing risk for those buildings expected to perform poorly in significant earthquakes, such as work to reduce seismic risk via seismic retrofit or other improvement measures where required. A general overview and key principles associated with seismic improvement are provided in Section A10, with further guidance and examples to be provided in separate documentation.

A1.4 Regulatory Interface

As noted above, this version of the engineering assessment guidelines forms an integral part of the framework for managing earthquake-prone buildings under the Building Act 2004 (as amended by the Building (Earthquake-prone Buildings) Amendment Act 2016), and also for other aspects of the Building Act relevant for existing buildings including change of use and alterations.

The earthquake-prone building framework includes the following interdependent components:

- the Building Act, which contains earthquake-prone building provisions
- associated regulations which define ultimate capacity, establish earthquake rating categories, prescribe the form of earthquake-prone building notices, and prescribe criteria whereby requirements to carry out seismic work to earthquake-prone buildings may be either exempted or completed earlier because of substantial alterations
- the EPB methodology, which describes how TAs identify potentially earthquake-prone buildings, how these are to be assessed, and how decisions about earthquake-prone buildings and their ratings are made by TAs, and
- these guidelines, which provide the technical means of meeting the requirements for engineering assessments undertaken for potentially earthquake-prone buildings in accordance with the EPB methodology.

Section B1 of the Building Code provides the reference point for the performance standard required for seismic assessments in general. Refer to Section A3.2 for further information.

For more detail on the way in which these guidelines are intended to be used in conjunction with the Building Act refer to Section A5.

Note:

It is expected that an engineer will have available, and be familiar with, the latest versions of the Building Act, associated regulations and the EPB methodology when completing a seismic assessment in accordance with these guidelines. Although these documents relate to the assessment for potentially earthquake-prone buildings the principles captured within them are applied to seismic assessments generally. This is discussed in further detail in Section A5.1.

A1.5 Requirements for Engineers Undertaking Assessments

All seismic assessments are expected to be undertaken by experienced engineers with considerable knowledge of how buildings respond to earthquakes, as well as an ability to exercise judgement regarding key attributes and their effects on building seismic behaviour.

These engineers need to develop a holistic understanding of how the building and its elements would perform during an earthquake and ensure that specialised assessments of building elements such as facades, ceilings and building services adequately address how they interact with the building during an earthquake.

It is therefore essential that every assessment is carried out under the direction of a New Zealand Chartered Professional Engineer (CPEng), or equivalent, who:

- has sufficient relevant experience in the design and evaluation of buildings for earthquake effects to exercise the degree of judgement required, and
- has specific training in the objectives of and processes involved in the assessment procedures contained in these guidelines.

When independent review is called for, the requirements outlined above for the assessment itself should also apply for the engineer overseeing the review.

The EPB methodology specifies qualification requirements for completing engineering assessments as part of the process to determine earthquake-prone status.

Note:

The requirement for high levels of judgement when establishing an earthquake rating from the ISA process cannot be understated, and is discussed further in Part B.

A1.6 Definitions and Acronyms

(New Zealand) Building Code	Section B1 of the New Zealand Building Code (Schedule 1 to the Building Regulations 1992)
Building Element	Any structural or non-structural component and assembly incorporated into or associated with a building. Included are fixtures, services, drains, permanent mechanical installations for access, glazing, partitions, ceilings and temporary supports (from the Building Code).
CERC	Canterbury Earthquake Royal Commission (of Enquiry)
Critical Structural Weakness (CSW)	The lowest scoring structural weakness determined from a DSA. For an ISA, all structural weaknesses are considered to be potential critical structural weaknesses.
Detailed Seismic Assessment (DSA)	A quantitative seismic assessment carried out in accordance with Part A and Part C of these guidelines
Earthquake-prone Building (EPB)	Has the meaning defined in section 133AB of the Building Act 2004, and explained in Section A5.1.1 of these guidelines.
Earthquake rating	The rating given to a building as a whole to indicate the seismic standard achieved in regard to human life safety compared with the minimum seismic standard required of a similar new building on the same site. Expressed in terms of percentage of new building standard achieved (<i>XXX%NBS</i>). The earthquake rating for a building as a whole takes account of, and may be governed by, the earthquake scores for individual building elements. For earthquake-prone buildings earthquake rating has the meaning defined in section 133AC of the Building Act 2004.
Earthquake Risk Building (ERB)	A building that falls below the threshold for acceptable seismic risk, as recommended by NZSEE (i.e. <67%NBS or two thirds new building standard)
Earthquake score	The score given to an individual aspect of the building (member/element/non-structural element/foundation soils) to indicate the seismic standard achieved in regard to human life safety compared with the minimum seismic standard required for the same aspect in a similar new building on the same site. Expressed in terms of percentage of new building standard achieved (<i>XXX%NBS</i>). The aspect with the lowest earthquake score is the CSW and this score will represent the earthquake rating for the building.
Existing building	A building that is complete and ready for use, i.e. a code compliance certificate is able to be issued
Existing members/elements	Members/elements that are part of an existing building and not defined as new members/elements as defined below
Importance Level (IL)	Categorisation defined in the New Zealand Loadings Standard, AS/NZS 1170.0:2002 used to define the ULS shaking for a new building based on the consequences of failure. A critical aspect in determining new building standard.
Initial Seismic Assessment (ISA)	A seismic assessment carried out in accordance with Part A and Part B of these guidelines. An ISA is a recommended first qualitative step in the overall assessment process.
Moderate earthquake (shaking demand)	Has the meaning defined in the Building (Specified Systems, Change the Use, and Earthquake-prone Buildings) Regulations 2005 (as amended).
New Building Standard (NBS)	Intended to reflect the expected seismic performance of a building relative to the minimum life safety standard required for a similar new building on the same site by Clause B1 of the New Zealand Building Code.

New building	A building is considered to be a new building until all of it is complete and ready for use (i.e. a code compliance certificate is able to be issued)
New members/ elements	Members/elements to be added to an existing building. Members/ elements are considered to be new until an alteration involving their addition is complete and a code compliance certificate has been issued.
Non-structural element	An element within the building that is not considered to be part of either the primary or secondary structure
Part (of a building)	An individual member or element or section of a building's structure (as distinct from the building structure as a whole), or a non-structural element. Refer also to the EPB methodology for the extent to which parts of buildings must be considered in assessments of potentially earthquake-prone buildings.
Primary gravity structure	Portion of the main building structural system identified as carrying the gravity loads through to the ground. Also required to carry vertical earthquake induced loads through to the ground. May also be part of the primary lateral structure.
Primary lateral structure	Portion of the main building structural system identified as carrying the lateral seismic loads through to the ground. It may also be part of the primary gravity structure.
Probable capacity	The expected or estimated mean capacity (strength and deformation) of a member, an element, a structure as a whole, or foundation soils. For structural aspects, this is determined using probable material strengths and a strength reduction factor set at 1. For geotechnical issues the probable resistance is typically taken as the ultimate geotechnical resistance/strength that would be assumed or calculated for design.
Probable material strength	The expected or estimated mean material strength. For geotechnical issues assessed in accordance with these guidelines it is typically the soil properties that would be used to calculate the ultimate geotechnical strength/resistance assumed for design.
Secondary structural element	A structural element that is not part of the primary structure
Secondary structure	Portion of the structure that is not part of either the primary lateral or primary gravity structural systems but nevertheless is required to transfer inertial and gravity loads for which assessment/design by a structural engineer would be expected. Included are pre-cast concrete panels, curtain wall framing systems, stairs and supports for significant building services items.
Serviceability limit state (SLS)	Limit state defined in the New Zealand loadings standard NZS 1170.0:2002
Severe structural weakness (SSW)	A defined structural weakness that is potentially associated with catastrophic collapse and for which the capacity may not be reliably assessed based on current knowledge. For an ISA, potential SSWs are expected to be noted when identified, and may extend to issues that require Detailed Seismic Assessment before they can be removed from consideration.
Significant life safety hazard	As described in Section A3.1.1.
Space Class	Classification of a particular space based on functional purpose and hazard
SSNS	Secondary structural and non-structural
Structural weakness (SW)	An aspect of the building structure and/or the foundation soils that scores less than 100%NBS. An aspect of the building structure scoring less than 100%NBS but greater than or equal to 67%NBS is still considered to be a structural weakness even though it is considered to represent an acceptable risk.

Ultimate capacity (seismic)	<p>Has the meaning defined in the Building (Specified Systems, Change the Use, and Earthquake-prone Buildings) Regulations 2005 (as amended) and explained in Section 5.1.1 of these guidelines.</p> <p>This definition is applicable for all assessments.</p>
Ultimate limit state (ULS)	A limit state defined in the New Zealand loadings standard NZS 1170.5:2004 for the design of new buildings
Unreinforced masonry (URM)	A member or element comprising masonry units connected together with mortar and not containing any steel, timber, cane or other reinforcement
(XXX)%NBS	<p>The ratio of the ultimate capacity of a building as a whole or of an individual member/element and the ULS shaking demand for a similar new building on the same site, expressed as a percentage.</p> <p>It is the rating given to a building as a whole expressed as a percent of new building standard achieved, based on an assessment of the expected performance of an existing building relative to the minimum that would apply under the Building Code (Schedule 1) to the Building Regulations 1992) to a new building on the same site with respect to life safety.</p> <p>A score for an individual building element is also expressed as a percent of new building standard achieved. This is expected to reflect the degree to which the individual element is expected to perform in earthquake shaking compared with the minimum performance prescribed for the element in Clause B1 of the Building Code (Schedule 1 to the Building Regulations 1992) with respect to life safety.</p> <p>The %NBS rating for the building as a whole takes account of, and may be governed by, the scores for individual elements.</p>
(XXX)%ULS shaking demand	<p>Percentage of the ULS shaking demand (loading or displacement) defined for the ULS design of a new building and/or its members/elements for the same site.</p> <p>For general assessments 100%ULS shaking demand for the structure is defined in the version of NZS 1170.5 (version current at the time of the assessment) and for the foundation soils in NZGS/MBIE Module 1 of the Geotechnical Earthquake Engineering Practice series dated March 2016.</p> <p>For engineering assessments undertaken in accordance with the EPB methodology, 100%ULS shaking demand for the structure is defined in NZS 1170.5:2004 and for the foundation soils in NZGS/MBIE Module 1 of the Geotechnical Earthquake Engineering Practice series dated March 2016 (with appropriate adjustments to reflect the required use of NZS 1170.5:2004). Refer also to Section C3.</p>

A2. Background

A2.1 Introduction

This version of the guidelines provides a comprehensive revision of the 2006 New Zealand Society for Earthquake Engineering (NZSEE) document - *Assessment and Improvement of Structural Performance of Buildings in Earthquakes* (the 2015 version incorporating Corrigenda 1, 2, 3 and 4).

This section provides background on the development over time of these guidelines to address earthquake risk and earthquake-prone buildings, and the historical role of the NZSEE in producing technical guidance in support of the building legislation and related activities of the time.

A2.2 Earthquake Risk and New Zealand Buildings

The earthquake risk of existing buildings has been recognised for many years. The initial legislation in 1968 (the Municipal Corporations Act) was directed at unreinforced masonry (URM) buildings, whose potential dangers were first apparent in the 1931 Hawke's Bay earthquake. URM construction ceased with the introduction of New Zealand's first earthquake standard in 1935, but large stocks of these buildings remain throughout the country. Action was taken by some TAs via the passage of by-laws in response to the 1968 legislation, and a number of buildings (most notably in Wellington) were strengthened to its requirements and sometimes beyond.

The level of strength below which a building required strengthening or demolition was set at one-half of the 1965 New Zealand Standard (NZS 1900 Chapter 8). While this has always been considered to be a low threshold by structural engineers, it was retained when these provisions were incorporated within the earthquake-prone building provisions of the 1991 Building Act.

The NZSEE first produced guidelines to assist in the assessment and strengthening of URM buildings in the 1970s. In 1986 the guidance was fully revised and published as the 'Red Book', a label that remained attached to subsequent versions.

Valuable information and experience has been brought back from overseas earthquakes via the NZSEE reconnaissance programme, funded by the Earthquake Commission (EQC). Most notably the Northridge (1994) and Kobe (1995) earthquakes brought to light concerns about the adequacy of more recent designs, particularly those constructed in the period of early seismic codes between 1935 and 1976. Most buildings designed before the publication of the 1976 structural loadings standard NZS 4203:1976 and its associated materials codes typically do not have either the level of ductility or appropriate hierarchy of failure (i.e. the principles of capacity design) required by current design standards.

Acknowledging these concerns in 1994, the Building Industry Authority commissioned NZSEE to produce a document setting down the requirements for structural engineers to follow when evaluating and strengthening post-1935 buildings. An initial 1996 draft was

further developed into the 2006 NZSEE Guidelines - *Assessment and Improvement of the Structural Performance of Buildings in Earthquakes* to accompany the widened scope of the earthquake-prone building provisions of the Building Act 2004.

The 2006 NZSEE Guidelines, and particularly the Initial Evaluation Procedure (IEP), were widely used both by TAs and structural engineers carrying out assessments and improvement measures for existing buildings.

The Building Act 2004 extended the scope of earthquake-prone buildings from URM to include any building found to be below the required earthquake rating. The threshold was raised to include buildings that would have their ultimate capacity exceeded in a moderate earthquake defined as one-third of shaking defined for the design of a similar new building.

TAs were required to have earthquake-prone building policies stating what their approaches and timetables would be to identify and require action on “earthquake-prone” buildings. Implementation by TAs varied considerably, but each TA had to assess its local earthquake risks in the course of producing a policy. Some TAs had active policies that typically involved screening of commercial buildings to identify those that were potentially earthquake prone (typically using the IEP); others had passive policies that only addressed earthquake-prone buildings when they came to their attention via consent applications. The extent of implementation nationwide was as a result quite variable.

The initial TA policies were due for their 5-year review in June 2011. In July 2010, the then Department of Building and Housing and EQC sponsored a major workshop for TAs, owners, developers and designers to share their experiences of developing and implementing earthquake-prone building policies. The aim was to better inform each TA ahead of the policy update.

However, the Canterbury earthquake sequence, which began with the Darfield earthquake on 4 September 2010, forced other priorities on affected TAs, owners, designers and communities. As a result, the revision of earthquake-prone building policies was put on hold in many locations while the impacts and implications of these earthquake events were considered.

A2.3 Drivers for this Revision

A2.3.1 General

A change to legislation was the key driver for this extensive revision of these engineering assessment guidelines. However, this was the culmination of a demand that began with damage to URM buildings in the 4 September 2010 Darfield earthquake and major damage to buildings across all types and eras in Christchurch and surrounding areas during the 22 February 2011 Christchurch earthquake. The impetus has continued with experiences of the Cook Strait earthquakes in 2013 and the Kaikoura Earthquake in 2016.

The Canterbury earthquake sequence led to an unprecedented number of seismic assessments being undertaken, both within the greater Christchurch region, for regulatory and insurance purposes, and nationally, in response to the heightened awareness of seismic risk. This sequence also provided a significant volume of information about the behaviour of New Zealand buildings.

It is clear from the experiences of the Canterbury earthquake sequence that URM buildings remain a significant challenge. The section of these guidelines covering URM buildings (released in 2015) was revised and expanded to incorporate additional research and to take advantage of the lessons from Canterbury.

When reviewing the factors contributing to the failure of buildings where lives were lost, the Canterbury Earthquakes Royal Commission (CERC) gave extensive consideration to the failure of URM buildings and to the collapse of the two non URM buildings where most lives were lost. Their recommendations and other research into building failures, were taken into account when developing these guidelines.

The Royal Commission recommendations also led to a government review of the earthquake-prone buildings regulatory framework in 2011 and the subsequent legislative change (refer to Section A2.3.2) also contributed to the need to update the technical guidance for engineers.

The number of structural and geotechnical engineers in New Zealand who were experienced in seismic assessments was relatively limited at the time that the Canterbury earthquake sequence began, and this resource quickly became overloaded. Many of the subsequent assessments have been undertaken by engineers with limited seismic assessment experience and little or no formal training in seismic assessment.

The 2006 NZSEE Guidelines focused on pre-1976 concrete and steel multi-storey and URM buildings, and provided little guidance on low-rise buildings generally, and timber structures in particular. It also had no guidance on geotechnical matters or building elements that are not part of a primary structural system.

These gaps, which led to many conservative assessments of low-rise buildings during the period from 2011 to 2014, have been addressed in this revision of the guidelines, along with a desire for greater consistency in assessment and reporting outcomes. It is recognised that improved consistency will require extensive and ongoing education and training of structural and geotechnical engineers conducting assessments.

These new guidelines therefore include consideration of the latest available information, take advantage of the lessons learnt from the Canterbury earthquakes, address the changes to the Building Act 2004 (refer also Sections A2.3.2 and A5), and target the wider areas of need and concern amongst engineers, owners and the public.

Note:

The changes to the Building Act 2004 and associated regulations specifically address earthquake-prone buildings. However, the key principles embodied in the assessment processes for earthquake-prone buildings also apply to all assessments completed in accordance with these guidelines. These include the concepts of:

- focusing on life safety
- earthquake ratings/scores and what should be included in determining the rating
- ultimate (probable) capacity
- relating the demand to that which applies to a new building on the same site
- the inclusion of building parts
- significant life safety hazard.

A2.3.2 Changes to legislation

The Building (Earthquake-prone Buildings) Amendment Act 2016 came into effect in July 2017 and provided another key driver for the revision of these guidelines.

Significant changes to the regulatory framework for identifying and managing earthquake-prone buildings under the Building Act have resulted.

A summary of these changes is provided on the following website:

<https://www.building.govt.nz/managing-buildings/managing-earthquake-prone-buildings/>.

What this means for engineers undertaking assessments of existing buildings for the purpose of identifying whether or not they are earthquake prone is outlined in Section A5 of these guidelines.

A3. Underlying Principles

A3.1 Life Safety Focus

These guidelines focus the assessment on life safety issues as the primary objective. This means that the earthquake scores or rating are based primarily on life safety considerations rather than damage to the building or its contents unless this might lead to damage to adjacent property. The earthquake rating assigned is, therefore, not reflective of serviceability performance and the reporting should warn of this.

There are two general forms of life safety hazard to consider; when the ultimate capacity of the building, a section of the building or a primary structural element is exceeded to the extent that a significant life safety issue arises, or when a falling secondary structural or non-structural (SSNS) building element poses a significant life safety hazard.

Determining when a significant life safety hazard is developed is an important aspect of assessments carried out in accordance with these guidelines. This is discussed in Section A3.1.1.

For the evaluation of earthquake-prone status it is the TA that needs to make the final decision as to whether or not a significant life safety issue exists. The EPB methodology sets out the process requirements to do this. Further information on respective roles in determining a building earthquake prone are explained in Section A5 of these guidelines.

Note:

Health and Safety considerations associated with building elements in general and contents are outside the scope of these guidelines.

The onset and progression of building damage, other than to the extent that it can affect adjacent property and the ability to egress a building, is not a primary consideration in the approaches outlined in these guidelines. Assessment of behaviour at serviceability limit state levels of loading is therefore not expected in the assessment process outlined. This is a significant difference to new building design, where the application of the serviceability limit state requirements is intended to limit damage at moderate levels of earthquake shaking and therefore often determines the minimum strength of a new element or of a new building as a whole.

Often building owners and occupiers may also be interested in the damage potential to the building, including structural and non-structural building elements, and how this might affect business continuity and economic considerations. These aspects are beyond the scope of these guidelines and the guidance provided will not necessarily address them.

A3.1.1 Significant life safety hazard

A significant life safety hazard is an unavoidable danger that a number of people are exposed to.

A significant life safety hazard, as distinct from a life safety hazard, is intended to preclude from consideration building elements that are of insufficient size to constitute a life safety

hazard of reasonable extent. Such items may include relatively small volumes of falling debris (e.g. individual bricks in an URM building or spalling of concrete in a reinforced concrete building), or small light weight items or items that fall from a relatively low height.

Failure of a building or building section as a whole (leading to collapse) is considered to be a significant life safety hazard but failure of individual members/elements in the primary structure will only constitute a significant life safety hazard, when considered individually, if their failure causes them to fall.

A significant life safety hazard can also result from the loss of gravity load support of a member/element of the secondary structure, or of the supporting ground, or of non-structural items that would reasonably affect a number of people.

Elements considered to represent a significant life safety hazard if they were to fall are set out in Table A4.1.

Note:

The life safety hazard exposure is only defined qualitatively. It would be very difficult to quantify this numerically in order to provide a uniform exposure to every possible danger, number of people exposed to it, and their exposure duration. The same difficulty applies to quantifying the number of people exposed.

A danger from a significant life safety hazard can be considered to be avoidable if furniture is present that would provide protection as part of the “drop, cover, hold” mitigation plan.

A3.1.2 Importance Level 4 buildings

The focus of seismic assessments using this document is on the life safety of those occupying and immediately outside the building. Therefore earthquake assessment of an Importance Level 4 (IL4) building (i.e. one with critical post-disaster functions) is expected to consider the enhanced ultimate limit state (ULS) requirement resulting from the higher importance level, but it is not expected to consider how earthquake-induced damage would affect operational requirements.

How damage would affect the ability of an IL4 building to continue to function in the post-disaster period is, however, an important consideration for the intended functional purpose of the building – i.e. serving community needs at a time of crisis. While this may be a life safety consideration in its broadest sense, this is not intended to be part of the decision on whether or not a building is earthquake prone or of its earthquake rating.

Note:

The serviceability required to provide confidence that an existing IL4 building will be able to maintain operational continuity (i.e. SLS2) may be satisfied by simply assessing behaviour at an appropriate level and using judgement to determine what the outcomes may be for usability.

Notwithstanding the focus on life safety, it is recommended that an IL4 building should either attain a 67%NBS (IL4) rating as a minimum and fully satisfy SLS2 requirements, or be re-designated.

For an IL4 building not to be found to be earthquake prone it is only necessary for it to attain a 34%NBS (IL4) rating as a minimum. SLS1 or SLS2 requirements are not expected to be met.

It may be necessary to guide owners through the differences between IL2 and IL4 requirements as they relate to the risks to general occupants in order to put earthquake ratings based on IL4 requirements into context.

A3.2 Seismic Performance and the Building Code

A3.2.1 Relationship between these guidelines and the Building Code

The Building Code provides (minimum) structural performance objectives for buildings in clause B1.

To meet the full performance requirements of clause B1 of the Building Code requires consideration of life-safety, amenity and damage to other buildings. The performance requirements are stated in holistic terms, referencing overall performance expectations over the whole building life, and do not relate this to a specific level of earthquake shaking in the case of seismic performance.

As noted in Section A3.1 the primary focus in seismic assessment of existing buildings is on life safety, although damage to other buildings also needs to be considered.

These guidelines use clause B1 of the Building Code to provide the minimum life safety performance standard for seismic assessments and, in particular, for the earthquake scores and ratings. This relationship is depicted in Figure A3.1.

A 100%NBS earthquake score or rating for an existing building (refer to Section A6 for the way in which these are calculated) indicates that the minimum life safety standard for earthquakes has been reached.

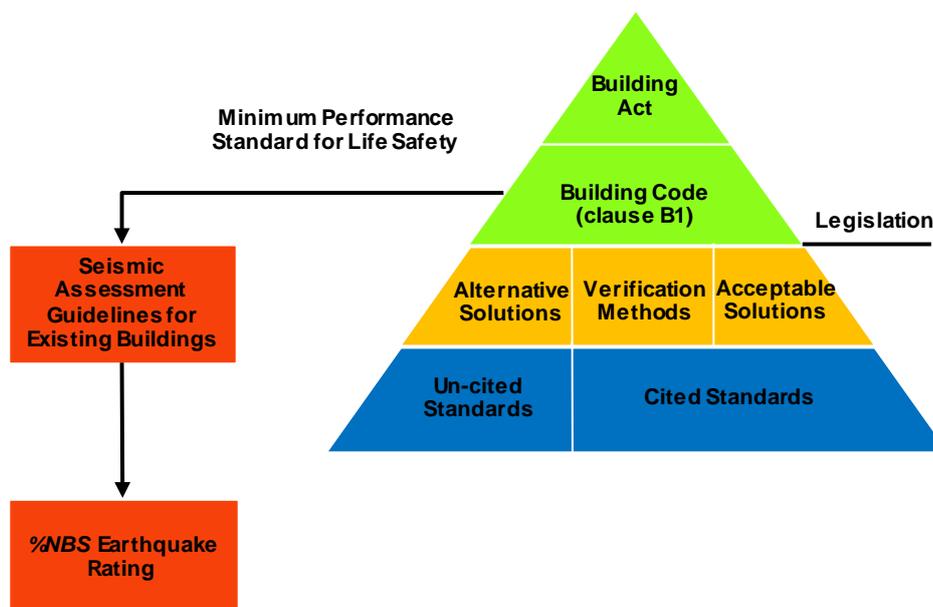


Figure A3.1: Relationship between Clause B1 of the Building Code and Earthquake Rating

An earthquake score or rating is not intended to convey any indication of performance relating to earthquake damage potential. This may be important for some assessments if business interruption or expected damage losses need to be estimated but these considerations are outside the scope of these guidelines.

For earthquake scores and ratings other than 100%NBS, a relative level of performance to the minimum level is implied. This is discussed in Section A3.2.4.

A3.2.2 Relationship between the Guidelines and the Building Code Verification Methods

The Building Code defines means of compliance that are intended to deliver the performance objectives set out in clause B1. There are several means of compliance paths given in the Building Code as indicated in Figure A3.1. The most commonly used path for new building design is the deemed to comply verification method B1/VM1.

The design methodologies set out in B1/VM1, including for the detailing of the structural elements, are all calibrated to provide reasonable assurance that the performance required by the Building Code will be met. However, the designer does not need to specifically consider how reliable the actual performance is, nor how much greater the resulting performance is compared with the minimum requirements.

Designers are generally only required to consider two design points or limit states (ultimate limit state (ULS), and serviceability limit state (SLS)), within the deemed to comply provisions of the design standards. The expectation is that if the building meets the prescribed provisions for these limit states the overall performance will meet or exceed the performance objectives in clause B1 of the Building Code taking into account the range and likelihood of earthquake shaking over the design life of the building.

When following this approach it is quite possible that satisfying SLS requirements may govern and improve the life-safety performance and vice versa.

There is the ability to mould a new building into a form that ensures all requirements of B1/VM1 can be met. This ability is not always achievable with an existing building. This is discussed further in Section A3.2.3.

These guidelines draw heavily on the verification methods contained within B1/VM1 (including the cited material Standards and the Standard for earthquake loadings) but recognise that it is not always necessary to meet all of the requirements of the verification methods to achieve the minimum required seismic performance standard for life safety.

Modifications to reflect that the buildings are existing, the need to better understand the seismic behaviour of the building in relation to minimum performance requirements rather than simply ensuring that every element exceeds minimum requirements, and the focus in these guidelines on life safety are therefore important aspects of the seismic assessment procedures outlined in these guidelines.

To this end it is intended that the verification methods can be used to meet the requirements of these guidelines, but the following modifications should be made:

- use of probable (expected) rather than characteristic material properties

- use of probable rather than dependable member/element capacities. This is achieved by using probable material properties and setting strength reduction factors to 1, and
- allow structural mechanisms to form to the point that a significant life safety hazard can be said to have developed.

Part C of these guidelines sets out how it is expected that these modifications will be carried out and other concessions that are considered acceptable to reflect that the building is existing and the focus is on the minimum life safety standard requirements for seismic actions.

Part C also provides guidance on how to assess the capability of historical details that are present in existing buildings but are no longer no longer considered appropriate for new buildings and therefore are not covered in B1/VM1. These details would be expected to typically rate less than 100%*NBS* although this is not always the case. Very poor detailing in existing buildings still needs to be appropriately rated even though this might be at low levels.

Note:

The degree of compliance with B1/VM1 should not be confused with the degree to which a building meets or does not meet the minimum performance requirements of B1. It is quite possible for a building not to meet the full requirements of B1/VM1 and still meet the minimum life safety performance requirements of B1. It is fundamental to the approach set out in these guidelines that a seismic assessment consider how well a building meets the minimum holistic performance requirements rather than solely the extent to which it satisfies the deemed to comply requirements of the prescribed verification method.

A3.2.3 Differences between existing and new buildings

The main difference between a new building at the end of the design phase and an existing building is that the existing building is a physical entity, whereas a new building, yet to be constructed, only exists in conceptual form. Definitions of existing and new buildings can be found in Section A1.6.

A seismic assessment is based on observations of a physical building. Aspects such as poor construction, poor design and poor integration of secondary structural and non-structural elements, when they are found by inspection to be present, can be explicitly allowed for.

While knowledge of an existing building (e.g. material strengths, hidden details, etc.) will be less than complete, the physical presence of an existing building, and what can be determined from it, is considered to provide a significant advantage from the point of view of understanding every (design and construction) issue over that of a theoretical building defined only by drawings. The drawings always convey the designers' intent rather than the constructed reality.

If a new building is observed to be well conceived, designed and constructed and then assessed in accordance with the guidance within this document after it has been constructed, its earthquake rating might be above the minimum required life safety standard associated with 100%*NBS*. This is to be expected given the underlying difference between the

objectives of design and assessment and the physical reality of an existing building that can be observed and confirmed. This is discussed further in Section A3.2.4.

Note:

Assessing a new building solely off drawings in accordance with these guidelines is not encouraged for similar reasons that comprehensive site inspections are always recommended for an existing building (refer to Section A7.4.2). Also, post-construction assessments by the original designer should be objective and include an appropriate evaluation of how well the design objectives (including any interaction with secondary structural and non-structural items) and construction objectives (including the quality of construction and materials) have been implemented in the actual building.

A3.2.4 Consistent expression of seismic performance

The life safety performance objectives for earthquake stated in clause B1 of the Building Code are not quantified nor are they restricted to consideration of only some levels of earthquake shaking. The intent is that the minimum level of performance is a holistic one, covering all levels of earthquake shaking that the building could be reasonably exposed to.

The ISA and DSA assessment processes outlined in these guidelines indicate the seismic performance/behaviour as an earthquake score or rating. The rating provides a measure of the expected performance from a life safety point of view, compared with the minimum required by the Building Code for new buildings. This is expressed as a percentage of the minimum standard required by the Building Code, or *%NBS*, the derivation of which is discussed in more detail in Section A6.

Note:

The use of *%NBS* to describe the result from all levels of assessment (ISA through to DSA) is deliberate. The rating for the building need only be based on the lowest level of assessment that is warranted for the particular circumstances. The *%NBS* assessed using a full DSA process is expected to be more reliable than one assessed using an ISA, but the latter may be sufficient to provide a result that the engineer is confident reflects the expected building behaviour.

Observations following actual earthquakes show there can be a considerable range of performance for quite similar buildings in reasonable proximity. Therefore, any prediction of performance in earthquakes has considerable uncertainty. This uncertainty arises from both a lack of current knowledge and the inability to predict the considerable variability in how earthquake waves propagate from their source to a building and how the building responds to the shaking. The building response is affected by the complex nature of its structure, involving the interaction of many elements, and the complex nature of the ground on which it sits.

Therefore, it is unreasonable to believe that seismic performance can be predicted in absolute terms, and it always needs to be communicated within a probabilistic framework. However, this is not easily done and is more difficult when a holistic view of performance across all levels of earthquake shaking is required.

Note:

The assessment processes outlined in this document are not intended to provide a means of predicting the actual performance of any particular building at any particular level of earthquake shaking or to quantify the performance across all levels of earthquake shaking. Nor is it intended that the risk be quantified beyond the approximate relative measures provided in Table A3.1.

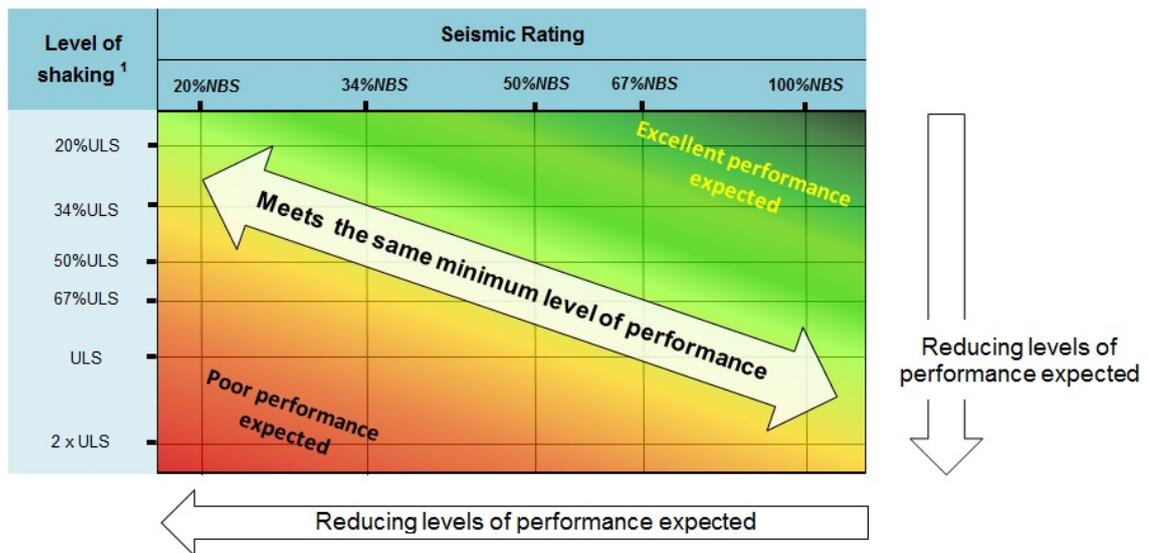
For these reasons, the approach used by these guidelines is to establish how the building is likely to behave in a structural sense and then to relate this to how the building will perform compared with a new building that just meets the minimum standard for life safety in earthquake indicated by clause B1 of the Building Code. By definition, the minimum standard is assumed to provide an acceptable level of performance when considered across all levels of earthquake shaking. Measuring building performance relative to a minimum acceptable level avoids the need to quantify the expected performance.

Therefore, these guidelines assign an earthquake rating to a building in terms of the percentage of the minimum standard that would apply to a similar new building, or $XXX\%NBS$. The rating is assigned by comparing various aspects of building behaviour against the minimum standard for a similar new building (expressed in terms of the ratio of the strength and available deformation capacity of the building and the shaking demand specified for a similar new building).

Figure A3.2 illustrates how a building is expected to perform for the full range of earthquake shaking for the difference levels of $\%NBS$ earthquake rating. In essence, a building will perform similarly (from a life safety point of view) to the lowest standard, when subjected to a level of shaking factored by the $XXX\%NBS$ earthquake rating. For example, a building rated at $34\%NBS$, subjected to shaking at 34% of the design level shaking for an equivalent new building (34% ULS shaking), is expected to perform to at least the same minimum level as a new building subjected to the design level of shaking (100% ULS shaking). Similarly, when subjected to 67% ULS shaking, this building would be expected to perform to at least the same minimum level as a new building subjected to 200% ULS shaking.

If two buildings are different, e.g. in configuration, size, material type, etc., a similar level of performance may not be expected at all levels of shaking factored by the rating for each. However, when a building is compared with a new building, the performance at any level of shaking should be at least the minimum required level when the shaking is factored by $\%NBS$.

Earthquake ratings are not expected to be determined for multiple levels of shaking. The assessment procedures typically focus on assessing how the building would respond to the ULS shaking factored by the determined $\%NBS$ ($XXX\%$ ULS shaking demand). Allowances within the assessment process are intended to provide confidence that the building will also meet the minimum life safety performance requirements at other levels of shaking, while recognising that the level of reliability of meeting the required performance will reduce as the shaking increases. Often these allowances are inherent within the general process, but sometimes specific adjustments need to be made.

**Notes:**

1. The diagram represents the tolerable (minimum) outcomes for buildings of any earthquake rating, at any level of shaking.
2. For any earthquake rating, the expected seismic performance represented on the vertical axis should be achieved over the full range of possible shaking levels.

Figure A3.2: Indicative relationship between seismic performance, earthquake rating and level of shaking

Discussion on how the earthquake rating is to be determined can be found in Section A6, and in Part B for the ISA and Part C for the DSA.

It is essential that the %NBS earthquake rating given to a building reflects its expected relative performance. Therefore, a building should not be rated as 100%NBS unless there is confidence that it will perform to the minimum level expected of a new building (life safety only) across all levels of shaking. The rating should be reduced until there is confidence that this will be the case.

Ratings of 120 to 150%NBS are possible when well configured buildings, designed to meet the current requirements of B1/VM1, are assessed in accordance with these guidelines and reflect a potentially higher life safety performance when compared with a building that just meets the minimum rating of 100%NBS. The actual level of performance is not expected to be significantly higher at any particular level of earthquake shaking (as can be observed in Figure A3.2, noting that the scales for %NBS and %ULS shaking are not linear in the figure), and well within the overall uncertainties that are contained in the assessment process generally when the likely overall performance of a particular building is considered across all levels of shaking.

Undue focus on these differences is not encouraged, and an earthquake rating presented as >100%NBS is recommended, rather than to present a fixed value. The exception is when change of use might be under consideration. Refer also to Section A8.2.

In addition to the %NBS earthquake rating, it is recommended that the corresponding seismic 'grade' and relative risk also be indicated to provide context. Table A3.1 outlines the grading system that was developed by NZSEE in 2000 and a relative risk description as it relates to life safety. Also given is an approximate indication of the risk relative to that of a new building.

Table A3.1: Assessment outcomes (potential building status)

Percentage of New Building Standard (%NBS)	Alpha rating	Approx. risk relative to a new building	Life-safety risk description
>100	A+	Less than or comparable to	Low risk
80-100	A	1-2 times greater	Low risk
67-79	B	2-5 times greater	Low to Medium risk
34-66	C	5-10 times greater	Medium risk
20 to <34	D	10-25 times greater	High risk
<20	E	25 times greater	Very high risk

The approximate relative risks given are the risk to occupants or to neighbouring buildings relative to a building that just meets the minimum performance standard indicated by clause B1 of the Building Code.

The risk descriptions given can be considered to be relative life safety risks if a large earthquake occurs.

A4. Assessment Process

This section covers:

- differences between the processes of seismic assessment and new building design
- engineering objectives of assessment, and
- required scope (extent) of the assessment, including considerations external to the site, parts of buildings and buildings comprising multiple interconnected structures.

A4.1 Differences between Seismic Assessment and New Building Design

A4.1.1 General

There are distinct differences between the processes used traditionally for design and for assessment. Further, a designer has the ability, within reason, to modify the behaviour of the building structure to support the design assumptions.

Most importantly, designers are generally only required to consider specific design points (e.g. ULS for life-safety), as the deemed to comply provisions of the design standards are intended to ensure that the performance objectives will be achieved across all expected levels of loading.

In contrast, engineers assessing existing buildings should be more aware of the range of possible building behaviour across the expected shaking levels, as the same safeguards do not necessarily exist. An existing building's potential behaviour is already determined by the form and detailing of the structure as it was originally designed and constructed, along with such alterations as it may have been subjected to since construction (including the effects of deterioration over time).

A4.1.2 Differences between traditional design and assessment processes

Figure A4.1 maps the key elements of the processes used for new building design and for assessment of existing buildings.

The traditional design process described above for new buildings, where design loads are determined based on a predetermined outcome (required at yield based on a level of ductility that is assumed will be available) and applied to a “model” of the building to determine design actions, and then uses these to proportion the strength capacity of the individual elements and then details the elements for the level of ductility assumed at the outset, is summarised in Figure A4.1(a).

The provisions of both the design loadings and materials standards within B1/VM1 are intended to ensure that the ductile deformation capability of the primary structural elements is sufficient to provide the defined global ductility. This is typically achieved by the process delivering a building form for which it is expected that the energy dissipation will be reasonably well distributed throughout the primary lateral system and that the vertical load carrying capacity of the primary gravity system will be assured at the expected level of lateral deformation.

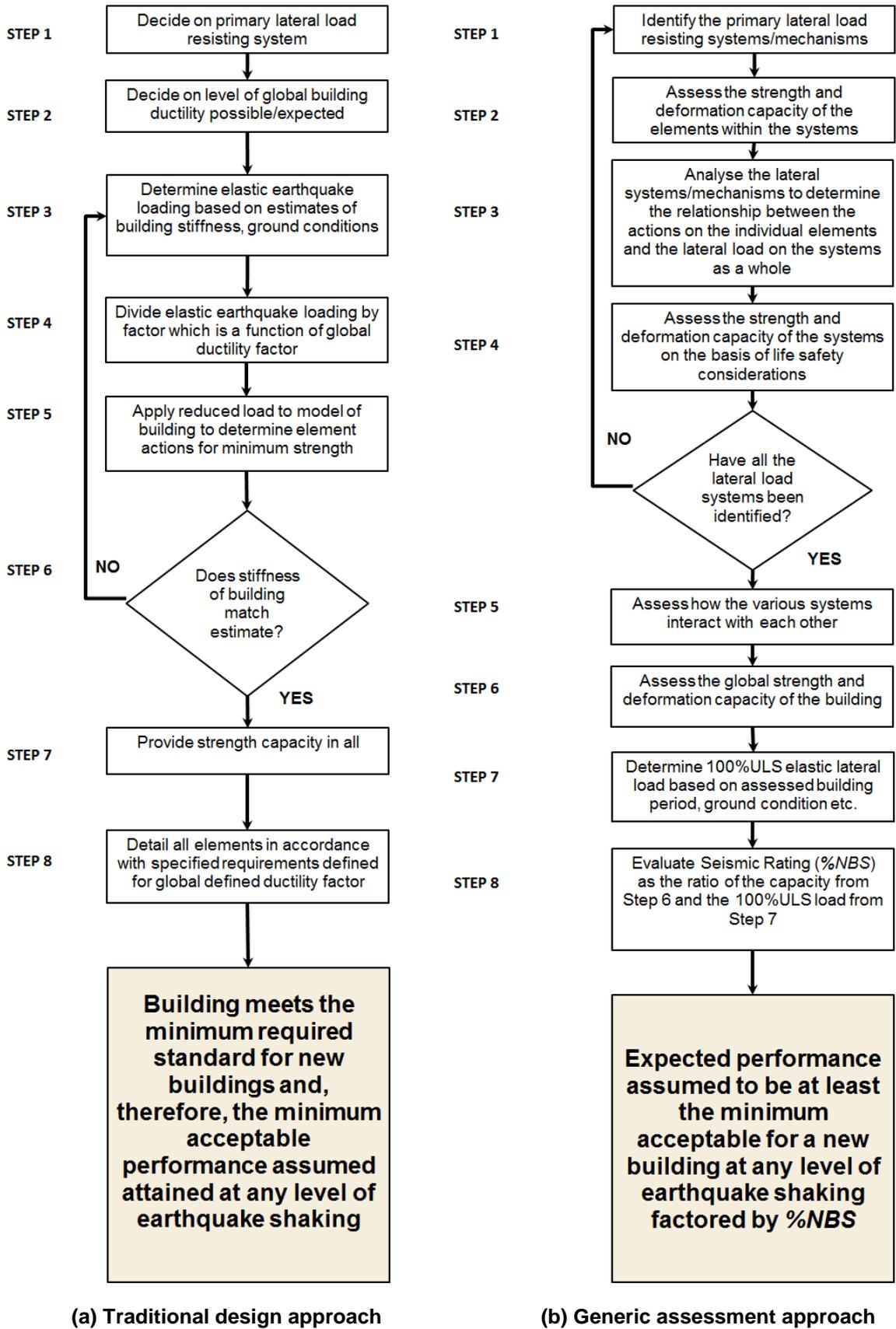


Figure A4.1: Design and assessment approaches compared

However, these fundamental assumptions for the traditional design process are rarely valid when assessing an existing building; unless the structure remains predominantly elastic. The approach to seismic assessment for existing buildings is therefore intended to be fundamentally different to that employed for the design of new buildings. The use of traditional design approaches for assessment can lead to an assessment result that is significantly incorrect if assumptions inherent in the design process are ignored. The result can be either excessively conservative or non-conservative.

The generic assessment process adopted in these guidelines is shown in Figure A4.1(b).

Note:

Practical considerations mean that the assessment process needs to follow a compliance type approach where the assessment process is defined and appropriate acceptance criteria are set, but the intent is to gain a much better understanding of how the building will behave under lateral loading than is necessarily required for design.

The identification of the various systems/mechanisms (Steps 1 to 4), and establishing how they work together (Step 5) are significant iterative parts of the assessment process that have seldom been used in the design of buildings, where reliance is at best placed on a particular mechanism chosen by the designer. In the case of assessment, the features that lead to the development of mechanisms are already present and need to be identified so they can be assessed.

Other differences between the design of new buildings and the assessment of existing buildings as outlined in these guidelines include:

- The focus is on life safety and not on damage prevention. The assessment process addresses the life safety focus by allowing elements or members that are not expected to lose gravity support (and, therefore, fall) once their capacity is exceeded, or if they were to fall would not be likely to lead to a significant life safety hazard, to either be removed from further consideration, or to maintain a residual capacity, with or without a deformation limit as appropriate.

The consequence is that, in assessment, the assumed system mechanism can be fully developed until the first element that constitutes a life safety hazard reaches its deformation capacity. This is a potentially significant concession compared with new building design.

Note:

An assessment that considers all elements but limits the global capacity of the building to the element with the lowest score, without considering whether or not this element is critical from a life safety perspective, will not meet a key principle of these guidelines.

Assessments carried out using these guidelines are not expected to consider performance against the SLS requirements.

- Design procedures for new buildings aim to deliver buildings that can be expected to meet or exceed the minimum seismic performance objectives set out in Clause B1 of the Building Code for overall life safety risk and acceptable loss of amenity. In contrast, the

assessment process seeks to establish how well an existing building will perform in terms of the minimum performance objectives for earthquakes defined in clause B1 of the Building Code.

- As a result of the process used, many new buildings are expected to exceed these minimum requirements if they are both designed as envisaged by the code writers and constructed as intended by the designer. However, this is not always realised in practice.
- When assessing an existing structure, realistic values for the material properties, particularly strengths, should be used to obtain the best estimate of the strengths and displacements of members, joints and connections. Seismic assessments make use of probable (expected) element capacities (as-built) to recognise that the building physically exists. The justification for using probable rather than nominal capacities for assessment is outlined in Section A4.2, and in more detail in Section C1.
- Mixed ductility structural systems may be present in new building design and, if they do occur, specific provisions are provided to ensure they are correctly incorporated. The experience suggests that designers have not always recognised the presence of mixed ductility systems and therefore these specific provisions have not always been complied with. In contrast, these systems are almost always present in older existing buildings and should be correctly evaluated if a realistic and reasonable assessment of the building's seismic behaviour is to be obtained.

A4.2 Engineering Objectives of Assessment

The main technical objective of any seismic assessment is to come to an understanding of the expected behaviour of the building in earthquakes. There are several important aspects to consider:

- A holistic assessment of seismic performance should consider a wide range of events that the building may be subjected to. Thus, when the standard that a building achieves is reported in %NBS terms (refer to Section A6), this implies different levels of reliability of performance across a range of shaking levels that, when considered together, imply that a minimum performance level is achieved. Although engineers may consider only one level of shaking in design, the other levels of shaking are implicitly accounted for in our general design methodologies.
- It is the intent of these guidelines that a full understanding of the behaviour of the building, including an assessment of this behaviour against ULS shaking, and the identification of severe structural weaknesses will also provide confidence that the minimum level of performance for a particular earthquake rating has been achieved overall without necessarily the need to assess at multiple levels of shaking. However, to achieve this objective, the level of experience and understanding of building behaviour in earthquakes needs to be at a significantly higher level for assessment, than required for design.
- The key assessment objective is to arrive at earthquake scores for individual elements with the potential to be significant life safety hazards and an overall earthquake rating for the building based on these.

Any element that limits the earthquake rating to below 100%NBS is referred to as a structural weakness (SW).

The SW that limits the earthquake rating of the building is referred to as the critical structural weakness (CSW). Particular care is therefore required to identify all possible

SWs. Also, the SWs identified in an ISA assessment are only considered to be potential CSWs until a DSA determines which of them is the CSW.

Note:

If the CSW is addressed by retrofit, the next SW that limits the building's rating becomes the CSW and so on. Ranking the SWs according to their effect on the rating of the building provides an important understanding the sensitivity of the scores and an invaluable basis for any retrofit strategy.

- Assessment should be undertaken to an appropriate level of detail, having due regard to the scale of the building, the potential consequence of its failure and the other work that may be undertaken in parallel with, or as an outcome of, the assessment.
- There needs to be a clear understanding that assessment is not a prediction of the way in which a particular building might perform when subjected to a particular level of earthquake shaking.
- Gaining an understanding of the expected mode of failure and physical consequences of failure is an important consideration for an assessment. These aspects are required to be reported on in the engineering assessment reporting (refer to Section A8.5.2) as part of the EPB methodology but it is considered desirable to include discussion on these for all assessments.

Although there is generally a desire on the part of building owners and occupiers to quickly arrive at an earthquake rating expressed as a single number, by far the most important part of any assessment is to form a view of the expected behaviour of the building. Behaviour encompasses both the elastic and potential inelastic deformation of a building under seismic loading; and its consequential effect on the other elements of the building. It should also include consideration of the potential effects of soil-structure interaction, which may significantly affect the overall building behaviour.

A summary of the key differences between assessment and design was outlined in Section A4.1.

The role of the engineer is to ascertain what the behaviour of the building is expected to be, with regard to these factors, and may need to explicitly address the consequences of failure of elements in more detail than a designer would. This means that an engineer should consider a number of factors, including:

- the materials that the building was constructed with, and how these may vary from what was originally intended
- the designer's intended structural form and behaviour, and how that could have been modified during the actual execution
- the detailing used in design (and as constructed), and how it may modify the intended behaviour
- the changes that may have happened over time and how they may impact on reliability and performance.

In all of the above, the role of the codes and standards of the day are significant, as they would have informed the design and construction process. However, engineers should not simply assume that anything that predates current standards will not perform adequately nor that the codes of the day would necessarily have been interpreted as intended or fully

complied with. One of the most significant issues is that, while a designer may have considered the lateral load resisting and gravity load resisting structures separately, engineers should consider the behaviour of both responding together as one structure. Decisions to exclude elements of the structure from an analysis should be made carefully.

The role of the engineer is therefore as much about investigation as it is about analysis. The engineer should be conscious of the designers' intent but open to consideration of any other factors may influence behaviour and that may not have been within the designers' knowledge, experience or ability to control during construction or subsequent alterations.

A4.3 Extent of the Assessment

A4.3.1 Considerations external to the site

The assessment of an earthquake rating for a building is not intended to extend beyond those aspects that an owner or owners of a building (including across multiple titles) could reasonably be expected to be able to address.

This means that the assessment of the earthquake rating can be restricted to those issues that relate specifically to the site boundaries. Factors that are not intended to be considered include:

- geohazards originating away from the site such as tsunami, rockfall, rolling boulders, slope instability from above (slope instability from below that could undermine the building foundations is intended to be included)
- items falling from adjacent buildings (this being included in the earthquake rating for the adjacent building).

Note:

Issues associated with pounding against adjacent buildings are intended to be included in the earthquake rating for the building. This distinction is made because pounding is an issue that occurs because the subject building is present (in conjunction with the adjacent building) and, while the owner may have no ability to influence the presence or otherwise of the adjacent building, the effects can nevertheless be mitigated by actions the owner of the subject building can take.

The site boundary is typically defined by the legal title boundaries. Determining the site boundaries for a building with multiple interconnected structures will need to include the full extent of the legal boundaries for the building sections and elements that could affect the earthquake rating for the section of interest.

Notwithstanding that these factors may not directly affect the earthquake rating for a building, they could nevertheless affect the overall seismic risk and should therefore be reported alongside the earthquake rating when they have been identified.

A4.3.2 Parts of buildings

The EPB methodology sets the scope of parts of buildings required to be considered in an assessment of a potentially earthquake-prone building. This scope is applicable to all assessments of existing buildings.

A building part requiring consideration in an assessment is an individual building element that would pose a significant life safety hazard (Section A3.1.1) if it is able to:

- lose support or fall, or
- cause another building element to lose support or fall from the building, or
- cause any section of the building to lose support or collapse.

The provision to consider if a significant life safety hazard exists provides for mitigation measures to be taken into account. While this reduces the scope of building elements that are likely to pose significant life safety hazards, it requires more information to be taken into account. For example, the most common form of mitigation will be furniture that the building occupants can reasonably expect to be able to shelter beneath as part of the national ‘drop, cover and hold’ Civil Defence Emergency Management advice.

Note:

Mitigation could also be provided using redundant and ductile connections (tethers) to attach the building element to the structure.

The types of building element and situations that are most likely to pose a significant life safety hazard and need to be included in engineering assessments are given in Table A4.1. This refers to five classes of floor spaces that are defined in Table A4.2.

Contents are not considered as part of the assessment of an earthquake rating.

Table A4.1: Parts that pose a significant life safety hazard

Parts that could pose a life safety hazard	Expected to be a significant life safety hazard	
	Yes	No
Vertical or horizontal cantilevering elements	Heavy (>25kg) elements (e.g. URM parapets, chimneys, cantilevering concrete beams, canopies)	Lightweight (≤ 25 kg) elements
Light cladding systems including curtain walls	Support frames that could fall into space class I	Lightweight cladding elements, including individual glazing elements (moderate sized panes of glass)
External cladding elements, including connections	Heavy elements (e.g. precast concrete panels (not integral with the primary structure) above space class I	Lightweight cladding elements
Appendages and ornamentation	Heavy elements above space class I	All Other
Stairs and their associated supports	Above or supporting space classes I, II and III and Above space classes IV	All other stairs
Ceiling systems and/or ceiling grids	Heavy ceiling systems above space classes I, II, III or IV Ceiling systems above space classes I, II, and IV Unrestrained ceiling tiles >7.5 kg/tile above space class I, II, III and IV	Unrestrained ceiling tiles < 7.5 kg/tile Conventional lightweight ceiling grid systems above space class III Ceiling grids/tiles within space class V
Partitions and walls	> 25 kg/m ² (e.g. blockwork or clay tiles) bordering space classes I, II, III or IV	≤ 25 kg/m ² (e.g. conventional timber or light gauge steel framed partitions and walls) Any partitions and walls within space class V
Signs or billboards	Large (> 25 m ²) or heavy with a fall height greater than 3 m onto space classes I, II, III and IV	All other
Plant and tanks with non-hazardous contents	Large/heavy elements where failure of restraints/supports could lead to the item falling onto building occupants Does not include the integrity of the item itself	All other
Vessels containing hazardous materials	Where spillage would pose a health hazard for building occupants or those within 3 m of its perimeter	Small robust containers that are unlikely to spill their contents
Storage racking systems	Heavy systems in generally occupied spaces	Lightweight systems Systems in space class V
In-ceiling building services	Only when failure of one building element could lead to failure of another that would pose a significant life safety hazard (e.g. a heavy ceiling over a class II area).	Lighting, heating, ventilation and air conditioning ducts and equipment
Explanatory Notes:		
A heavy element has a mass >25 kg		
A lightweight element has a mass ≤ 25 kg		
A large element has an area >25 m ²		

Table A4.2: Building space classes and their functional purposes

Space class	Functional purpose and hazard
I	Spaces that function as egress paths, provide emergency assembly or access, are public property or where people regularly congregate
II	Open spaces with minimal furniture
III	Furnished spaces where the furniture can reasonably be expected to provide shelter during an earthquake
IV	All spaces beneath overhead building elements that are heavier or could fall further than normal furniture can provide shelter from
V	Service or storage areas such as plant rooms or warehouses that are not expected to be occupied during an earthquake

Guidance on approaches to assessing SSNS building elements as part of an ISA and a DSA are included within Part B and Section C10 respectively.

A4.3.3 Buildings with interconnected structures

For the purposes of seismic assessment the boundaries of a building extend to include all structurally interconnected structural forms/systems. The structural interconnection may be in the form of common members/elements/structural systems providing vertical or lateral support. In some cases the building or the boundaries of the individual structural systems may extend beyond legal (title) property boundaries.

Note:

Separate structures that share a common foundation (as the only form of structural interconnection), and are not otherwise reliant on the interconnection for either lateral or gravity support, can be considered as separate buildings.

The approach taken to assessing a building comprising multiple interconnected structures crossing multiple titles is as follows:

- Ascertain the extent of the building perimeter by considering all structurally interconnected structural systems.
- Identify all separate primary lateral structural systems in the building.
- Identify any primary structural elements that cross between different structural systems.
- Identify any SSNS elements that could be considered to be a significant life safety hazard and their location relative to the property legal title boundaries.
- Determine the earthquake score for each structural system, each primary element crossing between each structural system and identified SSNS elements that are a significant life safety hazard.

For a building within one property boundary the earthquake rating is the minimum earthquake score determined in the final bullet item above.

The earthquake rating for a part of a building within particular property title boundaries, where the building extends beyond these boundaries, is the minimum of:

- the earthquake scores determined for all structural systems within the building
- any primary structural elements that cross between structural systems, and
- the scores determined for any SSNS elements that are considered to be a significant life safety hazard for the part/section of the building which is of interest.

Note:

In the case of a building extending beyond legal property boundaries a warning should be provided regarding the implications of future removal of any structural system(s) or supports of SSNS elements beyond the boundaries.

Adjacent structures that have no or minimal separation but are otherwise not structurally connected can be considered as separate buildings. For such situations the effects of pounding between the buildings will need to be considered. For separate URM buildings in a row this may require special consideration for the buildings on the ends of the row.

Note:

The approach outlined above for these often difficult and complex situations is a pragmatic one that is clear to apply.

However, application in the manner suggested will lead to situations where structurally interconnected structures (i.e. buildings) with different legal titles within a city or town block will all be provided the same earthquake rating based on the lowest score.

In such situations, an assessment of a part of the building for one of the owners may only be able to result in a *%NBS score* for that structure (considering the impact of adjacent structures), unless there is knowledge of all of the interconnected structures.

The engineer will need to be prepared to explain to clients/stakeholders what the impact of any SWs in building as a whole will have on the particular part that may be of interest and the reason why it is only possible to provide a score rather than a rating. For many situations, the difference will not be significant and will have no practical impact on the way in which that part of the building may be used.

A5. Assessments for Building Regulatory Purposes

These guidelines support seismic assessments undertaken for building regulatory requirements set by the Building Act 2004, including providing information relevant to determining the earthquake-prone status, change of use and also when evaluating alterations.

The following sections set out specific requirements for seismic assessments completed to meet legislative requirements.

A5.1 Seismic Assessments for Earthquake-prone Building Purposes

The Building Act 2004 sets out the framework for identifying and managing earthquake-prone buildings including that:

- TAs must identify potentially earthquake-prone buildings
- building owners of potentially earthquake-prone buildings must commission an engineering assessment
- Tas must use this information to determine whether or not a building or part is earthquake prone.

The EPB methodology (see Section A5.1.2 below) supports the Building Act by establishing process requirements to undertake these roles.

Engineers undertaking a seismic assessment of a potentially earthquake-prone building must use these guidelines to meet the requirements of the EPB methodology. The resulting information produced by a seismic assessment for this purpose assists Tas in determining whether a building or part of a building is earthquake prone or not.

Engineers should familiarise themselves with the entire EPB methodology to understand how the TA will use their reports to make this decision and to assign the earthquake rating category on the earthquake-prone building notice.

A5.1.1 Meaning of earthquake-prone building

Section 133AB of the Building Act 2004 sets out the meaning of earthquake-prone building. The definition was revised in the Building (Earthquake-prone Buildings) Amendment Act 2016.

The definition now:

- makes it clear that a building can be earthquake prone by virtue of its parts
- makes it clear that a building must be assessed for its expected performance and possible consequence
- ties the meaning to a moderate earthquake, i.e. the earthquake shaking used to design a new building at that site if it were designed on the commencement date.

The definition of an earthquake-prone building contained within the Building Act is:

133AB Meaning of earthquake-prone building

- (1) A building or a part of a building is **earthquake prone** if, having regard to the condition of the building or part and to the ground on which the building is built, and because of the construction of the building or part, -
 - (a) the building or part will have its ultimate capacity exceeded in a moderate earthquake, and
 - (b) if the building or part were to collapse, the collapse would be likely to cause –
 - (i) injury or death to persons in or near the building or on any other property, or
 - (ii) damage to any other property.
- (2) Whether a building or part of a building is earthquake prone is determined by the territorial authority in whose district the building is situated: see section 133AK.
- (3) For the purpose of subsection (1)(a), **ultimate capacity** and **moderate earthquake** have the meanings given to them by regulations

As covered in 133AB(3), to assist with application of this definition, both ultimate capacity and moderate earthquake are terms defined in the Building (Specified Systems, Change the Use, and Earthquake-prone Buildings) Regulations 2005 (as amended).

These regulations define **ultimate capacity** as:

The probable capacity to withstand earthquake actions and maintain gravity load support assessed by reference to the building as a whole and its individual elements or parts.

While defined for the purposes of undertaking engineering assessments of potentially earthquake-prone buildings, the definition for ultimate capacity is used for all types of seismic assessment carried out using these guidelines as described in Section A6.3.

These regulations define **moderate earthquake** as:

In relation to a building, an earthquake that would generate shaking at the site of the building that is of the same duration as, but that is one-third as strong as, the earthquake shaking (determined by normal measures of acceleration, velocity, and displacement) that would be used to design a new building at that site if it were designed on 1 July 2017.

The important change from the previous definition is the fixing of the date and therefore the version of the earthquake design actions standard that should be used for building assessments.

Note:

This change leads to an important potential difference between seismic assessments carried out to establish earthquake-prone status and assessments for general purposes. The earthquake shaking demand to establish the earthquake rating for earthquake-prone purposes is that which applied on the date that Subpart 6A of Part 2 of the Building Act,

2004, and associated amendments came into force. For assessments for other purposes the demand is that which applies at the time the assessment is completed.

This difference means that the %NBS scores determined in accordance with the EPB methodology may differ from those calculated for general assessments if the earthquake loads defined for the ULS in NZS 1170.5:2004 have been amended after the Building Act amendments come into force.

In such cases, it may be necessary to quote both ratings depending on the scope of the assessment.

A5.1.2 EPB methodology

The EPB methodology is set by the Chief Executive of MBIE in accordance with section 133AV of the Building Act 2004. It provides the operational basis for identifying potentially earthquake-prone buildings, assessing them and making decisions about whether or not they are earthquake prone.

Specifically, engineers undertaking engineering assessments of potentially earthquake-prone buildings must ensure these are completed in accordance with the requirements set out in the EPB methodology. There are requirements for:

- the qualifications of the engineers carrying out the assessment
- determining whether an ISA or DSA is the appropriate form of assessment
- the technical considerations that the engineering assessment must include and consider
- the contents of the report and summary report that must be supplied to the TA.

Note:

The EPB methodology gives the requirements for an ‘engineering assessment’ and refers to these guidelines for details of how they are to be carried out.

The technical requirements themselves are given in the relevant sections of this guidance to avoid unnecessarily extending the length of this overview.

It is important to note that the TA determines whether or not the building is earthquake prone in accordance with section 133AB of the Building Act 2004 and is required to assign its earthquake rating. The information contained in an engineering assessment will inform this.

Note:

Engineers should familiarise themselves with the entire EPB methodology to understand how the TA will use their reports to make this decision and to assign the rating. It also includes conditions under which the TA must accept and can reject an engineering assessment.

The technical considerations in the EPB methodology include the requirement to consider parts of buildings as set out in Section A4.3.2.

A5.2 Seismic Assessments for Other Building Regulatory Purposes

A5.2.1 Change of Use

A TA can only approve a change of use under section 115 of the Building Act 2004 when it is satisfied, on reasonable grounds that, in its new use, the building will comply, as nearly as is reasonably practicable, with the structural performance requirements of the Building Code.

The TA may require documentation to be submitted to accompany the owner's application for a change of use, including a seismic assessment. The nature and extent of this assessment, if required, will depend on the nature and implications of the change of use and the particular circumstances.

It is considered that a seismic assessment carried out in accordance with these guidelines, and in particular the earthquake rating determined, should be sufficient to establish the extent to which the building structure meets the life-safety performance requirements of the Building Code.

It may also be necessary to confirm other requirements of the Building Code have been met to the required degree, e.g. for amenity, to fully comply with the requirements of the Building Act.

Note:

The implication of using these guidelines for the assessment of the structural (seismic) status of the building from a life-safety point of view for “change of use” purposes is that it is acceptable to base the structural (seismic) capacity of the building based on probable capacities and other relaxations of B1/VM1 requirements contained within these guidelines.

A5.2.2 Alterations

The basic requirement of section 112 of the Building Act 2004 in terms of structure is that alterations cannot result in the building complying with the Building Code to a lesser extent than before the work (s112(1)(b)).

From a seismic point of view this requires that either the building's seismic capability is not diminished, or it can be shown that the building meets the minimum performance requirements of the Building Code.

It is considered that a seismic assessment carried out in accordance with these guidelines will provide an evaluative tool to help establish that the test under section 112(1)(b) is met. It may also be necessary to confirm other requirements of the Building Code have been met to the required degree, e.g. for amenity, to fully comply with the requirements of the Building Act.

Note:

The implication of using these guidelines for the assessment of the structural status of the building from a life-safety point of view for “alteration” purposes is that it is acceptable to confirm the structural (seismic) capacity of existing building elements based on probable capacities and other relaxations of B1/VM1 requirements contained within these guidelines.

Any new elements to be incorporated into the structure will need to be detailed to the full requirements of the Building Code for the actions resulting from application of the targeted XXX%ULS shaking demand. The intention for the retrofit of an existing building, where new building elements are being added to improve the overall earthquake rating of the building, is indicated in Figure A5.1. Refer also to Sections A10.2.4 and A10.2.5 for general considerations when seismic performance improvement works are being designed.

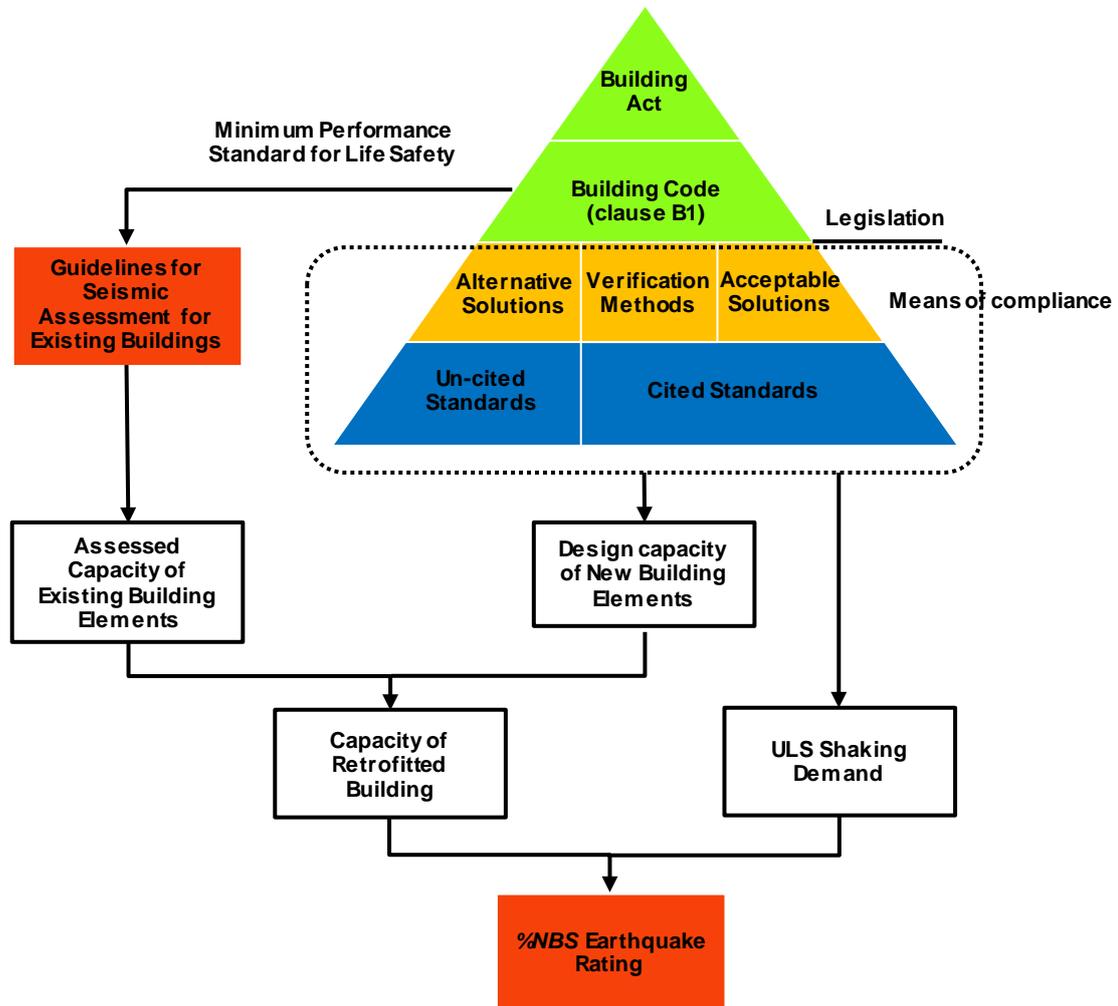


Figure A5.1: Use of Guidelines and Building Code to determine %NBS earthquake rating for alterations involving new building elements

Whether a building may be acceptable for alteration, with or without firstly, an engineering assessment and secondly, strengthening, will depend on the particular circumstances.

A6. Earthquake Scores and Rating

A6.1 Introduction

The earthquake rating or score (as appropriate) is intended to provide a measure of the seismic standard for life safety achieved by the building relative to the minimum that would meet the performance objectives set out in clause B1 of the Building Code. The earthquake rating and earthquake scores are expressed as the ratio of the ultimate capacity and the ULS seismic demand, or *%NBS*.

Note:

The intent is that an earthquake score is assigned to individual aspects of the building (these may include sections of the building, individual building elements or specific aspects such as slope stability in geotechnically dominated structures). The earthquake score of the lowest scoring element is the earthquake rating for the building. Therefore a building may have multiple earthquake scores but will have only one earthquake rating.

When establishing the earthquake rating or score, the procedures require consideration of the following in the context of the consequence to life safety:

- ultimate (seismic) capacity of the building as a whole (both strength and deformation)
- expected behaviour of the ground the building is founded on and how this might affect the response of the building
- influence of adjacent buildings (pounding)
- behaviour of elements in the primary gravity structure
- behaviour of secondary structure and non-structural parts.

The other input into the calculation of the earthquake rating or score is the seismic demand or ULS shaking demand.

A6.2 Calculation of *%NBS*

%NBS is obtained by dividing the calculated ultimate capacity (seismic) of the building or part by the ULS seismic demand as shown in the following equation:

$$\%NBS = \frac{\text{Ultimate capacity (seismic)}}{\text{ULS seismic demand}} \times 100$$

where:

Ultimate capacity (seismic) is taken as:

- probable capacity of the primary lateral structure of the building including the impact of geotechnical issues (refer to Section A6.6), or
- probable capacity of structural elements, the failure of which could lead to a significant life safety hazard (refer to Section A6.3), or
- capacity assessed for any identified SSWs (refer to Section A6.6), or

- probable capacity of SSNS elements which would pose a significant life safety hazard (refer to Section A4.3.2)

ULS seismic demand as described in Section C3, including the appropriate value of S_p (the structural performance factor) for the particular aspect under consideration. Refer to Section A6.4 for further discussion.

The earthquake rating will be the minimum value of *%NBS* calculated as above.

Note:

This is essentially the same for both the ISA (typically via the IEP) and the DSA. For the ISA (IEP), *%NBS* for the primary structure is assessed qualitatively against the design requirements that would have applied at the time the building was designed (adjusted for presence of SWs and the presence of secondary and critical non-structural items), whereas for the DSA it is determined quantitatively.

The earthquake rating should always be quoted together with the Importance Level that was assumed to determine the ULS seismic demand. The recommended presentation format, showing the percentage as *XXX*, the Importance Level as *Y*, and with “*%NBS*” always italicised, is:

XXX%NBS (ILY)

The Importance Level assumed when setting the demand, and therefore the basis for the earthquake rating, is critical to establishing the standard to which the building has been assessed.

A6.3 Ultimate Capacity (Seismic)

Ultimate capacity is a term defined in the Building (Specified Systems, Change the Use, and Earthquake-prone Buildings) Regulations 2005 (as amended), and set out in Section A5.1.1 of these guidelines.

While this definition relates to the use of the term ultimate capacity within the meaning of earthquake-prone building set out in the Building Act, it is applicable for all assessments of existing buildings carried out in accordance with these guidelines.

It is intended that ultimate capacity be calculated for the building as a whole and also for any building elements that are determined to be a significant life safety hazard.

The ultimate strength and deformation capacities are based on probable or expected values.

A6.4 ULS Seismic Demand

For the purposes of a seismic assessment, the ULS seismic demand is the 100% ULS shaking demand determined from the appropriate version of NZS 1170.5.

The Building (Specified Systems, Change the Use, and Earthquake-prone Buildings) Regulations 2005 (as amended) define the term moderate earthquake, which is used to

evaluate potentially earthquake-prone buildings under the Building Act. The definition fixes the date and version of the earthquake design actions standard, and therefore the ULS seismic demand, that must be used for assessments of potentially earthquake-prone buildings under the Building Act.

For assessments undertaken for other purposes, the demand is determined using the current version of the loadings standard applicable at the time of the assessment (rather than commencement of the earthquake-prone building provisions in the Building Act). This means that over time the demand used may differ between assessments to inform whether or not a building is earthquake prone and assessments for other purposes.

The quantification of the seismic demand is required for the DSA and is discussed further in Sections C1 and C3.

A6.5 %NBS Threshold for Earthquake-prone Buildings

One of the criteria that the TA use to determine if a building is earthquake prone is that its ultimate capacity will be exceeded in a moderate earthquake (refer to Section A5.1.1).

The moderate earthquake is defined as generating shaking at the site that is of the same duration and one third as strong as that used to design a similar new building. This is equivalent to 34%ULS shaking if the focus is to be on life safety.

Therefore, it follows from the equation given for %NBS in Section A6.2, that for the criterion above to be met, the %NBS for the building must be less than or equal to 33.3% or less than 34% if rounded.

The threshold can, therefore, be considered to be 34%NBS.

The same approach can be taken for a part of a building, i.e. the ratio of its ultimate capacity to the ULS shaking demand that would be used to design a similar part for a new building will be less than 34%NBS.

A6.6 Structural Resilience

The %NBS earthquake rating must reflect the ability of the building to continue to perform in earthquake shaking beyond the XXX%ULS shaking demand levels (where XXX%NBS is the determined earthquake rating). This ability is defined in these guidelines as the available structural resilience.

Structural resilience is necessary to allow a building to meet the overall performance objectives set in the Building Code. These objectives would not be met if the building had a high probability of failure once the XXX%ULS shaking demand levels are exceeded. Structural resilience is inherent in most building systems as observed from actual building performance in earthquakes that exceed XXX%ULS levels of shaking demand.

However, experience indicates there are some systems that have little structural resilience, are susceptible to a sudden reduction in their ability to continue to carry gravity load as the earthquake shaking increases beyond a particular value, and are difficult to quantify based

on current knowledge or inability to analyse. These are referred to in these guidelines as severe structural weaknesses (SSWs). If SSWs are present they require careful assessment and a process that ensures that there is sufficient margin against them causing system failure.

The general criteria for a SSW feature is that it must satisfy **all** of the following conditions:

- **the system has a demonstrated lack of structural resilience** so that there is very little margin between the point of onset of nonlinear behaviour (e.g. cracking of structure or large deformation of soil) and a step-change brittle behaviour of the building that could result in catastrophic collapse, and
- **there would be a severe consequence** if catastrophic collapse occurs. A severe consequence is intended to only be associated with building typologies with potentially large numbers of occupants and where the mode of failure could lead to full collapse, and
- **there are recognised limitations in the analysis and assessment of the behaviour** so that the reliability of the assessment of probable capacity of the expected aspect is low. This could be simply because there is currently considered to be insufficient experimental data or experience to confirm the behaviour to generally accepted levels of reliability.

The currently identified potential SSWs (ISA) and actual SSWs (DSA) are listed in Part B and Section C1 respectively, and cover aspects such as columns and walls in multi-storey buildings with high levels of axial load under dead and live loads, significantly inadequate connections between floor diaphragms and lateral load resisting elements and complex slope failure situations.

The manner in which the effect of the SSWs is to be accounted for is covered in Part B and Part C for an ISA and DSA as appropriate.

A6.7 Geotechnical Considerations

Geotechnical issues are covered in a similar manner to structural weaknesses. To affect the calculation of %NBS, the ground behaviour must lead directly to a significant life safety consequence for the building.

Ground conditions influence the behaviour of buildings in several ways, depending on the nature of the ground, the expected building behaviour and the nature of the earthquake. Some of these are discussed below.

The first direct influence is on the seismic actions in the building or its parts, as the soil class is a critical input to the spectral shape factor in NZS 1170.5:2004. For ISAs and relatively simple DSAs, it will generally be suitable to infer the soil classification from local knowledge, surrounding buildings and desktop study if required. For a more complex DSA, where the soil classification could significantly impact on the outcomes, more detailed investigation may be required.

Soil-foundation-structure interaction effects may significantly influence the assessment where there is significant non-linearity, either through the behaviour of the soils, for example in cases involving liquefaction, or through the behaviour of the building itself, for example where foundation rocking occurs.

Nonlinear behaviour in the soil requires careful consideration, but a key question to consider in all cases is whether the non-linearity will impact life safety or just amenity and serviceability. Only life safety concerns that relate to the behaviour of the building need to be addressed in assessing %NBS, although in some cases, the brief may include a request to consider serviceability. That is beyond the scope of this document, although some of the guidance provided may be relevant.

The most obvious form of soil non-linearity is liquefaction, but it is important that the impact of liquefaction on building behaviour is considered before embarking on exhaustive geotechnical analysis. The significant settlement that results from widespread liquefaction may not have any significant impact on life safety, especially if the foundations are well connected and when there is an element of toughness in the building superstructure. Conversely, even relatively nominal differential effects may have a significant life safety impact on unreinforced masonry buildings with isolated footings.

Foundation rocking (often by those that were originally designed as fixed base foundations) has often been regarded as the saviour of buildings that may otherwise have been significantly overstressed by larger earthquakes. Rocking has the effect of lengthening the building period and consequently increasing the displacements of the system. In many cases, this will not be critical, but the consequences of the additional displacement should be considered, particularly on the primary gravity structure, which must ‘go along for the ride’.

A7. Planning a Seismic Assessment

A7.1 Introduction

This section outlines the steps involved in planning a seismic assessment, which involves working through the steps of briefing, gathering information, carrying out physical inspections and investigation, undertaking initial qualitative assessments followed by quantitative assessments to the extent considered appropriate.

Emphasis is placed on developing a strategy and approach that reflects both the assessment objectives and the nature of the building, taking into account the level of available information.

A7.2 Assessment Procedure

A generalised assessment process is illustrated in Figure A7.1. The steps in the process are summarised in the sections that follow.

A7.3 Briefing – Clarifying Scope and Objectives

Before commencing an assessment, the brief should be clearly understood.

It is important to verify the brief carefully to ensure the client receives everything they require from the assessment process. Accepting a brief from a client is an opportunity to develop an understanding of their needs. Think about:

- What is driving the need for the study? In particular, consider whether potential alterations or change of use requirements may force the evaluation at a higher level than the earthquake prone assessment.
- Does the client wish the study to be limited only to those aspects of the building that require assessment under the earthquake-prone building framework, or do they require the scope expanded to address a broader range of building elements?
- Is the assessment in response to another assessment (e.g. by a TA). If so, does the scope of the proposed assessment address all of the issues that have been raised?
- Are upgrading options to be considered, and if so, what is the performance objective (noting that this is partly about the target loading, partly about the tolerable damage that will be acceptable)? Are there multiple performance objectives?
- Do future insurance requirements have a bearing on the decisions that may need to be taken for the building?
- Does the building have a heritage rating, and/or what are the major heritage features of the building that should be retained?

It is recommended that a reflected brief be prepared and returned to the client for approval before finalising an assessment contract. This reduces the potential for miscommunicating expectations.

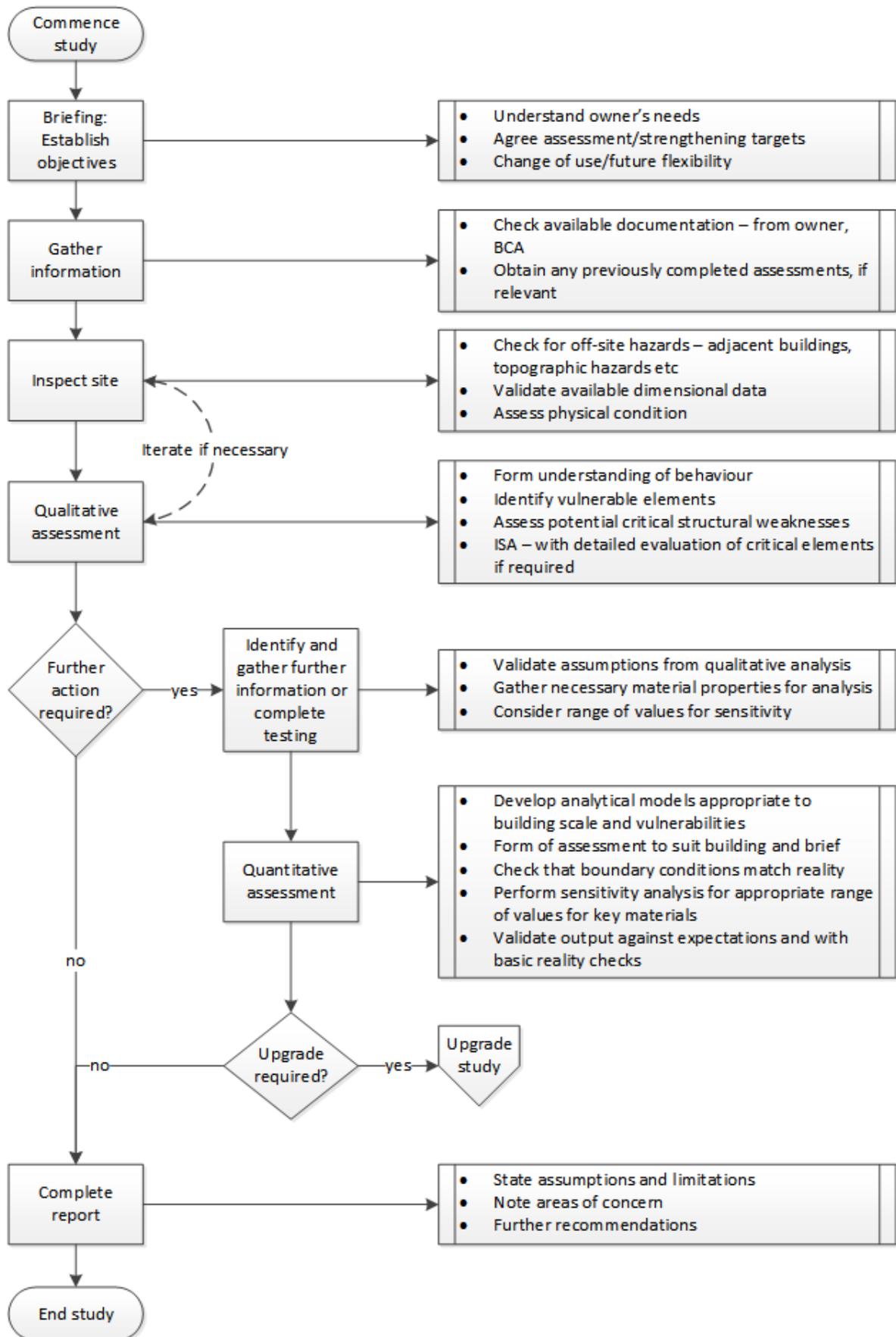


Figure A7.1: Generalised assessment process flow

A7.4 Gathering Information

Assessment of existing buildings requires careful information gathering, the level of which may vary considerably according to the building type and the purpose of the assessment. In general, the more complex the building and the more detailed the study, the more care should be taken to assemble the information required.

Equally, it may be possible to complete an ISA with limited information on key aspects of the building only, to a level that may be sufficient for the purposes of determining whether or not a building is potentially earthquake prone. There may be limited value in obtaining further information if this is the sole purpose of the assessment.

Information gathering is generally iterative. It may be more time efficient in many cases to perform preliminary analysis using relatively approximate data, in order to develop an initial understanding of a building; this may then inform the subsequent detailed information gathering. A targeted information gathering process may then be developed that places more emphasis on the most critical elements.

Equally, it is often found that a study may be limited by the information available. In such cases, the underlying assumptions should be clearly stated and recommendations made on further information that is required to give a more comprehensive assessment. In such cases, a reasonably conservative set of assumptions may be appropriate and should be based on knowledge of the generic details of the age and form of the construction.

Note:

Information gathering should include obtaining access to any prior assessments. All previous views should be taken into account when reviewing a building, although care should be taken to verify any differences in the briefing requirement, particularly when these may lead to differences in the assessment outcomes.

A7.4.1 Accessing documentation

Building documentation may be held by a number of sources, including:

- TAs
- building designers (from both original design and for subsequent alterations)
- builders
- owners, either original or subsequent
- facility maintenance contractors.

It is important to note that the documentation provided may not always be the most current. It is common for construction documentation to vary considerably from the consent (or permit) documentation, and old records often contain a mix of structures that were built and others that were not. Documentation for subsequent alterations may not always be archived or stored with the original documentation. Engineers should satisfy themselves thoroughly that the documentation is representative of the building being studied before relying on it.

Documentation may not be available for all buildings, in which case more reliance needs to be placed on inspections and testing to provide the information required to complete the assessment.

A7.4.2 Inspections

A visit to the building is a key part of the assessment process and should be completed as part of both an ISA and a DSA.

It is possible for an ISA to be completed using only external inspection. Where this is the case, it should be noted in the report so that suitable allowance can be made for this when the assessment is being used by others.

Note:

For assessments of potentially earthquake-prone buildings being undertaken in accordance with the EPB methodology, an external inspection of the building is required, and an internal assessment is also required where it is appropriate to do so.

An initial visit (before any analysis) is essential to develop a broad understanding of the building and to verify that the documentation obtained is truly representative of the building. The engineer would generally have made a qualitative evaluation of the building first, in order to identify key elements or details for review. Matters to be considered include:

- verification that the general arrangement of the building matches the drawings or assumptions
- checking of key dimensions for overall accuracy
- consideration of neighbouring buildings – assess the potential for pounding
- consider the extent of the building so that the affected building owners can be involved where the building extends over more than one title
- consideration of the expected geotechnical conditions and how these may vary with shaking intensity (including accounting for variability)
- consideration of off-site hazards, such as landslide
- general condition assessment – can key elements develop their calculated probable capacity?
- identification of key configurational issues, such as irregularity, diaphragm openings, etc.
- identifying the other building elements that need to be assessed and any of those that will require specialised assistance.

Note:

Fundamental differences between available drawings and what has actually been built can be observed, even from a relatively brief exterior inspection at the time an ISA is completed. A full inspection to confirm details and potential interaction of primary structure with other building elements is considered an essential part of a DSA process.

Subsequent visits will be required to investigate key elements and details more closely. This will normally follow sufficient analysis to have a preliminary opinion of the building behaviour, allowing investigation on site to verify that the most critical elements are as analysed.

Note:

Inspections could identify building elements that meet the Building Code performance requirements for earthquake but may not meet its requirements for other physical situations such as wind or for clauses other than B1 - Structure. These guidelines are not intended to be used to assess building element performance in those situations.

A7.4.3 Geotechnical investigation

All building assessments require some consideration of the geotechnical conditions, in order to assess the ULS shaking demand, any soil-structure interaction and structural response.

The level of geotechnical investigation required may vary from a desk-top study for relatively small structures on ‘good’ ground (i.e. not expected to be subject to significant differential settlement or liquefaction) for the purposes of determining whether or not a building could be earthquake prone, to comprehensive studies for large, complex structures on ground with the potential for significant differential settlement.

In general, it is recommended that the level of investigation required is determined in conjunction with a suitably experienced geotechnical engineer who has a level of familiarity with the expected site conditions.

Soil conditions may be assumed, based on knowledge and experience, for qualitative analysis. However, such assumptions should be clearly described and should be verified on site in the event that further quantitative analysis is required.

A7.4.4 Intrusive investigations

Intrusive inspection may be required for the verification of key details and for material testing.

In the case of verification of key details, engineers should be aware of the potential for variation within the building and choose enough locations throughout the building to develop an appropriate degree of confidence in the assumptions that are being made. This may vary depending on the criticality of the details being investigated, the stage of the assessment, and the convenience of exposing the details.

For example, in URM buildings, the floor-wall connections are critical. At the preliminary stages of assessment, it may be sufficient to expose only one or two locations to verify whether there are any connections at all, i.e. is there a load path. In later stages, the precise detail and spacings may be critical, in which case further investigation may be required.

Where investigation requires a level of destructive testing or exposure of concealed elements, locations should be selected carefully to provide all of the information that may potentially be required. For example, if exposing reinforcement in concrete buildings, locations should be selected to verify not only the size and location of the reinforcement, but also key detailing and conditions that may affect underlying assumptions. These include:

- Are the bars plain or deformed?
- Where are the laps located relative to potential plastic hinges?
- Where is the transverse (confining) steel and how is it anchored?
- What is the condition of the reinforcement in key locations?

A7.5 Assessment

A7.5.1 Different levels of seismic assessment

All assessments need to have a clearly defined set of objectives, without which the outcomes may be unclear and inconsistent. This is often a significant factor when assessments of the same building by different engineers have had very different outcomes. Regardless of the purpose of the assessment, a clearly identified set of objectives should be defined at the outset and the outcomes of the assessment should be validated against these objectives on completion.

The objectives of the ISA and DSA were introduced in Section A1. This section provides a more detailed contrast between these two forms of assessment and also the continuum in assessment available across and within each.

When undertaking ISA and DSA assessments, it is important that the quality and quantity of data discovered on the form and condition of the existing building is appropriate to the level of reliability required for the assessment and is recorded as part of the assessment.

The EPB methodology gives the requirements for assessments under the earthquake-prone building framework set by the Building Act.

A7.5.2 Assessment continuum

The ISA and DSA processes presented in these guidelines provide two slightly overlapping bands within a continuum of possible seismic assessments. This is represented in Figure A7.2.

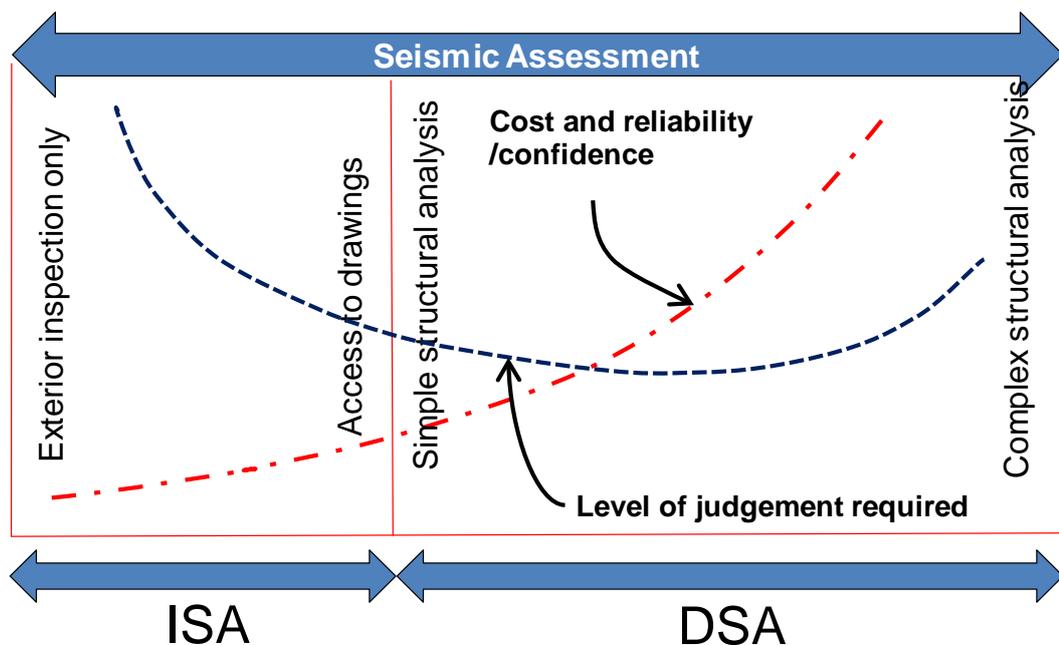


Figure A7.2: Assessment continuum

Each of the ISA or DSA processes can be carried out with a varying degree of knowledge and detail. At the extremes, a well-executed ISA may yield a result that is at least as reliable as a DSA carried out using very simplistic analyses.

Generally, however, the further the assessment processes moves to the right in Figure A7.2, the more reliable should be the result, albeit at generally greater cost for the assessment.

At all levels of assessment, the judgement of the engineer is an important input. As shown indicatively, the level of judgement required is highest during an ISA when there is little data on which to base the assessment. The level of judgement reduces as the assessment proceeds from ISA to DSA as the understanding of the attributes of the building become clearer. However, the need for judgement/experience rises if more sophisticated analysis techniques are employed in a DSA because the results can become very dependent on the inputs, and experience will be necessary to judge if the results are reasonable and valid.

A7.6 Distribution of Assessment Outcomes

All assessment involves assumptions such as:

- materials used in the original construction
- structural mechanisms that will form as the level of shaking increases
- founding conditions for the building
- alterations to the building over time.

As the assessment proceeds, assumptions are validated or changed to suit what is learned. The more assumptions that are validated, the greater the knowledge of the building's expected behaviour. Hence the assessment may be considered more reliable.

Of necessity, the more unverified assumptions that are involved, the more conservative the assessment of capacity should be, relative to the actual capacity of the building.

It is a matter of judgement as to how much effort should be expended to refine the assessment, either by completing more extensive (and possibly destructive) investigation of the building itself, or by using more elaborate methods of assessment. In some cases, it may be more appropriate to use the time (and cost) to instead provide improvement, especially in cases where the building is clearly earthquake prone.

Note:

Additional information and new findings over the course of an assessment may reduce (or increase) the assessed earthquake rating.

A7.7 Level of Detail of Assessment

Assessment of existing buildings requires considerable judgement to be exercised, not least in determining what elements of the building require assessment and how detailed that assessment should be.

There are three generally useful principles¹² that engineers should be mindful of:

- The Principle of Requisite Detail, which states that there is a minimum level of detail necessary in a (system) model for adequately emulating the reality that is intended to be modelled. In other words, it is important that engineers do not over-simplify the assessment to the extent that poor behaviour of a building is not identified or captured.
- The Principle of Decision Invariance, which states that the system should be sufficiently detailed that the addition of further refinement will not affect the decision. The point here is that there is no value in making models ever more complicated or comprehensive in the name of accuracy, if the additional detail makes no difference to the outcome; in fact, it may serve to obscure the outcome and simply add time and cost to the assessment.
- The Principle of consistent crudeness, which states that the quality of the output of a model cannot be greater than the quality of the crudest input or of the model itself, modified according to the sensitivity of the output to that input.

It may often be the case that until a model has been run and the hypothesis tested, a suspected outcome cannot be discounted. However, there is little point in modelling elements to a high level of detail, if there are other aspects of the building that have much more significance for the overall performance, within the broad range of interest of the assessment.

Note:

Boundary conditions assumed in modelling often play a critical role in the assessment and should be carefully considered. An example of a critical boundary condition is whether to assume a fixed base condition under a shear wall. If a fixed base is assumed, the building model may be artificially stiffened, shortening the period and increasing demand, which may at first look conservative. However, this may also have the effect of decreasing the displacement of the system, which may artificially reduce deformation demand on the primary gravity and secondary systems. Conversely, if the wall is modelled with too soft a foundation support, the base may rotate more than it should, reducing load demand but possibly over-estimating drifts.

A realistic assessment of the geotechnical conditions is one of the most important boundary condition assumptions for building modelling. It is advised that a range of soil stiffness options should be considered when modelling building systems for which this may be critical. Typically, this will occur when there are soft soil conditions and/or where assessing building types that are vulnerable to significant ground deformations. This includes in particular URM, which has relatively little tolerance to ground deformation. At the other extreme, most moment frame structures should be able to tolerate significant differential settlements.

¹ Brown CB & Elms DG (2015), Engineering decisions: Information, knowledge and understanding, Structural Safety 52 (2015) 66-77, Elsevier.

² Elms DG (1985), The principle of consistent crudeness,, Purdue University, IN, 1985 Proc Workshop on Civil Engineering Application of Fuzzy Sets, Purdue University, IN, 1985.

A7.7.1 Qualitative assessment

The first step in any building evaluation should be a qualitative assessment. The ISA provided in Part B is essentially a qualitative assessment. Qualitative assessment is a vital predecessor to quantitative analysis. It informs the engineer of the key elements of the building and assists in focusing the subsequent detailed evaluation.

This requires the engineer to consider not only the mechanisms that may have been envisaged by the original designer, but also the combined effect of unrecognised load paths, structural incompatibilities (that may be better understood now than at the time of design) and the impact of alterations over time. The last may include the effects of time itself. That is, aging of the building and maintenance (or lack of it).

The ISA should include assessment of available plans and specifications; but this should always be approached with caution. Often the plans that are available are not those that were built from and may not include subsequent alterations. Moreover, then as now, buildings were not always built according to the plans. Part of the role of the engineer is to consider the possible impact of these variables and make reasonable allowance for them in the assessment.

Qualitative assessment should include (but is not limited to) an IEP. This is at least a useful benchmarking exercise that enables engineers to consider at a high level those attributes of the building that may have significant impact on the behaviour of the building. By approaching this in a qualitative sense before detailed assessment, it gives a sound basis for self-checking of the outcomes of future detailed analysis.

Qualitative assessment may include some ‘back of envelope’ calculations of key element capacities and demands, in order to test how critical mechanisms or details are and to verify the findings or judgement calls of an IEP.

A7.7.2 Quantitative assessment

Quantitative assessment generally consists of a DSA in the form outlined in Part C. It is informed by the findings of the qualitative assessment, which should assist in identifying likely failure mechanisms that should be investigated in more detail.

Prior to commencing quantitative assessment, the outcomes of the qualitative assessment should be reviewed, with emphasis on what matters may need to be included in a detailed assessment, including consideration of:

- Is further investigation required to confirm assumptions made in the qualitative assessment?
- What boundary conditions have been or will be assumed and how do these relate to reality?
- What foundation conditions have been assumed?

Geotechnical conditions are a key consideration for quantitative analysis, requiring a suitable degree of investigation in order to validate assumptions and to provide the inputs required for detailed evaluation.

Note:

Particular emphasis should be given to the impact of significant differential settlements, with close attention being paid to the range of possible outcomes. For example, in sites that are expected to have significant liquefaction at a given level of shaking, consideration should also be given to the possibility that liquefaction does not happen. In such cases, liquefaction may be considered to be a limiting factor for the building's rating, but a premature failure of a brittle element under higher levels of shaking may pose a greater risk for occupant life safety.

A7.8 Establishing the Assessment and Analysis Strategy and Approach

The assessment procedure followed will be determined according to a number of factors, including:

- The objectives of the study. If the primary purpose is simply to provide information to assist TAs in establishing whether a building is earthquake prone, it may be enough to complete an ISA, based on relatively generic information, so long as this meets the requirements of the EPB methodology. However, if a client requires a more comprehensive assessment of risks for a building for other purposes, that may determine the need for a detailed assessment.
- The complexity of the building. Although scale may determine the risk (as it impacts occupant numbers), the complexity of the structural form is a more significant factor in determining the assessment methodology.
- For example, simple, regular, low-rise structures may be assessed using a combination of an ISA with specific analysis of identified critical elements to establish an overall earthquake rating. The scale of such a building may not be relevant, provided that the load paths are simple and the building may be relied upon to respond in a regular fashion. Conversely, a mid-to-high rise building with significant irregularity (for example a corner building with walls on the internal boundaries) is expected to behave poorly, and is expected to require a full higher order analysis.
- The degree of influence of soil conditions. This can be a significant influence, particularly when there is potential for significant differential settlement, with or without liquefaction. The analysis of buildings should include appropriate allowance for soil non-linearity, foundation flexibility and possible variations (through sensitivity analysis).

In all cases, engineers should consider the limits of applicability of the assessment processes being considered. This is particularly important when assessing buildings with mixed systems and/or unknown ductility demand, or irregular buildings with diaphragms of sufficient rigidity to redistribute actions between lines of support (i.e. the potential for torsional response).

A8. Reporting Seismic Assessment Results

A8.1 Introduction

It is important to report assessment results in an appropriate context, at both the ISA and DSA levels of assessment.

This includes %NBS earthquake scores and rating at an appropriate levels of precision, and a seismic grade and qualitative risk classification.

For assessments of potentially earthquake-prone buildings, the EPB methodology sets out reporting requirements, which includes the completion of a report summary to be submitted with the full assessment report. It is recommended that this summary is prepared for all assessments, whether or not they are being completed for earthquake-prone building purposes. The template summary report is discussed further in Section A8.5.

Note:

Adherence to these recommendations is considered essential. It is very important that the report correctly describes the result of the assessment in terms that define the scope of the assessment and the basis for it. Just providing a %NBS earthquake rating without these could suggest that the building meets the new building standard generally (i.e. including gravity and wind, etc.) and earthquake provisions in particular without inclusion of the existing building concessions that are included in these guidelines.

It is important to include a discussion of the grading and level of risk to put the earthquake rating in context. Without this, there is no reference point for the rating and the recipients could perceive it requires an unintended immediate action (e.g. vacating a building).

A8.2 Level of Precision in Reported %NBS Earthquake Scores and Rating

The %NBS earthquake rating given needs to reflect the reliability/accuracy implied. For this reason, earthquake ratings should only be quoted as a whole number. Except for 18, 19, 33, 34, and 67%NBS earthquake ratings that are close to the two earthquake-prone and the earthquake risk thresholds respectively, it is further recommended that the whole number scores be rounded to the nearest 5%NBS (up or down).

Numerical scores above 100%NBS may provide an erroneous indication of expected performance. It is recommended that these are simply stated as >100%NBS unless, for example, there is a need to reflect a score or rating relative to a different importance level standard in which case a rating of 130%NBS (IL2) may be relevant as representing 100%NBS (IL3) in change of use discussions.

Likewise scores below 15%NBS have no practical meaning unless the building's expected seismic performance is extremely tenuous which will rarely be the case. Therefore, it is recommended that a score or rating is not quoted as less than 15%NBS.

Table A8.1 indicates the intent of the recommended rounding.

Table A8.1: Rounding of %NBS earthquake ratings

Raw (Assessed) score	Assigned rating for reporting purposes
0% - 17%	15%NBS
18%	18%NBS
19%	19%NBS
20% - 22%	20%NBS
23% - 27%	25%NBS
28% - 32%	30%NBS
33%	33%NBS
34%	34%NBS
35% - 37%	35%NBS
38% - 42%	40%NBS
...	
63% - 66%	65%NBS
67%	67%NBS
68% - 72%	70%NBS
...	
98% - 102%	100%NBS
> 102%	>100%NBS

Engineers should consider carefully before rating a building between 18%NBS and 20%NBS, 30%NBS and 37%NBS or between 65%NBS and 70%NBS. The ramifications of not exceeding each threshold level can be significant in terms of implications for additional assessment and action required and should be carefully considered. More detailed consideration of the CSW in a DSA may move the rating away from these critical ranges. Refer to Part B for further discussion on the reliability available from the ISA and how to deal with this.

A8.3 Grading Scheme

The NZSEE developed a grading system to complement the %NBS earthquake rating. This bands the assessment results to reduce the emphasis of the percentage value within an earthquake rating.

The wider objective of the grading scheme is to raise industry awareness and allow market forces to work in reducing earthquake risk.

The NZSEE grading scheme and the linkage with the %NBS earthquake rating is summarised in Table A3.1.

The NZSEE grading system is not a requirement of the Building Act. Instead, earthquake rating categories (which are consistent with this scale) are established in the Building

(Specified Systems, Change the Use, and Earthquake-prone Buildings) Regulations 2005 (as amended) and assigned by TAs to earthquake-prone buildings.

Note:

Other grading schemes are also currently under development, e.g. Quakestar. These can consider a broader range of seismic issues than just life safety and structural issues.

A8.4 Qualitative Risk Classification

It is useful to provide a qualitative risk classification to provide context for reporting the assessment results.

The intended risk classifications are shown in Table A3.1.

Buildings that are classified as earthquake prone in accordance with the Building Act are regarded as high risk buildings. Those with $\geq 67\%NBS$ are regarded as being low risk. This leaves a group in between that meet the requirements of the Act but cannot be regarded as low risk. These have been termed low to medium risk.

Note:

For many years NZSEE has referred to buildings $<67\%NBS$ as being earthquake risk. Broadly speaking, these can be assumed to be all buildings not classified as low risk.

A8.5 Assessment Summary Reports

A8.5.1 General

Part B provides a reporting framework and covering letter for ISAs and a corresponding framework is provided in Part C (Section C1) for DSAs.

A suggested template table, referred to as an Assessment Summary Report, is also provided on www.EQ-Assess.org.nz as a separate file. This table summarises the key points from seismic assessments, and should accompany both ISA and DSA reports. For seismic assessments for earthquake-prone building purposes, the EPB methodology requires the engineer to provide an assessment summary report.

The purpose of the summary is to provide better consistency in both the information provided and the way it is provided, and hence provide clearer communication between all parties. All judgements made need to be justified/substantiated, and preferably recorded, as part of the assessment process.

Assessment Summary Reports should provide the following information:

Building information

- Address etc., No. of storeys, year of design, structural system, previous retrofit

Assessment information

- Person responsible for the assessment, when inspected, what information reviewed, geotech info, previous reports referred to

Summary of engineering methodology and key parameters

- Assessment methodology used, and how these Guidelines were applied

Assessment outcomes

- %NBS rating, seismic grade and qualitative risk classification, governing CSW; mode of failure and physical consequences statements (refer Section A8.5.2).

A8.5.2 Understanding and Determining Building Failure Modes

One of the reporting requirements for engineering assessments from the EPB methodology is the need to report on modes of failure where the building is found to have an earthquake rating of less than 34%NBS. This includes parts of buildings as well as the building as a whole where the scores are less than 34%NBS.

Building failure, in common language, implies the complete failure of a structure, resulting in widespread physical harm to the occupants. However, failure requires a more comprehensive definition for the purposes of building assessment. In a life safety context (as discussed in Section A3.1.1), building failure implies a form of failure that will lead to a significant life safety hazard (noting that the Building Act 2004 is also concerned with damage to adjacent buildings).

Once again, the differences between design and assessment (refer to Section A4.1) are critical:

- When designing buildings, it is relatively straightforward to ensure that building elements will meet or exceed their target capacity (either strength or displacement). It does not preclude the failure of elements, but the design approach (including, for example, the principles of capacity design), generally provides confidence in the overall building performance. By detailing elements for the assumed ductility demand and keeping redistribution within code limits, designers are assured that elements are not pushed beyond their expected deformation capacity. This is especially critical for elements that carry significant axial gravity load. Confidence is also provided that the building will continue to perform satisfactorily at levels of shaking well beyond design levels.
- In assessment, it is important to address the implications of element failure more comprehensively. Failure of individual elements within a building does not necessarily lead to failure of the building as a whole or the need to consider the element as a significant life safety hazard.

For example, a beam that has its shear capacity exceeded may ‘fail’, but is expected to hang in catenary action and so would not be regarded a significant life safety hazard. However, a column that has its shear capacity exceeded also loses the capacity to resist simultaneous axial load and hence may cause a localised or more widespread collapse condition. The former does not limit the building’s capacity, but the latter does.

Note:

While exceeding the shear capacity of individual beams may not in itself constitute a significant life safety hazard, successive shear failures in multiple beams in a concrete frame, for example, is expected to lead to deterioration in lateral capacity and a significant life safety issue for the building as a whole.

The Mode of Failure and Physical Consequence statement is a description by the engineer of the manner and extent to which the lowest building element scoring less than 34%NBS could collapse or fall and give rise to a significant life safety hazard.

Table A8.2 provides sample Mode of Failure and Physical Consequence statements for some building elements relating to the building overall and parts. The entries are illustrative of both the information required and the brevity expected. The entries in the Exposure of People column are indicative only, to illustrate how it is anticipated that TA officers will consider the numbers of people or other people that could be exposed to the hazard described in the mode of failure statement as they apply s133AB(1)(b) as the final step in making an earthquake prone decision.

Table A8.2: Sample summary statements of the mode of failure and significant life safety hazard (building or parts) for selected situations

Engineering statement of structural weaknesses <34%NBS and location	Mode of failure and physical consequence statement (including the nature and extent of impact giving rise to a significant life safety hazard)	Exposure of people or damage to other property
ENGINEER TO DETERMINE		TA TO DETERMINE
Building overall		
Building column shear failure	A sudden loss of gravity support for a section of the floor, leading to collapse of part or all of the building within or beyond its footprint	People inside or outside the building People in adjacent building(s)
Failure of wall bracing	Building may displace excessively, leading to overall collapse	People inside or outside the building
Parts of buildings		
Unrestrained URM parapet	Parapet sections may fall from the building onto areas outside the building and/or inwards onto roof	Public access in street in front of building People in or around vehicles in the accessway alongside the building
Precast panel connection unable to accommodate lateral movement of the building	Panel(s) may fall on the areas outside the building	People in main entry lobby inside the building
Roof diaphragm connection to perimeter wall elements	Wall panels may fall outside the footprint of the building	People in the neighbouring building(s) Damage to the roof structure of the neighbouring building(s)

Inadequate restraint for air handling units of mass greater than 50 kg within suspended ceiling system

Air handling units could fall more than 3 m to floor (and/or impact the suspended ceiling system and cause that to fall also)

People in the building

A8.6 Acknowledging Other Assessments

The report should list any other known seismic assessments of the building, and acknowledge any differences in the assessment results (e.g. earthquake rating) and the reasons for them.

Note:

The explanation need not present technical detail other than to note if the various assessments were DSAs or ISAs, that there were additional inspections, that it included material test results, etc.

When noting the differences on an Assessment Summary Report it is advisable for all comparisons to be with the current assessment and to note on the form “The earthquake rating increased/decreased to XXX%NBS (ILY) because...” rather than giving the superseded rating(s) to avoid confusion with the current earthquake rating being reported.

A9. Reconciling Differences in Assessment Results

Due to the nature of the seismic assessment process, it should not come as a surprise that, in some circumstances, assessments of the same building by two or more experienced engineers may differ – sometimes significantly. This is to be expected, especially if a different level of information was available to each engineer. This will particularly be the case for earthquake ratings determined using the ISA process, but can also happen should multiple DSAs be completed for the same building.

However, it is expected that experienced engineers will be able to identify the critical issues that are expected to affect seismic behaviour and that, through discussion, a consensus position should be able to be agreed. If the assessments are at the ISA level and consensus cannot be reached, a DSA is recommended (refer to Part B). If the disagreements occur at the DSA level and cannot be readily resolved, the differences in opinion should be acknowledged and recorded.

Note:

Any assessment that has been independently reviewed is expected to provide a more robust earthquake rating than one based solely on the judgement of one engineer. Therefore, independent review is encouraged.

A10. Improving Seismic Performance

A10.1 Introduction

There are many buildings in New Zealand constructed prior to the introduction of the modern earthquake design approach in 1976. The cost to the community that would be requiring for full compliance with current standards (i.e. all buildings brought to 100%*NBS*) would be considerable, and arguably disproportionate to the risk reduction.

Note:

It is considered that the community would accept a higher level of risk in an existing building than for a new building, if only for the reason that it will, in general, be economically more feasible to provide higher levels of dependable strength and reliable ductility in a new building than in an existing one. As a result, existing buildings that can be shown to have an earthquake rating $\geq 67\%NBS$ can be considered to represent a low to medium risk in regards to life safety.

Accepting an earthquake rating of 67%*NBS* as a minimum for existing buildings to be categorised as low/medium risk corresponds to an increase in risk for an existing building of up to approximately five times that of an equivalent new building. This is judged reasonable and compares well to equivalent levels set for the evaluation of existing buildings in the United States. For example, the approach taken in ASCE 41-13 (2014) leads to approximately 75% of the new building standard for the defined performance objective BPOE (basic performance objective for existing buildings).

While this increase in risk could appear high on a building-by-building basis, it appears a reasonable minimum target overall and needs to be considered in the context of the low level of risk implied in absolute terms.

Upgrading to as nearly as is reasonably practicable to new building standard is recommended. However, it is considered more important and realistic to identify the high risk buildings, and reduce the risk they pose to a more acceptable level, rather than to attempt to ensure that all existing buildings comply with the latest standards. The elimination of non-ductile failure mechanisms and CSWs is in itself of greater importance than the actual assessment and strengthening level. Buildings rarely fail during earthquakes solely because the design forces have been underestimated. More often than not, poor performance is the result of some obvious configurational or detailing deficiency.

A10.2 Overview of Improvement Processes

A generalised assessment process is as illustrated below in Figure A10.1. The steps in the process are summarised in the sections that follow.

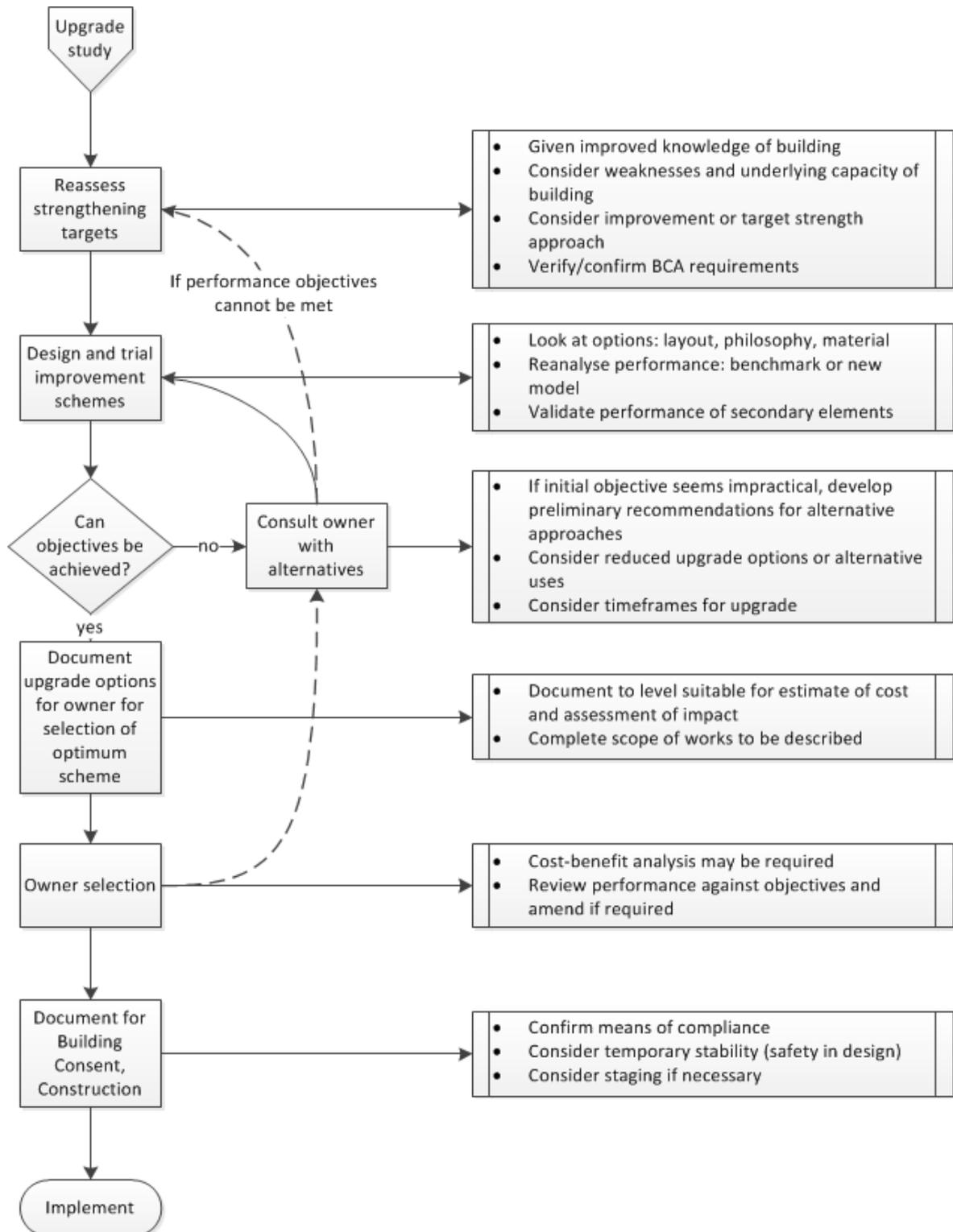


Figure A10.1: Generalised seismic upgrade process flow

A10.2.1 Establishing performance objectives

It is important that a detailed understanding of the owner's future performance requirements/expectations is achieved. Although this will often be expressed simply as a strengthening target in terms of %NBS, this may only provide a part of the picture.

With improving the performance of buildings essentially about risk reduction, it is important that the owner's risk appetite and main concerns over likely outcomes are both well understood. Factors that may be considered include:

- compliance with Building Act 2004 requirements
- usability following earthquake
- reparability
- cost of repairs
- non-structural performance
- future flexibility.

Determining the owner's performance objectives and requirements will inform the repair strategies that may be worthy of investigation.

A10.2.2 Improvement philosophy

There are many different methods for improving buildings. Some of the most common may be broadly categorised as follows:

- **Replacement:** Inserting a new lateral system that will resist the majority of the seismic load. This may be used where a building's rating is very low and would be difficult to improve, or where a building is being extended.
- **Enhancement:** Improving the existing lateral systems without substantially changing the mode of behaviour. May be used where a building requires only a relatively minor increase in rating.
- **Protection:** Increasing the capacity of the structure (principally the gravity system) to tolerate the imposed displacements. May be used where the primary lateral load resisting structure has sufficient capacity but the primary gravity system and/or other building elements have insufficient displacement capacity to tolerate the ultimate drift.
- **Reduction in demand:** Reducing the demand on the building by isolation or by increasing the damping in the system. May be used where there is a need to reduce damage to contents or where the primary systems cannot tolerate the imposed displacements.

Several alternative approaches and different levels of intervention should be investigated before adopting any one particular approach. Although direct cost is often one of the primary criteria for assessing improvement concepts, there are other important considerations, including those mentioned in Section A10.2.1 above.

It is generally recommended that improvement is not approached dogmatically with a specific rating target in mind - that is to say, compromise in the desired performance objectives or outcomes should be considered.

Note:

There is generally not a linear relationship between upgrading cost and rating improvement. For example, introduction of new elements into a building may create a step change in cost, but there may only be a minor incremental cost increase to improve the building's rating to the limits of what the new element could contribute.

A10.2.3 Other considerations**A10.2.3.1 Improving buildings with higher importance levels**

Buildings of higher importance levels (IL3 or IL4) may require improvement to satisfy functional requirements including post-disaster use, or for reduced levels of damage.

Where reduced levels of damage are an essential outcome of the improvement process, consideration should be given to displacement limits based on the most displacement sensitive elements that need protecting.

For buildings that require improvement in order to become an IL4 facility, it is recommended that full compliance with SLS2 requirements is targeted, along with a minimum of 67%NBS for ULS requirements. All parts that are required to be operational following the SLS2 event, or the failure of which might limit the building's use for its intended post-disaster purpose require consideration.

A10.2.3.2 Improving heritage buildings

Many heritage buildings are either earthquake prone or earthquake risk buildings. While the assessment of these buildings will generally follow the same principles as other buildings, their improvement requires more careful consideration in order to determine an acceptable upgrading strategy. In practice this often requires a significant degree of compromise between heritage impact and structural upgrading objectives.

This is outside the scope of this document, but the principles outlined herein will be generally applicable. Reference should be made in particular to the ICOMOS New Zealand charter³.

A10.2.3.3 Improving buildings with more than one structure

Improving the performance of an individual structure that is either structurally connected to or expected to be affected by its close proximity to one of more other structures requires careful consideration.

Note:

Improving the performance of these structures requires similar considerations to their assessment, with the general condition that improvement of one structure cannot adversely affect the others it is connected to or in close proximity to.

Close attention needs to be paid to how load is expected to be transferred between the structures – either intentionally or unintentionally (e.g. through pounding). Particularly where there are stiffness incompatibilities between adjacent structures.

³ ICOMOS New Zealand Charter, for the Conservation of Places of Cultural Heritage Value, 2010.

Some additional considerations apply with regard to party walls.

There is an obligation on the owners of the property on either side to consider the implications of the work they propose on both existing and future configurations. There may be some legal constraints if there are specific agreements in place (for example a party wall agreement or right of support). However, the support of the wall and what it supports should be considered both with and without the adjacent building in place.

When separating the structure under consideration from the neighbouring property, the adverse effect of the separation to the adjacent structure(s) should be considered. In such cases, the party doing the work is responsible for ensuring that the adjacent property is made no worse by the alteration. This may require new wall anchors to be provided for the roof and/or floor(s) in the other property in order to provide the separation.

A10.2.4 Use of analysis methods from this document in conjunction with the design of new strengthening elements

The design of new elements of buildings must comply with section 17 of the Building Act 2004, which requires that all new work must comply with the New Zealand Building Code, to the extent required by the Act. Buildings that are not being upgraded to 100%*NBS* require careful consideration. Depending on the improvement philosophy being followed, new elements are required to interact with the existing structure in different ways.

In general, the following approach is recommended:

- New building elements should be designed using current building code methods and detailing, so that their dependable capacity meets or exceeds the demand calculated to the seismic provisions of the relevant standards, factored by the target %*NBS* for the overall building.
- Where the new systems are augmenting the existing building capacity, the new elements may be designed to resist a greater proportion of the overall seismic demand, provided that due allowance is made for the ability of the structure to redistribute loads (through diaphragms or collectors). This may require additional collector elements or diaphragm enhancement, which may be designed for the lesser of the overstrength capacities of the elements being loaded by them, or by rational analysis at the target %*NBS*. Where a capacity approach has been used, probable capacities may be used for design, in accordance with the appropriate material standards.
- Regardless of the ductility capacity of the new elements, the displacement compatibility of the new and existing elements should be carefully considered. The distribution of demand to new elements may be limited by the displacement capacity of the existing building (refer to Section C2).
- To provide validation of the proposed improvements (if necessary), the building should be re-assessed with the new elements, assuming probable (expected) strength properties in accordance with Part C, as if the new elements were already in place. This approach may be of most value when using nonlinear techniques to provide a potential rating for the improved building, possibly in comparing alternatives improvement strategies. This step would not generally be required when simply adding elements to meet or exceed a target rating (for example, improving a building so that it is no longer earthquake prone or earthquake risk) and using linear analysis to determine design actions.

Note:

When the proposed improvement measures essentially replace or substantially replace the existing lateral systems, this step would generally be omitted, providing that the stiffness compatibility of the new system has been assessed to ensure that a premature failure of the gravity system is not expected to occur assuming the worst combination of stiffnesses of existing and new structures. Such analysis should include consideration of the potential impact of foundation strength and stiffness.

For buildings that require improvement solely for the purpose of ensuring that the building is no longer earthquake prone, the building and its parts need only be improved to 34%*NBS* and only those building elements that require consideration as noted in Section A3 need be upgraded.

A10.2.5 Regulatory requirements for improvements

Where buildings are being altered with no change of use, section 112 of the Building Act 2004 must be complied with. This requires that the building complies with the Building Code (for provisions relating to structure) to at least the extent that it complied before the alterations. If the building is earthquake prone, the TA may request that the building is upgraded to no longer be earthquake prone at the same time.

Where buildings are undergoing a change of use, section 115 of the Building Act 2004 must be complied with. This requires that the building comply as nearly as is reasonably practicable with the Building Code as if it were an equivalent new building.

Note:

The determination of “as nearly as is reasonably practicable” may vary between TAs according to local regulation and practice.

In the past, a level of 67%*NBS* was regarded as sufficient to comply with section 115 for most uses. However it is recommended that consideration be given to what additional work may be required to bring the building to full compliance, especially for IL4 buildings. A simple cost-benefit study often enables a suitable target load level to be established.

The Building Act 2004 promotes progressive upgrades of earthquake-prone buildings (in section 133AT) by only allowing a building consent to be granted for a substantial alteration when the alteration includes the seismic work necessary to ensure the building will no longer be earthquake prone. The trigger for a substantial alteration is set out in the Building (Specified Systems, Change the Use, and Earthquake-prone Buildings) Regulations 2005 (as amended), and is applied by TAs.

A10.2.6 Temporary stability of buildings during construction

Unlike new buildings, which generally increase in capacity as the building work progresses, existing buildings may have their capacity reduced during the construction process, prior to the upgrading work being completed. This may occur, for example, through activities such as:

- undermining of foundations to install underpinning

- partial removal of URM walls in order to replace them with reinforced elements
- separation of diaphragms from primarily lateral elements.

It may not be practically possible to ensure no reduction in rating during construction, and the provisions of the Building Act 2004 regarding change of use and alterations generally consider the building in its completed condition. It is recommended that designers collaborate with the owner and contractor(s) responsible for the work and consider safety on site and to the public, where appropriate, to develop a solution that satisfies health and safety requirements and good risk management practice.

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