Low Damage Seismic Design

Volume 2: Performance Framework

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RESOURCES

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Acknowledgements

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Executive Summary

Low Damage Seismic Design (LDSD) is a building design philosophy that enables buildings to achieve better seismic performance than New Zealand Building Code minimum requirements. The key goal of LDSD is to deliver buildings that are less likely to be damaged and thereby limit disruption and losses in future earthquakes.

This document is Volume Two of a three-volume LDSD Guidance Series:

- Low Damage Seismic Design: Benefits, Options, and Getting Started (Volume One).
- Low Damage Seismic Design: Performance Framework (Volume Two).
- Low Damage Seismic Design: Technical Guidance (Volume Three).

Low Damage Seismic Design: Benefits, Options, and Getting Started (Volume One) introduces the philosophy and benefits of LDSD, and is intended to help building owners and tenants decide if LDSD is right for their project.

Low Damage Seismic Design: Performance Framework (Volume Two – this document) has been written for building owners, developers, tenants, project managers and design consultants. This document defines the recommended performance framework for LDSD projects and defines the LDSD outcome objectives and related performance goals.

Low Damage Seismic Design: Technical Guidance (Volume Three) has been written for project managers, design consultants, contractors and facilities managers. The purpose of Volume Three is to inform designers how to achieve LDSD to the agreed outcome objectives and post event performance goals defined in Volume Two. This document provides technical design criteria which can be used by design teams to demonstrate that a building design meets the requirements for LDSD, in addition to complying with the New Zealand Building Code.

The seismic design of buildings is by its very nature an imprecise exercise. There are many variables relating to how buildings and their surrounding environments respond to earthquakes that influence their performance in any given event. This wider context of design uncertainty applies to the application of LDSD. While the performance goals for buildings that are designed in accordance with these guidelines are expressed in numerical terms, the inherent uncertainty associated with these values needs to be recognised by all parties involved.

Contents

1. Introduction

Low Damage Seismic Design (LDSD) is a building design philosophy that achieves better than New Zealand Building Code minimum requirements. A key goal of LDSD is to deliver buildings that are less likely to be damaged and thereby limit the disruption and losses in future earthquakes.

LDSD emphasises thoughtful early decisions in design, including site selection and structural regularity. Stiff, regular buildings on good ground have been shown to perform well in earthquakes when secondary and non-structural elements are adequately restrained (e.g. partition walls and ceiling systems). Importantly, LDSD does not always require novel seismic devices (e.g. base isolation or viscous dampers); conventional systems, when thoughtfully applied, can often meet LDSD performance goals.

This guidance document draws upon knowledge that has been developed both in New Zealand and internationally, and defines the recommended performance framework for LDSD projects and defines the LDSD outcome objectives and related performance goals.

The adoption of LDSD on any project is voluntary. If building owners, developers and tenants choose not to adopt LDSD, many of the principles detailed in this guidance document related to building functionality and asset protection are considered of value as good practice.

1.1 Overview of Guidance Documents

This document is Volume Two of a three-volume Low Damage Seismic Design (LDSD) Guidance Series:

- Low Damage Seismic Design: Benefits, Options, and Getting Started (Volume One)
- **Low Damage Seismic Design: Performance Framework (Volume Two)**
- Low Damage Seismic Design: Technical Guidance (Volume Three)

Low Damage Seismic Design: Benefits, Options, and Getting Started (Volume One) is intended to help building owners and tenants decide if LDSD is right for their project. The document introduces the philosophy and benefits of LDSD. It contains an explanation of key concepts and terms involved with LDSD and outlines the value of an LDSD approach to building design for building developers and owners. It also provides advice on how to start an LDSD project.

Low Damage Seismic Design: Performance Framework (Volume Two – this document) has been written for building owners, developers, tenants, project managers and design consultants. The document defines the recommended performance framework for LDSD projects and how LDSD projects fit within the New Zealand building regulatory system.

Low Damage Seismic Design: Technical Guidance (Volume Three – this document) has been written for project managers, design consultants, contractors, and facilities managers. It provides designers with a methodology to achieve the LDSD outcome objectives and post event performance goals.

1.2 Purpose and Scope

The purpose of this document is to define the recommended performance framework for LDSD projects. This framework consists of LDSD outcome objectives and corresponding performance goals and physical states, with criteria as appropriate which have informed the development of the technical guidance in detailed in Volume Three. This document also defines the seismic intensity levels that are to be used by design consultants for LDSD projects, and describes how LDSD fits within the New Zealand building regulatory system.

The scope of this document is primarily aimed at new buildings; however, the concepts are also applicable to existing buildings.

1.3 Document Background

Various resources were referred to during the development of this framework, including documents such as FEMA P-58 (FEMA, 2018), ASCE 41 (ASCE, 2023) and REDi (Arup, 2013), NZSEE Resilient Buildings Stage 3 report (NZSEE, 2024) and Health NZ Technical Guidelines for the Seismic and Structural Design of Hospital Buildings (HNZ, 2025). These documents identified the need for an increased emphasis on improving amenity and functionality outcomes for our new building designs.

Volume Two was initially developed by a working group drawn from the SESOC Low Damage Seismic Design project team during the period May to July 2023, with funding from the Natural Hazards Commission - Toka Tū Ake and Health New Zealand - Te Whatu Ora. It has been developed further during 2024 and 2025 for the development of Volume Three.

2. Regulatory Context

The general expectation is that the performance of LDSD designs will exceed the minimum requirements of the New Zealand Building Code. However, compliance with the Building Code needs to be demonstrated as part of the building consent process.

This section provides a recap on the regulatory requirements and compliance pathways for buildings generally, and indicates how the compliance of LDSD designs with the Building Code can be demonstrated.

An overview of how LDSD designs can be verified as meeting the requirements and expectations of this performance framework outlined in this volume is also provided.

2.1 Building Act and Code Requirements and Compliance Pathways

Building regulatory framework

The legislation and regulations work together as the building regulatory system:

- Building Act 2004 – the primary legislation governing the building and construction industry
- Building Code – contained in Schedule 1 of the Building Regulations 1992, this sets the minimum performance standards buildings must meet.
- Other Building Regulations – including details of particular building controls (e.g., prescribed forms, list of specified systems, definitions of change the use and moderate earthquake, levies, fees, and infringements).

The pyramid on the following page illustrates the hierarchy provided by the building regulatory system with respect to the minimum legal requirements and compliance pathways. The Building Code is subordinate to the Building Act in the regulatory hierarchy. It includes Objectives, Functional Requirements, and Performance Criteria.

The Building Code employs a performance-based approach, specifying the required outcomes and considerations for buildings rather than prescribing specific design and construction methods. This performance-focused system allows designers, architects, and builders to employ flexible and innovative solutions while meeting Building Code requirements.

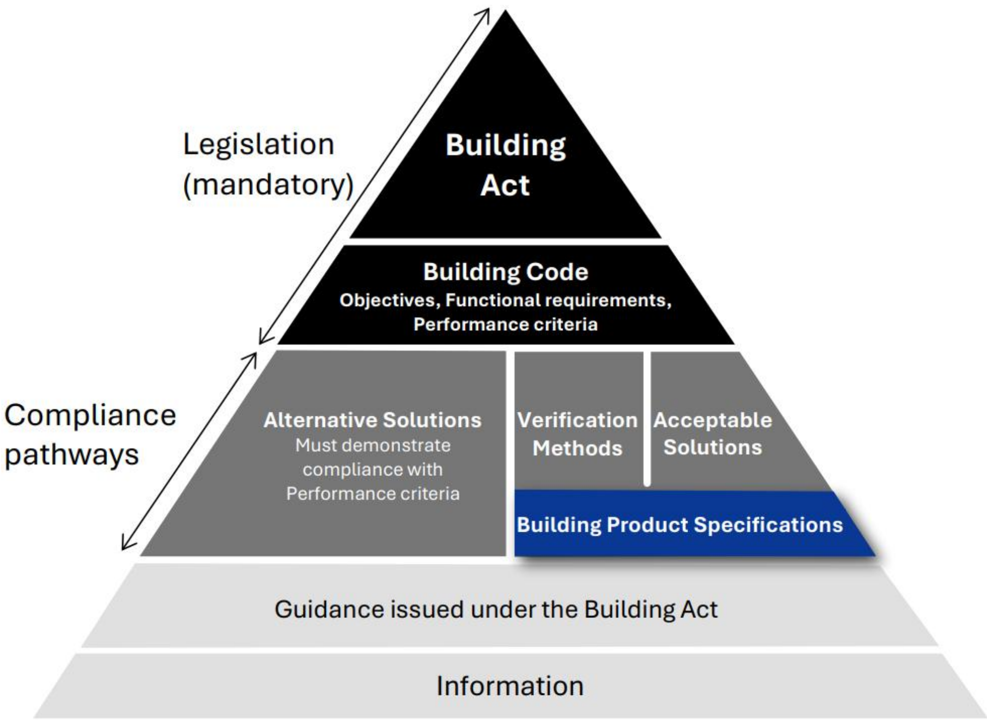

Figure 2-1: Building Regulatory 'Pyramid'

All buildings are required to meet or exceed the minimum performance criteria outlined in the Building Code. For a building consent to be issued, a Building Consent Authority (typically the local council) must receive and accept evidence demonstrating compliance with the requirements of the Building Code.

Clause B1 Structure of the New Zealand Building Code outlines the objectives, functional requirements, and performance criteria that buildings, their elements, and associated site work must meet. The primary objective of the B1 clause in seismic regulations is to protect human life during significant earthquake events. This clause mandates that buildings must maintain sufficient structural integrity to allow occupants to safely exit, even if the structure sustains considerable damage from an earthquake. The focus is on life safety, rather than preventing all damage to the building itself.

In other words, the Building Code acknowledges the potential for earthquakes to cause varying degrees of structural and non-structural damage to the buildings. However, its primary focus is on maintaining a low probability of collapse to safeguard people from significant injury or death. The Building Code does not explicitly control the extent of damage to the building itself or the potential financial losses that may result from a significant earthquake. However, certain buildings are designated to have higher 'importance', which necessitate more stringent seismic design requirements. For example, buildings with special post-disaster functions are expected to sustain less damage during seismic events, reflecting their critical role in the response and recovery phases. The Building Code seeks to strike a balance between effective risk management and considerations of cost and practicality across the country.

Compliance pathways

There are different pathways for demonstrating compliance with the Building Code. Prescriptive acceptable solutions (AS) and verification methods (VM) provide a 'deemed to comply' pathway. This means designs following the acceptable solutions and verification methods published by MBIE e.g. verification method B1/VM1, or acceptable solution B1/AS1, must be accepted (without scrutinising the design further) by the Building Consent Authority when making building consent decisions.

The ‘deemed to comply’ pathway may include cited building standards and information as part of the compliance pathway.

Acceptable solutions provide more prescriptive design solutions which if met, establish conformance with the minimum performance criteria of the Building Code. Verification methods provide methods of testing, calculations, or modelling which if followed establishes compliance with the performance criteria of the Building Code. Verification methods therefore can include analytical methods and numerical models, laboratory testing of prototype components or systems (often destructive), or in-situ testing (non-destructive) specifically suited to prescribed related Building Code requirements.

Alternative solutions are frequently employed in complex projects or when implementing new design and construction methods to demonstrate compliance with the Building Code. This approach is used when the entire building design, or a portion thereof, deviates from the prescribed acceptable solutions or verification methods. In such cases, Alternative solutions are employed to illustrate how the proposed design and building work still meet the Building Code’s requirements. The alternative solution pathway serves as a means to present evidence to Building Consent Authorities. This evidence may include non-referenced international documents, testing procedures, or methodologies, which are then contextualised within the framework of the New Zealand Building Code and its performance requirements.

When proposing an alternative solution in relation to the performance clauses of B1, which are qualitative in nature, an effective approach for justifying the proposed design could be to compare and evaluate it against the established acceptable solutions or verification methods. These existing conformance methods often serve as valuable benchmarks for assessing the adequacy of a proposed alternative solution. This comparative method provides a reliable framework for demonstrating that the alternative solution meets or exceeds the required performance criteria, despite deviating from the prescribed acceptable solutions or verification methods.

Issuing guidance, information, and resource documents

The lower levels of the pyramid comprise guidance and information documents. MBIE publishes guidance documents under Section 175 of the Building Act and resource/information documents – either independently or in collaboration with other organisations. Neither type of these documents hold regulatory status. These documents are designed to assist individuals in making informed decisions regarding compliance with the Building Code and, in some cases, exceeding its requirements.

Information, resources, or technical materials not referenced in acceptable solutions or verification methods may also help to show compliance as an alternative solution. This tier of the triangle includes New Zealand or overseas standards, codes of practice and other information provided by the building and construction industry.

In numerous instances, both designers and clients may desire to exceed the minimum performance requirements set forth in the Building Code, particularly in areas such as seismic resilience or the energy efficiency of structures. By issuing the relevant information and resource materials, MBIE helps ensure that designers and building owners have the necessary knowledge and guidance to make informed decisions about exceeding minimum performance standards.

The LDSD documents are an informational resource which present an enhanced framework for seismic design, incorporating recent research findings and advancements in the field. They include new design principles, performance criteria, and design methods. The LDSD documents enable practitioners in the field to incorporate various degrees of seismic resilience more effectively into the design and construction processes of buildings.

Demonstrating regulatory compliance

Producer Statements, while not legally binding under the Building Act 2004, provide professional opinions to support building consent applications. Building Consent Authorities generally identify when and on which aspect of the building work they expect to receive Producer Statements during the building consent or construction process[1].

Designers must demonstrate how their design complies with the minimum requirements of the Building Code. Where a PS1 – Design Producer Statement is issued, it is essential that the means of compliance used for the relevant structural elements be clearly and consistently identified. The need for a peer review or construction monitoring should be established by the design team in consultation with the Building Consent Authorities at an early stage in the design process. A PS2 – Design Review Producer Statement or a PS4 – Construction Review Producer Statement may also be requested, however they should be accompanied by a record of the peer review and the construction monitoring inspections.

For LDSD projects, depending on the complexity of design, and experience of the responsible Building Consent Authority, it may be that a further compliance check is contracted during the processing of the building consent. This process should be clarified in collaboration between the client, design team and the relevant Building Consent Authority.

On completion of the works, the structural designer is often requested to confirm the structural aspects of the building work has been carried out in accordance with the consented plans and the Building Code, along with evidence and a PS4 statement. If the designer requires that specific elements of construction be inspected, they should provide a list of the elements and specify the level and frequency of construction monitoring with the consent documentation.

2.2 LDSD Verification Pathways

LDSD buildings must meet the requirements of the Building Code and the LDSD provisions recommended in this document. Three verification pathways are available to demonstrate that a building will meet the LDSD provisions:

- Prescriptive Design Method;
- Direct Design Method; and
- Direct Assessment Method

These verification pathways are summarised below.

Prescriptive Design Method

The *Prescriptive Design Method* is limited to buildings which meet certain regularity restrictions or building components, elements or systems where expected performance is reasonably reliable, and the design method is covered by the Building Code generally through an acceptable solution or verification method, or by guidance issued under Section 175 of the Building Act.

It is envisaged that the *Prescriptive Design Method* will be applicable to most buildings. For buildings using this pathway the LDSD design process is similar to the current Building Code design process,

[1] https://www.building.govt.nz/projects-and-consents/apply-for-building-consent/support-your-consent-application/producer-statements

albeit there is an increased requirement for design collaboration and reporting. Provided the prescribed design parameters and/or methods are used, and the type of system or component fits within the scope, then the *Prescriptive Design Method* is deemed to satisfy the LDSD provisions, provided the required process, reporting and documentation expectations are met.

Direct Design Method

The *Direct Design Method* is used for buildings, systems or components that will not meet the requirements of the *Prescriptive Design Method*. It is for those elements, systems or components that are new or innovative, and would be considered alternative solutions by the Building Code. Demonstrating compliance via this method will require the design team to follow recognised methods, or experimental testing in accordance with recognised standard testing procedures, to validate the performance of potentially affected building elements, systems or components will not compromise LDSD performance goals.

Direct Assessment Method

The Direct Assessment Method pathway is an explicit assessment method that enables design teams to demonstrate compliance with LDSD performance goals. Design teams are required to use recognised performance assessment procedures such as the FEMA P58 (FEMA, 2018) approach to directly compute project-specific building damage and repair costs.

Further guidance, technical design criteria and related project requirements for the three LDSD verification pathways are provided in Volume 3.

Demonstrating compliance with LDSD provisions

A PS1 statement alone is not considered to be sufficient to establish compliance with the provisions of the LDSD documents. Hence, to demonstrate compliance with the LDSD requirements, design consultants should include a short, dedicated section within their Design reports/DFRs. That section should include a description of how compliance with the LDSD requirements has been demonstrated with specific references to the relevant Design Requirements sections in Volume Three. The expectation is that this will not be a particularly onerous requirement for design consultants to meet.

A statement from each design consultant within this section of their Design report/DFR is also required to confirm, based on sound reasoning and sufficient justification, that their design meets the LDSD requirements.

3. Understanding the Terminology

To design a building, some key decisions need to be agreed between the client, project manager and the design consultants. Some of the important technical terminology that may be referred to as part of this process is explained below - such as Limit States, Importance Levels, Annual Probabilities of Exceedance, Expected Annual Loss, Risk and Resilience - with more definitions provided in the Appendix A.

3.1 Building Limit States

The term *limit state* refers to the condition (or 'state') of a building following an earthquake. This is like the performance 'bar' set for a building to achieve.

The following building limit states are considered for LDSD projects:

- Serviceability Limit State 1 (SLS1)
- Damage Control Limit State (DCLS)
- Serviceability Limit State 2 (SLS2)
- Ultimate Limit State (ULS)

New Zealand building standards (SNZ, 2004) set out the requirements for the two Serviceability Limit States (SLS1 & SLS2) and the Ultimate Limit State (ULS). Requirements for the Damage Control Limit State (DCLS) are provided for in the LDSD guidance documents. Further information about these limit states is provided below.

Serviceability Limit State 1 (SLS1)

SLS1 is about avoid damaging from relatively small earthquakes.

What does it mean for damage?

SLS1 aims to avoid damage that would prevent buildings from being used as intended without repair.

What does it mean for building functionality?

Typically, the time required to return a building to full functionality is expected to be short for SLS1. There should be minimal damage to building components, with disruption largely limited to building contents and furniture.

What does SLS1 look like?

Figure 3-1: Example of building damage that could be expected at SLS1. Damage generally limited to building contents. Repairs to the building are not expected (Photo credit Beca Ltd, Damage from Kaikōura earthquake 2016).

Damage Control Limit State (DCLS)

DCLS is about limiting building damage from significant earthquakes.

What does it mean for damage?

At DCLS some damage is likely to occur, but that damage is expected to be limited to a level that is economically repairable such that the Damage Control performance goals in Section 7 are met.

What does it mean for building functionality?

By limiting building damage, the time to return a building to functionality is likely to be significantly less compared with a building designed to the minimum requirements of the Building Code.

What does DCLS look like?

Figure 3-2: Example of building damage typical of DCLS where some damage is expected (cracking to non-loadbearing plasterboard partition walls shown). Extent of damage is expected to be limited to a level that is economically repairable (Photo credit Beca Ltd, Damage from Kaikōura earthquake 2016).

Serviceability Limit State 2 (SLS2)

SLS2 is about maintaining the operational continuity of buildings. This is most often associated with IL 4 buildings that have special post-disaster functions and is typically not considered for LDSD projects.

What does it mean for damage?

At SLS2 some damage is likely to occur, but that damage is expected to have a minimal effect on the required post-earthquake functionality of the building, or if it does affect it, the damage should be readily and rapidly repairable. Significant damage can still occur to other non-critical areas of the building provided this damage does not impact the required functionality.

What does it mean for building functionality?

SLS2 criteria seek to return buildings to an operational state within an acceptably short timeframe (usually minutes to hours, rather than days).

What does SLS2 look like?

Damage similar to that shown in Figure 3-2 for DCLS.

What is the difference between SLS2 and DCLS?

It is acknowledged that SLS2 and DCLS are similar limit states. The main difference between them is that the primary objective of SLS2 is maintaining functionality without requiring consideration of repair costs, whereas for DCLS the primary objective is controlling damage so the extent of building damage and related repair costs are limited.

An example of how DCLS differs from SLS2 can be illustrated in terms of façade damage. If it was determined that minor façade damage was not critical in terms of enabling the intended function of the building to be delivered, then SLS2 (if it applied) would be considered to be met. However, such damage could be costly to repair due to the need to access both the interior and the exterior of the building to complete the repairs in addition to the disruption these repairs might cause to building users, and DCLS requirements would be unlikely to be met.

Ultimate Limit State (ULS)

ULS is about protecting Life Safety for major earthquakes

What does it mean for damage?

At ULS, buildings are expected to suffer significant damage but should not collapse (i.e. they should protect life safety).

What does it mean for building functionality?

Reoccupation times for ULS levels of damage are expected to be long. It is likely that structural repairs taking months or years might be required. The damage sustained by the building might not be economical to repair and the building might need to be demolished.

What does ULS look like?

Figure 3-3: Example of building damage typical of ULS where significant damage is expected. May have large repair costs and long reoccupation times (Saatcioglu, et al., 2013).

3.2 Building Importance Levels

What are Building Importance Levels?

Building Importance Levels (ILs) are used to categorise buildings into different types in relation to the value of the building and/or its use to the community and the consequences of building failure. The different building types are defined in New Zealand building standards such as AS/NZS 1170.0 (SANZ, 2002) and a simplified summary is provided in Table 3-1 following.

Table 3-1 Importance levels for building types

Importance Level	Consequence of Building Failure	Description
IL1	Low	Minor structures: farm buildings, fences etc.
IL2	Medium	Normal buildings: offices, factories, typical residential, commercial and industrial buildings etc.
IL3	High	Major buildings (affecting crowds): theatres, large education and commercial buildings, etc.
IL4	Very High	Buildings with post-disaster functions: hospitals, fire stations, designated emergency operations centres etc.

The purpose and function of Importance Levels in building design can be summarised as:

Importance Levels primarily define the intensity of ground shaking to be considered for *Life Safety* (ULS) design.

Importance Levels will not usually have a significant influence on the extent of building earthquake damage.

An exception is *Importance Level 4* which triggers stringent *Operational Continuity* (SLS2) requirements for this building type. As noted in Section 3.1 above, these operational continuity requirements are intended to limit damage to ensure the damage does not impact the continuing operation and function of the building.

LDSD provides additional criteria that define DCLS across IL2, 3 and 4. LDSD is of particular benefit for IL2 and IL3 buildings where the Building Code does not impose any requirements in between SLS1 and ULS.

3.3 Annual Probability of Exceedance

What is Annual Probability of Exceedance?

Annual Probability of Exceedance (APoE) is a statistical concept used to express: *the likelihood that a specific event, such as the level of ground shaking at a given location, will be exceeded in any given year*. It is commonly expressed in three equivalent ways:

1. As a percentage: For example, a 1% APoE means there is a 1% chance of the specified event being exceeded in any given year.
2. As a fraction: The same 1% APoE can be expressed as 1/100.
3. As a return period or recurrence interval: The reciprocal of the APoE gives the average time between occurrences, also called the return period. A 1% APoE corresponds to a 100-year return period.

APoE can be difficult to conceptualise due to the low probabilities commonly involved. Often the APoE is more tangible when it is related to the probability a particular level of ground shaking will be exceeded in a given time period. This can be calculated as:

$$P = 1 - \left(\frac{(R-1)}{R}\right)^{T_p}$$

Where:

P =	probability of exceedance of a particular level of ground shaking.
R =	return period which is the reciprocal of the APoE as noted above.
T_p =	specified time period being considered.

Table 3-2 summarises the probability of exceedance of an event with APoE's of 1/100, 1/250 and 1/500 for a various time periods.

Table 3-2 Probability of exceedance of an event with APoE's of 1/100, 1/250 and 1/500 for various time periods.

APoE	Return Period (years)	Time Period (years)	Probability of Exceedance
1/100	100	1	1%
		10	10%
		50	40%
1/250	250	1	0.4%
		10	4%
		50	20%
1/500	500	1	0.2%
		10	2%
		50	10%

New Zealand building standards (SANZ, 2002) use APoE as a metric for specifying the intensity of earthquake ground shaking used for seismic design.

3.4 Expected Annual Loss

What is Expected Annual Loss?

Expected Annual Loss (EAL) is the long term expected financial loss in each year, averaged over many years, related to a particular hazard being considered. The Expected Annual Loss is commonly referred to as the Average Annual Loss within the insurance industry. The EAL can be calculated as:

$$EAL = \sum (Exposure \times APoE \times Loss\ Ratio)$$

Where:

Exposure = building replacement cost.

APoE = annual probability of exceedance.

Loss Ratio = financial loss as a percentage of the building replacement cost.

Consider a hypothetical example of a commercial building with a $10 million replacement cost. Table 3-3 summarises earthquake hazard and related loss estimates for the example building.

Table 3-3 Example of earthquake hazard and loss estimates for a commercial building

Earthquake Intensity	APoE	Expected Loss Ratio
Minor	1/50	2%
Moderate	1/100	10%
Significant	1/500	50%
Major	1/1000	90%
Severe	1/2500	100%

The EAL for the example building can then be calculated as:

$$
\begin{aligned}
EAL = \quad & \$10{,}000{,}000 \ \times 1/100 \ \times 0.02 \\
& + \$10{,}000{,}000 \ \times 1/500 \ \times 0.10 \\
& + \$10{,}000{,}000 \ \times 1/500 \ \times 0.50 \\
& + \$10{,}000{,}000 \ \times 1/1000 \ \times 0.90 \\
& + \$10{,}000{,}000 \ \times 1/2500 \ \times 1.0 \\
= \quad & \$37{,}000
\end{aligned}
$$

This analysis shows that the property owner can expect, on average, to experience about $37,000 in earthquake related losses annually. EAL is commonly expressed in terms of a percentage of the building replacement cost, so for this example the EAL would be 0.37%.

3.5 Risk and Resilience

What is seismic risk?

Risk is something that we all understand intuitively, but it can be difficult to measure. Simply put, risk is the possibility that something unwelcome will happen.

The New Zealand National Disaster Resilience Strategy (MCDEM, 2019) defines risk as *"the potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specified period of time, determined as a function of hazard, exposure, vulnerability and capacity."*

Seismic risk is fundamentally comprised of ***hazard likelihood***, ***building vulnerability***, and ***consequence*** (the exposure of people and the direct and indirect losses generated from damage).

Large earthquakes occur relatively frequently around New Zealand, but most happen in locations where there are few people or structures. Risk becomes significant when we have earthquakes in more densely populated urban areas and there is a greater potential for damage and human and economic consequences. Evaluating seismic risk is made more complex by the fact that buildings respond differently depending on the particular nature of the earthquake, as was highlighted in the 2016 Kaikōura earthquake.

In the context of LDSD, seismic risk focuses on the probability that people will suffer economic loss as a result of damage to their buildings. Understanding the consequence of earthquakes on buildings and their surrounding environment is therefore a key area of focus of LDSD.

What is resilience?

Resilience is more subjective, but the National Disaster Resilience Strategy defines it as: *the ability to anticipate and resist the effects of a disruptive event, minimise adverse impacts, respond effectively post-event, maintain or recover functionality, and adapt in a way that allows for learning and thriving*.

3.6 Loss and Downtime

What are seismic losses?

Seismic losses refer to the damages and consequences resulting from earthquakes, encompassing economic, physical, social, and human impacts. These losses can be categorised as *direct* and *indirect*. Direct losses relate to building damage that prompts repairs or complete replacement. Indirect losses relate to consequential costs such as business disruption costs (which may be affected by outside factors such as city-wide cordons) or damage due to the collapse of neighbouring buildings. Indirect losses can also include the less measurable costs of psychological impacts, disrupted schooling etc.

For LDSD the primary focus is on limiting direct losses – recognising that this will also help limit some forms of indirect loss, such as business disruption costs. Direct losses can be calculated using established methodologies such as those described in FEMA P-58 (FEMA, 2018).

What is downtime?

Downtime refers to the period during which a building cannot be occupied or perform its intended function following an earthquake. This can be due to physical damage, inspection requirements, repair needs, disruption to lifeline utilities or post-earthquake cordons. Downtime will naturally increase as the amount of damage suffered by a building increases. The management of downtime is more directly about recovery time, rather than avoiding loss of function.

At the time of writing, it is considered there is not enough data to confidently quantify downtime. Nevertheless, by limiting damage to building components, the downtime associated with repairs and replacement will be reduced. The client and design consultants can help limit downtime by identifying what is required in order for building functionality for the intended occupants – which may vary from one building owner or building use to another – and take steps to mitigate this loss of functionality.

4. The Scope and Limitations of Low Damage Seismic Design

Low Damage Seismic Design focuses on buildings and the elements within

There is a wider awareness of the need to reduce the impacts of earthquakes on our communities, including potential social and environmental losses. LDSD forms a key part of a broader set of initiatives to enhance community resilience by focusing on buildings and the elements within. This involves looking beyond the imperative of ensuring life safety for large earthquakes to minimise damage and maximise functionality after lesser but still significant earthquakes.

There are however a range of external factors beyond the site that can impact on the functionality of a building. These include disruptions to access the building and lifeline utility services on which the building depends. Evaluation of these operational risks and any decisions to provide specific backup systems and arrangements requires location-specific consideration, and hence sits outside the scope of LDSD.

Site selection is therefore an important consideration in the early stages of planning for an LDSD building.

The potentially limited resource availability for undertaking building repairs following an earthquake is another aspect that is outside the control of a design team.

There is always a need for business continuity planning to address the consequences of disruption due to these external factors.

Controlling building damage by limiting deformations

LDSD adopts a philosophy of controlling building damage by limiting building deformations (typically inter-storey drifts). Overseas experience has shown that this approach generally works well. One downside of this philosophy is that stiff buildings experience higher floor accelerations during significant earthquakes when compared with more flexible buildings.

High floor accelerations can damage acceleration-sensitive building components and cause uncontrolled movement of, and damage to, unsecured building contents. However this damage can be suitably limited for LDSD projects by ensuring building components are appropriately secured by seismic restraints, and for some cases of buildings in higher seismic hazard regions, by ensuring critical acceleration-sensitive building components have the appropriate seismic certification.

Floor accelerations can be controlled by using building technologies such as base isolation and fluid viscous dampers. Such devices can also be effective in reducing building inter-storey drifts.

Understanding the relationship between damage and functionality

The focus of LDSD is limiting damage in significant earthquakes in order to protect assets. This has a secondary benefit in reducing damage that may lead to a loss of functionality of the building for its intended use. Functionality cannot be assured due to the range of external factors indicated above, but the likelihood of functional continuity being maintained can be improved, as discussed below.

The secondary objective of LDSD is therefore expressed as *improved functionality*. Indicative operational states that are an associated outcome of LDSD are outlined later in this document (refer Section 7.2).

Higher levels of building functionality

Design teams should discuss the provision of backup systems with building owners and tenants. When building owners and tenants have a low tolerance for loss of building functionality this should be recorded in the project brief. Functional continuity typically needs a combination of damage avoidance (which can be improved by following LDSD principles), and specific consideration of building system reliability (which usual requires back-up systems or redundancy).

Furthermore, the project brief should clearly identify the backup systems and arrangements necessary for the level of building functionality being sought so that these can be separately specified by the design team. For some projects this might include the provision of emergency power and backup water supplies.

Designing for ease of inspection and repairability

One of the challenges in addressing building damage following earthquakes is the ability to access key elements (both structural and non-structural) to establish whether or not damage has occurred. The closely related point is the ability to repair damaged elements while minimising the impacts on the fabric and operation of the building.

In acknowledgement of this, designing for ease of access and repairability is therefore an important consideration of LDSD.

Post-earthquake regulatory compliance

Post-earthquake regulatory compliance can be impacted by damage to non-structural elements and key building services. While maintaining post-earthquake compliance is clearly a desirable outcome objective, it is not a specific component of LDSD. There are many other considerations associated with the assessment of the state of compliance of a building that has sustained minor earthquake damage, including the activities within a building and how they are managed.

It is nevertheless considered that low damage solutions should be able to be more easily returned to a compliant state.

Recognising the uncertainties associated with LDSD

The seismic design of buildings is by its very nature an imprecise exercise. There are many variables relating to how buildings and their surrounding environments respond to earthquakes that influence their performance in any given event.

This wider context of design uncertainty applies to the application of LDSD. While the performance goals for buildings that are designed in accordance with these guidelines are expressed in numerical terms, the inherent uncertainty associated with these values needs to be recognised by all parties involved.

5. Hierarchy of Framework Elements

The LDSD seismic performance framework is represented by *Outcome Objectives, Performance Goals* and *Physical States.* These elements (i.e. the 'What') are defined in Volume Two, and they establish the context for the *Technical Design Criteria* in Volume Three that enables designers to implement LDSD (i.e. the 'How').

The relationship, scope and form of these framework components are indicated in Table 5-1 below. The form and definitions of the *Outcome Objectives, Performance Goals* and *Physical States* are summarised in the following sections.

Table 5-1 Hierarchy and Relationship of Framework Elements

Framework Level	Scope and Form	Relevant Volume and Section
Outcome objectives[1] – *overall objectives* corresponding to the building performance aspects of *life safety*, protection of other property, *damage control* (asset protection) and *functionality* (operability)	Short qualitative objective statements	Volume Two - Section 6
Performance goals[2] – maximum expected levels of damage and anticipated *functional states* corresponding to different levels of ground shaking	Performance criteria that correspond to the *outcome objective* statements	Volume Two - Section 7
Physical states - *levels of damage* corresponding to the performance goals at different levels of ground shaking	Qualitative statements of physical states/damage onset thresholds corresponding to the *performance goals*	Volume Two - Section 9
Technical design criteria – *acceptable parameters* that correspond to the physical states	Quantitative values that enable designers to meet the damage level expectations (and hence functionality objectives)	Volume Three

Notes:

1. Outcome Objectives are akin to the "Objective, Functional Requirements, and Performance Statements" of B1.
2. Performance Goals can be considered akin to the relationship between limit states and APoEs in Section 3 of AS/NZS 1170.0 (SANZ, 2002).

6. Outcome Objectives

Outcome objectives for buildings subject to LDSD are summarised in Table 6-1 below. The outcome objectives are primarily intended for Importance Level 2 and 3 buildings but can be used to inform Importance Level 4 buildings.

The outcome objective relating to damage is highlighted in this table, as this is the primary focus of LDSD.

Table 6-1 LDSD Outcome Objectives

Aspect	Overall Outcome Objective	Comments
Life safety	Low probability of loss of life or significant injuries	Considered met through *Ultimate Limit State* design for the appropriate Importance Level
Damage (Building Asset Protection)	Low probability of damage leading to significant economic loss	Addressed through a *Damage Control Limit State* Expected economic losses due to seismic damage are significantly lower than a minimum code compliant building
Improved Functionality	By reducing the probability of damage, the time to return to *functionality* is likely to be significantly lower than a minimum code compliant building.	Articulated through *Operational States* Note that in significant earthquakes, disruption and return to function can often be controlled by aspects beyond the building envelope, such as cordons, utility outages, and labour shortages

Notes:
1. Life safety (and damage to other property) objectives are addressed in meeting Building Code requirements.
2. There may be additional project-specific considerations in relation to functionality that should be considered that go beyond the general scope of this framework. For example, particular building occupancies may feature acceleration-sensitive contents or components for the fit out. General guidance is provided in Volume Three.

7. Performance Goals

7.1 Damage Control (Asset Protection)

Three different LDSD categories are provided for in the LDSD guidelines - LDSD Category Level 1, Level 2 and Level 3.

LDSD Category Level 1 is essentially a code compliant building with careful consideration of design features which are known to influence the level of damage in earthquakes. While LDSD Category Level 1 buildings do not have specific damage control performance goals, the LDSD design provisions detailed in Volume Three will help ensure these buildings perform in a predictable and controlled manner when subject to ground shaking.

Damage Control *performance goals* for LDSD Category Level 2 and 3 buildings are detailed in Table 7-1. These goals correspond to limiting the Expected Annual Loss (EAL) for the building, and limiting the probability of building damage exceeding 5% of the building replacement cost in an earthquake in a 10 year period. The second column of Table 7-1 uses EAL as a metric to achieve the targeted economic loss. While EAL represents the average economic loss in each year resulting from all possible earthquakes, the third column of Table 7-1 is aimed at limiting the extent of damage under a single event.

The values in Table 7-1 have been validated from a limited benchmarking study outlined in Section 8 which was carried out as part of the development of the LDSD guidelines. There is an inherent uncertainty associated with these values which simply reflects the many variables relating to how buildings and their surrounding environments respond to earthquakes.

Table 7-1 LDSD Damage Control Performance Goals

LDSD Category	Expected Annual Loss (EAL)	Approximate probability, over a 10 year period, that an earthquake causes damage exceeding 5% replacement cost in an earthquake
Level 1	N/A	N/A
Level 2	0.15%	5%
Level 3	0.05%	2%

Commentary

While LDSD Category Level 1 buildings do not have specified damage control performance goals it is anticipated they will experience lower levels of damage than those that just meet current code requirements. Specifically, Level 1 buildings might be categorised as 'thoughtful' code-compliant buildings and have LDSD design provisions to ensure they behave in a predictable manner when subject to earthquake shaking by applying fundamentally good engineering practice.

The expectation is for most LDSD Category Level 2 and 3 buildings there will not be a need for design teams to explicitly demonstrate compliance with the limiting EALs and probabilities of exceedance detailed in Table 7-1. The LDSD Prescriptive Design Method and Direct Design Method pathways have been calibrated so the performance goals detailed in Table 7-1 will generally be met for most buildings (refer to Section 8 for further discussion).

The Direct Assessment Method pathway can also be used by design teams to explicitly demonstrate compliance with the performance goals detailed in Table 7-1 by means of a project-specific loss assessment.

7.2 Improved Functionality

One important aspect of reducing the time to return a building to an operational state is by reducing the probability of damage. It is difficult to accurately assess the time required to return a building back to an operational state following an earthquake, as the time required is affected by a large number of variables. Many of these are outside the control of the project design team and/or clients (i.e. wider impacts beyond the site such as cordons, utility outages or labour shortages).

Table 7-2 outlines three indicative building operational state categories – *Shelter in place (OS-I)*, *Partial functionality (OS-II)* and *Full functionality (OS-III)*. An additional state representing the potentially non-operational state of a building that only meets life safety objectives of the building code is also included in the table as a point of reference.

It is considered that buildings designed to LDSD Level 2 and 3 have a significantly higher likelihood of achieving Operational State II following a significant earthquake than an equivalent, minimum code compliant building. However, it is acknowledged that wider impacts beyond the site, or damage to critical secondary or nonstructural elements, in larger earthquakes may lead to increased reoccupation timeframes.

Table 7-2 Indicative Building Operational States

Operational State Category	Operational State	Description
N/A	Safe egress only	A building which only meets life safety objectives without any expectation of post-earthquake occupancy or functionality (i.e. code-compliant design).
OS-I	Shelter in place[4]	A building for which post-earthquake functionality has been significantly reduced. Building services such as HVAC, water supply and electrical systems may be damaged and unavailable until necessary repairs are completed[1,2] The deformation capacity and strength of the building has not been significantly reduced due to the prior earthquake, and the building is able to withstand another major earthquake.
OS-II	Partial functionality	A building for which post-earthquake structural and nonstructural damage is limited to the extent that the *basic* intended functions of the building's pre-earthquake use are maintained or can be restored within an acceptable time (usually measured in *days* rather than *weeks*).[3]
OS-III	Full functionality	A building for which post-earthquake structural and nonstructural damage is limited to the extent that the intended functions of the building's pre-earthquake use are maintained or can be restored within an acceptable time (usually measured in *minutes to hours* rather than *days*).

Notes:

1. Residents who are sheltering in place will need to be within walking distance of a neighbourhood centre that can help meet basic needs.
2. Repairs to reinstate basic building functions could be expected to take weeks or months.
3. Other repairs need to return the building to a full functionality state can be completed over a longer timeframe provided these can be undertaken outside normal working hours or as part of normal annual maintenance.
4. Operational state description is taken from Spur (2012).

Commentary

Figure 7-1 illustrates a graphical representation of building functionality vs time post event for the three operational state categories detailed in Table 7-2.

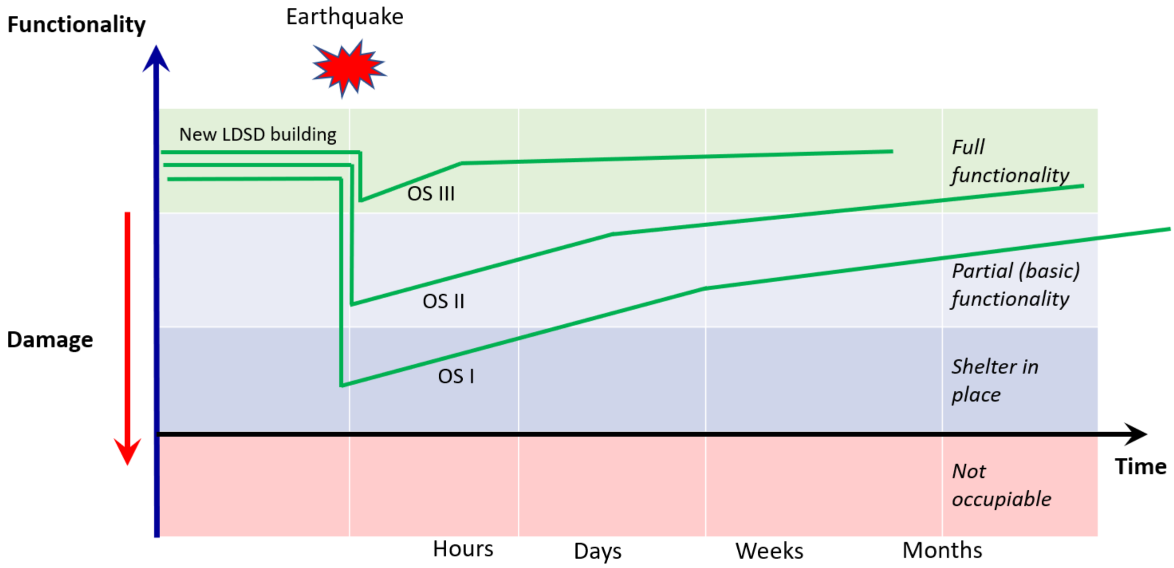

Figure 7-1: Graphical representation of functionality vs time post event for Operational State (OS) Categories I – III

Critical non-structural elements and systems necessary for an operational state should be identified by the project team. A strategy should be established for each of the critical non-structural elements and systems to enable the specified operational state to be returned within an acceptable timeframe. Such a strategy could include:

1. *Limit damage to the component to extent that it could likely continue to function as necessary to enable the operational state, or*
2. *Identify alternative short-term management strategies so that these can be implemented while repairs to the damaged component are completed, or*
3. *Identify and establish a repair strategy for the component so that it could likely be repaired within the acceptable timeframe.*

It is recognised that controlling damage to structural and nonstructural elements will generally reduce the time required to return a building back to an operational state. Referring to the building operational states detailed in Table 7-2, damage considerations can also be used to rank the relative importance of different building systems and the related mitigation measures required for these systems.

Variables outside the control of the project team that could affect the time required to return a building back to an operational state include:

- *Time taken to reinstate utilities such as power, water, wastewater and data.*
- *Potential impact of other damaged buildings and infrastructure, including the wider transport network, on the operability of the building.*
- *Labour or material shortages delaying the completion of the repairs.*
- *Post-earthquake cordons established by emergency services limiting access to the site.*

8. Seismic Hazard Design Intensity Levels

Design intensity levels of ground shaking (expressed in terms of APoE) to be used for LDSD buildings are detailed in Table 8-1.

Table 8-1 LDSD Annual Probabilities of Exceedance (APoE) for IL 2 buildings

Limit State	Annual Probability of Exceedance		
	LDSD Category Level 1	LDSD Category Level 2	LDSD Category Level 3
SLS1	1/25	1/50	1/50
DCLS	N/A[1]	1/250	1/500
ULS[2]	1/500	1/500	1/500

Notes:

1. There is no requirement for LDSD Category Level 1 buildings to consider DCLS.
2. For the required ULS APoE for IL3 and IL4 buildings, refer to AS/NZS 1170.0 (SANZ, 2002).

When explicit consideration of building performance at the Collapse Avoidance Limit State (CALS) is required, CALS design actions should be derived by applying a 1.5 scaling factor to the ULS seismic design spectrum.

Commentary

The APoEs detailed in Table 8-1 have been determined from a limited benchmarking study so the damage control performance goals detailed in Section 7.1 will generally be met by most LDSD Category Level 2 and 3 buildings (recognising LDSD Category Level 1 buildings do not have specific damage control performance goals). For details of the benchmarking study refer Volume Three Appendix C and Sullivan et al. (2025).

The benchmarking study consisted of loss modelling studies to quantify the seismic performance of LDSD buildings located in Auckland, Christchurch and Wellington. The seismicity of these three cities could be described as low, high and very-high respectively. Three lateral load resisting systems were examined at each site: 4-storey steel moment resisting frame (MRF) systems, 4-storey cantilever reinforced concrete (RC) wall systems, and 3-storey timber-framed wall systems.

Results from the loss modelling studies indicated considerable variability across structural system type and building location. The loss modelling studies also show that for conventional, non base-isolated, LDSD Category Level 2 structural systems (e.g. cantilever RC walls, steel MRF) in very-high seismic zones (e.g. Wellington), achieving 5% probability of exceeding 5% replacement cost in an earthquake in a 10 year period may be unachievable – and that probabilities in the 5-10% range may be more realistic. Studies also show that seismic isolation technology may be necessary to achieve 2% loss probabilities for LDSD Category Level 3 buildings in high and very-high seismic hazard regions (e.g. Christchurch and Wellington).

TS 1170.5 (SNZ, 2025) does not define an annual probability of exceedance that should be considered for CALS, nor does it specifically identify what an appropriate margin beyond ULS might be. The recommended ULS scaling factor of 1.5 is intended to limit the annual individual fatality risk associated with earthquake shaking *to around 1×10^{-6}, which in turn has been interpreted as limiting the annual probability of collapse to around 1×10^{-4}. However, it is acknowledged there is some uncertainty as to what the ULS scaling factor should be, in part due to the considerable uncertainty regarding collapse predictions.*

The scaling factor recommended in this document is consistent with the TS 1170.5 requirement that potential step-change in soil behaviour should be explicitly considered for shaking intensity up to 150% of the applicable ultimate limit state demand. This value has some precedent within NZ design, e.g. as inferred by the Commentary to NZS 1170.5 (SNZ, 2004), NZS 3101 (SNZ, 2017), NZ Industry NLRHA Guidelines (SESOC, NZSEE and NZGS, 2025), NZSEE Draft Seismic Isolation Guidelines (NZSEE, 2019), NZ Seismic Assessment Guidelines – Part C1 (NZSEE, 2025) and NZTA Bridge Manual (NZTA, 2022).

When considering CALS in regions with high and very-high seismicity, and when significant nonlinear soil/rock behaviour is anticipated, site-specific seismic (probabilistic) hazard analyses can be used to provide more appropriate seismic design actions (refer to Volume Three Section 4 for more information).

9. Physical States

The physical state description is the link between the performance goals and the engineering design criteria. It describes the expected state of each system at a given limit state, that would achieve the performance goals.

The focus of LDSD is limiting building damage in significant earthquakes to an extent which is economically repairable within a relatively short space of time and reduces the likelihood of the building not being able to be occupied and used for its basic intended function (i.e. achieving Operational State OS-II – Partial Functionality).

As previously noted in Section 4, there are a range of external factors beyond the site that could impact the ability of a building to function, but are beyond the scope of LDSD. The physical states/damage thresholds in Table 9-1 may therefore not be applicable for those projects when building owners and tenants have a lower tolerance for loss of building functionality. More conservative physical states/damage thresholds might be needed, or additional backup systems and arrangements may be required, to provide the level of assurance of building functionality being sought.

Source documents: FEMA P-58 (FEMA, 2018), ASCE 41 (ASCE, 2023), REDi and Health NZ Technical Guidelines for the Seismic and Structural Design of Hospital Buildings (HNZ, 2025).

Table 9-1 Expected Physical States for DCLS Ground Shaking for Various Building Elements

ID	Building Element	Sub-Component	Expected Physical States/Requirements *For DCLS Ground Shaking*
1.	**Primary and Secondary Structure**	Foundations	Manageable absolute settlement relative to surrounding ground, meaning not requiring immediate foundation relevelling nor significantly affecting the potential for flooding from overland flow. Manageable differential settlement meaning damage to superstructure elements is limited to that which is economically repairable (as described in subsequent descriptions) and does not prevent the building from being occupied and used for its basic intended function (i.e. achieving Operational State II – Partial Functionality)[2,3]. Minor cracking of concrete foundation members not requiring repair.
		Structural Members	Minor damage or yielding of structural members. No significant reduction in capacity, and tolerable residual drift. Practical and economical to repair. For concrete members this could include minor cracking and isolated spalling of cover concrete—able to be reinstated by practical extents of epoxy injection or mortar repair and not requiring reinforcing bar replacement. For structural steel elements, minor permanent distortion but no buckling of plate elements. Access for these repairs may require minor work, e.g. removal of areas of ceiling, not major work like the removal of large areas of cladding.
		Floors	Minimal damage. Minor cracking of concrete slabs. No significant spalling. Otherwise, similar to *Structural Members*.
		Roof Framing	Generally similar to *Structural Members*. Structure retains sufficient stiffness to avoid compromising watertightness of roof enclosure[1].

ID	Building Element	Sub-Component	Expected Physical States/Requirements *For DCLS Ground Shaking*
2.	**Building Envelope**	Facades	Enclosure overall should retain water shedding ability. Minor water ingress acceptable in high wind/rainfall conditions. Minimal damage to façade panels, no cracked glass. Localised tearing to sealant joints and minor dislocation or damage to flashings. Minor damage at seismic joint locations.
		Roof Sheeting & Membranes	Minor movement/ junction damage only. Watertightness maintained.
		Balconies and Terraces	No damage to handrails and balustrades to balconies and terraces that would affect their 'barrier' functionality. No cracked or broken glass panels. Where terraces have internal spaces under them, minor movement/ junction damage only. Watertightness maintained.
		Canopies	Minor damage to framing elements, similar to *Structural Members*. Localised tearing to sealant joints and minor dislocation or damage to flashings.

ID	Building Element	Sub-Component	Expected Physical States/Requirements *For DCLS Ground Shaking*
3.	**Building Services**	HVAC Systems	Systems are able to function to a level sufficient to enable the building to be occupied and used for the basic intended function (i.e. achieving Operational State II – Partial Functionality)[2,3]. Minimum heating and cooling performance will depend on climate zone, building characteristics and building user quality expectations.
		Electrical Systems	Systems are able to function to enable the building to be occupied and used for the basic intended function (i.e. achieving Operational State II – Partial Functionality)[2,3].
		Data & Communication Systems	Systems are able to function to a level sufficient to enable the building to be occupied and used for the basic intended function (i.e. achieving Operational State II – Partial Functionality)[2].
		Water Supply and Drainage Systems	Systems are able to function to a level sufficient to enable the building to be occupied and used for the basic intended function (i.e. achieving Operational State II – Partial Functionality)[2,4]. Containment (avoiding rupture of tanks or piping as a result of earthquake shaking) to be maintained.
		Fire Protection Systems	Systems are able to function to a level sufficient to enable the building to be occupied and used for the basic intended function (i.e. achieving Operational State II – Partial Functionality)[2,4]. Containment (avoiding rupture of tanks or piping, and avoiding sprinkler action as a result of earthquake shaking) to be maintained.
		Emergency Lighting & Escape Route Signs	Lighting and egress signs are able to function to enable the building to be occupied and used for the basic intended function (i.e. achieving Operational State II – Partial Functionality)[3].
		Lift Systems & Supports	For buildings greater than three storeys high, reasonably avoid physical damage to lift systems, including guide rails and supporting structure, that would prevent them from working. No residual displacement of car or counterweight. Lift reset by lift technician post event is permitted. For buildings less than or equal to three storeys high, minor damage to lift systems permitted provided it is readily repairable[5].

ID	Building Element	Sub-Component	Expected Physical States/Requirements *For DCLS Ground Shaking*
4.	**Egress Routes**	Corridors	Egress routes clear of obstructions. Egress doors remain operable with minimal damage. For fire rated doors, partitions and ceilings as per *Passive Fire* below.
		Stairs & Ramps	Minimal damage to stair flights, landings and ramps, similar to *Structural Members.* Any damage to seismic joints readily repairable. No damage to handrails and balustrades that would affect their 'barrier' and 'handrail' functionality. For fire rated partitions and ceilings as per *Passive Fire* below.
5.	**Fitout Elements**	Ceilings	For suspended ceilings minimal damage to ceiling grid, some local loss of lightweight ceiling tiles[6] - limited to tiles without building services. For direct fix ceilings cracking in plaster and paint along panel edges, isolated screw pull-through or popping. Minimal damage to plasterboard.
		Partitions (General)	Minor damage generally limited to cracking in plaster and paint along panel edges, isolated pull-through or popping of fasteners. Repair should be predominantly sealant and/or plaster and paint. Repair may require some refixing, but sheet replacement should generally not be required.
		Tiled Partitions in Wet Areas	No damage to waterproof membranes under tiles. Minimal damage to tiles. Watertightness of tiled partitions in wet areas maintained.
		Lighting Systems	Lighting systems are able to function to a level sufficient to enable the building to be occupied and used for the basic intended function (i.e. achieving Operational State II – Partial Functionality)[2]. Damage to non-essential feature lighting permitted provided this does not prevent the building from being occupied.

ID	Building Element	Sub-Component	Expected Physical States/Requirements *For DCLS Ground Shaking*
6.	**Passive Fire**	Fire Rated Walls, Floors and Ceilings	Damage limited to that which can likely maintain reasonably adequate passive fire resistance. This means that the level of assurance in the performance of fire safety systems can be reduced compared with newly installed compliant/tested systems. However, there should be reasonable confidence in the expected performance of safety systems to provide basic protection in the event of a credible fire scenario—in conjunction with practical enhanced management strategies[2,7].
		Fire Rated Doors & Windows	Doors remain operable, otherwise similar to *Fire Rated Walls, Floors and Ceilings*.
		Fire Protection of Structural Steel & Timber	Minor damage to fire protection systems permitted, provided structural elements maintain a reasonable fire resistance, otherwise similar to *Fire Rated Walls, Floors and Ceilings*.
7.	**Building Contents**	Specialist Equipment	Specialist equipment is able to function to enable the building to be occupied and used for the basic intended function (i.e. achieving Operational State II – Partial Functionality)[2].
		High Value Contents	Avoid damage to high value contents identified in the project brief.
		General Contents	Excluded. No specific damage limitation requirements[8].
8.	**Landscaping and External Services**	Perimeter Accessways	Minor damage to accessways to building entries permitted provided access is not impeded.
		External Services	Avoid damage to building services entering and exiting the building that would prevent the building to be occupied and used for the basic intended function (i.e. achieving Operational State II – Partial Functionality)[1]
		External Retaining Walls	Minor horizontal sliding and/or rotation of external retaining walls permitted provided this does not cause consequential damage to the building or impede access. Otherwise, similar to *Structural Members*.

Notes:

1. Includes consideration of in-plane racking of roof and potential related localised damage of roofing at flashings and joints between roof sheathing.
2. Limited damage to sub-component is permitted provided repairs necessary to reinstate basic building functionality can be completed within the acceptable timeframe or short-term management strategies can be implemented while the repairs are completed (refer to Section 7.2).
3. Could include the use of permanent on-site emergency generators or facilities for portable generators to cover the situation of network outages when higher levels of dependable building functionality are sought.
4. Secondary water supply sources may be required to cover the situation of network outages.
5. This makes the assumption building users are able to walk up to 3 storeys until the lift systems have been repaired and are back in service. This may not be appropriate for all building occupancy types so should be considered on a project-by-project basis.
6. The complete avoidance of tile loss generally requires taping or clipping of all tiles. This can be impractical as it precludes straightforward maintenance access to the ceiling plenum. As a minimum, strategies for securing tiles should ensure any tiles containing fittings such as sprinkler heads, lighting and electrical fittings, ventilation diffusers and the like cannot become dislodged. Furthermore, the potential dislodging of non-secured tiles should have a low likelihood of affecting adjacent tiles with fittings—especially those supporting emergency lighting, and sprinkler heads.
7. Regulatory decisions about acceptable timeframes return to an ANARP compliant state after an earthquake lie with local authorities and currently lacks guidance. This requirement is to enable the building to be restored to partial functionality for a time under tolerable risk compromises. This should be assessed against the expected performance of safety systems, and under the expected levels of damage. This can then be followed by a return to an ANARP compliant state economically over longer timeframes.
8. Building owners and tenants might identify additional damage limitation requirements for general contents in the project brief, however these are outside the scope of required asset protection considerations for LDSD buildings.
9. If building owners and tenants identify additional Building Elements not addressed by Table 9-1, they should collaborate with the design team during the project brief development to establish appropriate expected physical states and requirements for these elements.

References

Arup. (2013). *Rating System Resilience-based Earthquake Design Initiative for the Next Generation of Buildings Version 1.0.* Arup.

ASCE. (2023). *ASCE/SEI 41-23 Seismic Evaluation and Retrofit of Existing Buildings.* Reston, VA: American Society of Civil Engineers.

FEMA. (2018). *FEMA P-58-1 Seismic Performance Assessment of Buildings: Volume 1 - Methodology (Second Edition).* Washington D.C.: Federal Emergency Management Agency.

HNZ. (2025). *Design Guidance Note: Technical Guidelines for the Seismic and Structural Design of Hospital Buildings.* Wellington: Health New Zealand | Te Whatu Ora.

MCDEM. (2019). *National Disaster Resilience Strategy.* Wellington, New Zealand: Ministry of Civil Defence & Emergency Management.

NZSEE. (2019). *Draft Guidelines for the Design of Seismic Isolation Systems for Buildings.* Wellington, NZ: New Zealand Society for Earthqauke Engineering.

NZSEE. (2024). *The Resilient Buildings Project. Relating Societal Expectations to Building Seismic Performance: Report for Stage 3.* Wellington, New Zealand: Bulletin of the New Zealand Society for Earthquake Engineering .

NZSEE. (2025). *Engineering Assessment Guidelines - Part C1 General Issues.* Wellington, NZ: New Zealand Society for Earthquake Engineering.

NZTA. (2022). *NZTA Bridge Manual SP/M/022.* Wellington, New Zealand: NZ Transport Agency Waka Kotahi.

Saatcioglu, M., Palermo, D., Ghobarah, A., Mitchell, D., Simpson, R., Adebar, P., .Hong, H. (2013). Performance of reinforced concrete buildings during the 27 February 2010 Maule (Chile) earthquake 1. *Canadian Journal of Civil Engineering, 40(8)*, 693-710.

SANZ. (2002). *AS/NZS 1170.0 Structural design actions, Part 0: General principles.* Wellington: Standards Australia, Standards New Zealand.

SESOC, NZSEE and NZGS. (2025). *Nonlinear Response History Analysis Design Guide.* Wellington, NZ: Structural Engineering Society New Zealand.

SNZ. (2004). *NZS 1170.5:2004 Structural Design Actions Part 5: Earthquake Actions - New Zealand.* Wellington: Standards New Zealand.

SNZ. (2017). *NZS 3101.1&2:2006 Inc. Amd. 1-3 Concrete structures standard.* Wellington, NZ: Standards New Zealand.

SNZ. (2025). *TS 1170.5 Structural Design Actions Part 5: Earthquake Actions – New Zealand.* Wellington, NZ: Standards New Zealand.

Sullivan, T. J., Dong, C., Francis, T., & Oliver, S. J. (2025). Developing a Prescriptive Method for Low-Damage Seismic Design in New Zealand - Under preparation. Earthquake Spectra.

SPUR. (2012). *Safe Enough to Stay.* San Francisco, CA, US: SPUR.

Appendix A – Definitions and Acronyms

Annual Probability of Exceedance (APoE)	The likelihood that a specific event (e.g. a defined level of earthquake shaking) will be exceeded in any given year.
ANARP (As near as is reasonably practicable)	A concept used in some sections of the Building Act allowing flexibility in the level of compliance with the Building Regulations (the ANARP test). This document also uses the same term in specific situations that give flexibility to the level of compliance achieved with this guideline's additional requirements.
Base isolation	This building construction method places seismic isolators (base isolators) between the foundation and the bottom of the building superstructure. During an earthquake, the isolators effectively decouple the superstructure from the foundation, avoiding damage to the building.
Building Code (NZBC)	Secondary legislation that sits directly below the Building Act 2004. It specifies the minimum performance standards for buildings to achieve. For the purposes of this guide, the Building Code refers to the minimum seismic performance and functional requirements that buildings are required to be constructed to.
Downtime	See Re-occupation time.
Earthquake shaking levels	Qualitative descriptors used to broadly characterise different levels of earthquake shaking intensity.
Moderate earthquake	An earthquake where damage is possible and can be expected on a more frequent basis than a significant or major earthquake. In this document, the term 'moderate earthquake' is not associated with the same term used within the Building Act 2004.
Significant earthquake	An earthquake where some damage is likely; and is more severe than a moderate earthquake and can be expected on a more frequent basis than a major earthquake but less frequent than a moderate earthquake.
Major earthquake	An earthquake where significant damage is possible; and is more severe than a significant earthquake and can be expected on a less frequent basis than a moderate or significant earthquake.
Severe earthquake	An earthquake where substantial structural damage is possible; and is more severe than a major earthquake and can be expected on a less frequent basis than a significant or major earthquake.
Expected Annual Loss (EAL)	Long term expected annual financial loss in each year, average over many years, related to a particular hazard. Often expressed in terms of a percentage of building replacement costs.

Fluid viscous damper (FVD)	Proprietary seismic device that dissipates energy by forcing a viscous fluid through an orifice, similar to a car shock absorber. They are commonly used in seismic and wind load applications to reduce structural movements.
Inter-storey drifts	The horizontal displacement of one storey of a building relative to the storey below, typically caused by lateral forces like wind or earthquakes.
Lifeline utilities	Entities that provide essential infrastructure services to the community. For example, water, wastewater, transport, energy and telecommunications. These services support communities, enable business, and underpin the provision of public services.
Low Damage Seismic Design (LDSD)	A building design philosophy that achieves better than New Zealand Building Code minimum requirements. A key goal is to deliver buildings that are less likely to be damaged and thereby limit disruption and losses in future earthquakes.
LDSD Category Levels	Used to describe categories of building which meet specific Low Damage Seismic Design requirements.
LDSD Category Level 1	LDSD Category Level 1 buildings incorporate some design features that help to minimise damage in addition to complying with minimum seismic design standards. LDSD Category Level 1 building are designed with lesser performance standards than LDSD Category Level 2 and 3 buildings.
LDSD Category Level 2	LDSD Category Level 2 buildings are designed to have a high level of seismic performance including specific damage control performance goals.
LDSD Category Level 3	LDSD Category Level 3 buildings are designed to have a very high level of seismic performance including specific damage control performance goals.
Limit state	Used to describe a condition beyond which a structure no longer fulfils its design criteria.
Serviceability Limit State 1 (SLS1)	This condition is reached when a building sustains damage that would prevent it from being used as originally intended without repair as defined in TS 1170.5 (SNZ, 2025).
Damage Control Limit State (DCLS)	This condition is reached when a building sustains damage that would no longer be economically repairable and would prevent the Damage Control performance goals defined in Section 7 being met.
Serviceability Limit State 2 (SLS2)	This condition is reached when a building sustains damage that would prevent it from remaining operational for that role for which had been assigned.
Ultimate Limit State (ULS)	This condition is reached when the capacity of a structure is reached based on design strengths and deformation limits specified for the ultimate limit state in TS 1170.5 (SNZ, 2025). The structure as a whole may have sustained significant structural damage, but still has reserve capacity to avoid structural collapse.

Collapse Avoidance Limit State (CALS)	This condition is reached when a building sustains substantial structural damage but retains a reasonable margin against overall collapse.
Loss	Damages and consequences resulting from a specific event i.e. earthquake. Can be categorised as direct and indirect losses.
Direct losses	Losses directly related to building earthquake damage that requires repair or building replacement.
Indirect losses	Losses that are not directly related to building damage such as business interruption after an earthquake or costs associated with temporary relocation.
Importance levels (ILs)	Importance levels are used to categorise buildings into different types in relation to the value of the building to the community and the consequence of building failure. The different building types are defined in New Zealand building standards such as AS/NZS 1170.0 (SNZ, 2002).
New building	A building that is designed and constructed to at least the minimum performance requirements within the Building Code.
Non-structural element (NSE)	Elements within a building that are not part of the primary or secondary structure but are needed for the building to function. Examples include ducts, pipes, suspended ceilings and partition walls
Operational State	A description of the operational state of a building, independent of time. The definitions below are given in the context of LDSD.
Full functionality	A building for which post-earthquake structural and non-structural damage is limited to the extent that the intended functions of the building's pre-earthquake use are maintained or can be restored within an acceptable time (usually measured in minutes to hours rather than days).
Partial functionality	A building for which post-earthquake structural and non-structural damage is limited to the extent that the basic intended functions of the building's pre-earthquake use are maintained or can be restored within an acceptable time (usually measured in days rather than weeks).
Shelter in place	A building for which post-earthquake functionality has been significantly reduced. Building services may be damaged and unavailable until necessary repairs are completed. The capacity of the building has not been significantly reduced due to the prior earthquake, and the building is able to withstand another major earthquake.
Safe egress only	A building which only meets life safety objectives without any expectation of post-earthquake occupiability or functionality.
Primary structure	The main structural system of a building. This includes all building elements that are necessary to keep the structure standing. Examples include beams, columns, floors, structural walls and foundations.
Re-occupation time	The expected period to re-occupy a building after an earthquake.

Secondary structure	Structural elements in a building that are not part of the primary structure, but nevertheless are still needed to support floor loading and non-structural elements. Examples include stairs and façade support framing.
Seismic performance	The expected response of a building or structure during a given earthquake.
Seismic performance framework	A structured approach to for managing and improving the seismic performance of buildings. The definitions below are given in the context of LDSD.
Outcome objectives	Overall objectives corresponding to the building performance aspects of life safety, protection of other property, damage control (asset protection) and functionality (operability).
Performance goals	Performance criteria that correspond to the outcome objectives.
Physical states	Qualitative statements of physical states/damage onset thresholds corresponding to the performance goals.
Technical design criteria	Quantitative values and methods to be used by building designers to meet the damage level expectations (and hence functionality objectives).
Seismic risk	Comprised of hazard likelihood, building vulnerability, and consequence (the exposure of people and the direct and indirect losses generated from damage). In the context of LDSD, seismic risk is the probability people will suffer economic loss as a result of earthquake damage to their buildings.