PROPOSED LOW DAMAGE DESIGN GUIDANCE – A NZ APPROACH

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Abstract

At present, there is no New Zealand industry guidance or standard for the design and construction of low damage buildings. Developers, owners and occupiers are requesting and incorporating low damage technology into the design of new buildings, particularly in the premium end of the commercial building market. The lack of authoritative guidance means building developers often don't have a good understanding of what benefits they are getting (or not getting) and building users cannot be assured of getting the performance that they expect. For example, some recently constructed buildings are claimed to be low-damage design but, in many cases, this is limited to the structure only, i.e., to 25% of the building value, and neglects non-structural systems and contents that are the main causes of cost and disruption, even in smaller earthquakes. One of the primary reasons for the guidance document is to address this concern by providing an industry-recognized framework for more holistic low damage design.

Low Damage Design is not simply a 'bolt on' component but rather a philosophy that must be followed through the whole design and construction process, including seismic resisting and gravity structure, as well as non-structural and contents aspects.

The paper will cover the progress to date on the project, highlight the need for a robust brief with the owner and the importance of the whole design team being involved in the process. Additionally, there is some work being done to benchmark this work against the Californian "Functional Recovery" work that is currently underway.

Introduction

On September 4, 2010, the structural engineering community of New Zealand changed overnight. This date marked the start of the Canterbury earthquake sequence and a journey of both technical and people related issues. Often these two issues were and remain inextricably linked. Then on February 22, 2011, structural engineering and building performance was put under the public microscope like never before. Overnight everyone had an opinion on building performance. While the engineering community may not have been surprised by the performance of Christchurch buildings, the public and insurance industry were. In the author's opinion; this leads to the first lesson – that 'life safety' code based design standards were not universally understood. The second lesson is that as engineers, historically, we have not done a good job at communicating the building performance of our designs.

What followed was a period of response involving assessments, demolitions and learnings on a technical front. On a people front, fear of insurance (or lack thereof), community resilience and temporary exclusion from the central business district (CBD). There were and are many lessons that we as a profession must learn from. The third lesson is the amount of time that people were excluded from the CBD was another surprise and influencer of decisions going forward.

Part 1: A Christchurch Experience

Background

With a backdrop of insurance, downtime, safety and safety perception issues, many developers, owners and occupiers started to question if there was an option other than 'code compliant', life safety design.

When it came time for the re-build, structural engineers were suddenly put in front of clients and had influence over architecture like never before. This influence, coupled with willingness from clients and users to hear about more than just traditional structural systems, saw a dramatic increase in base isolation, bucking restrained braces, viscous damping and replaceable element designs being employed. At about the same time, the Canterbury Earthquake Royal Commission (CERC) heard submissions about the performance of buildings incorporating 'low damage building technologies' and the term 'Low Damage Design' (LDD) started to take off.

Volume three of the CERC report "Low-Damage Building Technologies" recommended:

"[the government] in conjunction with industry ensure evidence-based information is easily available to designers and building consent officials to enable low damage technologies to proceed more readily through the building consent process". - recommendation 67

"[the government] should foster greater communication and knowledge of the development of low damage technologies among building owners, designers, building consent authorities and the public". - recommendation 69

At the 2012 New Zealand Earthquake Engineering (NZSEE) conference, Hare et all presented a paper titled "Performance Objectives for Low Damage Seismic Design of Buildings" and people started to ask the questions "what does low damage mean?" and "what performance qualifies as LDD?"

Developers, real estate agents and marketers all started to talk about safety, risk, LDD and percentage new building standard (%NBS). Buildings started to be actively marketed as LDD or a variant thereof. Lesson four is that without a common definition, technical terminology can be embraced by the public and take on a 'life of its own' that the engineering profession never really expected.

The Structural Engineering Society of New Zealand (SESOC) became concerned that term LDD was being used without a common understanding of meaning. To some it appeared to mean design incorporating new technology and techniques, sometimes without full testing or redundancy. Others seemed to be talking about the structural element design rather than a 'system approach'. SESOC quickly formed the view that performance outcomes of LDD were those of the whole building and the judge of this performance would be the owners and users, not engineers.

Without a common meaning, our profession has not learnt from the lessons above. Ultimately this could lead to a significant reputational issue for the profession and individuals involved in a building that did not perform as expected.

A Need for Leadership

Recognising that there is no New Zealand guidance or standard for LDD, SESOC proposed to fill this gap. One of the primary reasons for a Guidance document is to address concerns that some low-damage systems are unproven and the basis for calling them low-damage may be arbitrary.

Part 2: A New Way of Thinking About Performance

Vision and Objectives

The vision for the guidance is to become the framework for an industry standard approach to LDD.

It will achieve this by satisfying the following objectives:

1. Provide high level guidance to stakeholders on what LDD should achieve
2. Provide guidance to building designers (architects and engineers) on the design criteria that must be satisfied to achieve recognised LDD solutions that meet an acceptable industry standard
3. Provide assistance to building consent officers and reviewers in assessing levels of compliance for LDD buildings.

It is expected that industry-wide adoption of the guidance will ensure that systems which are claimed to achieve low damage do, in fact, perform in accordance with measurable expectations. It is hoped that the guidance will be acknowledged by the Regulator, the Ministry of Business, Innovation and Employment (MBIE). In essence, the document will guide engineers and building owners in deciding whether to design buildings to higher standards than the Building Code and, if so, to what level.

Stakeholders

The proposed guidance should help guide a briefing process, considering the needs the stakeholders:

- The public – as users, the public have a basic right to understand the risk to which they are exposed. Societal expectations for buildings have been poorly understood at best and it is the duty of engineers to better inform the public. This includes the obligation not simply to elect a level of risk on the public's behalf, but also to facilitate debate and understanding and to reflect intent.
- Building owners and developers – as the purchasers (and frequently marketers), this group is the most potentially affected. This group needs to have assurance firstly that they are appropriately briefed (or being reverse briefed by) their building designers so that the outcome meets their expectations; and secondly that they are not misrepresenting their buildings to the users.
- Building Consent Authorities (BCAs) – in order to support the consenting process. As many LDD solutions are likely to be alternative solutions, the industry would benefit from a means of distinguishing true (code) compliance matters from 'over-performance'.
- Other designers (architects, services engineers) – by providing consistent guidance on the implications of LDD for non-structural systems.
- Contractors – having the primary responsibility for implementation, particularly for the services and non-structural elements often without direct involvement of the structural engineers.
- Researchers – by providing a framework and parameters for LDD, it is expected that the guidance will be an important adjunct to future research into low damage solutions

The document should increase confidence to insurers around their potential or reduced exposure with the application of low-damage systems and this could influence insurance negotiations.

Practical Considerations

The document should be freely available and more readily encourage building owners and designers to consider incorporating low damage systems in future new buildings and retrofitting existing buildings. The guidance is intended for the engineering profession, building official and the general public. Put simply it is intended to encourage and document a conversation about performance between the whole design team and the client/user.

The guidance is planned to be an overarching document that identifies performance requirements of buildings designed and built to have improved resilience to earthquakes and that incorporate low-damage systems. Further while the document is performance based, system and material agnostic, it is expected to provide a unifying framework for a suite of subservient technical guidance documents for specific low-damage systems such as base isolation, buckling restrained braces and viscous damping.

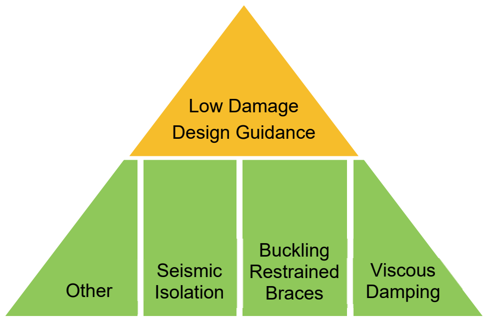

Figure 1. Guidance hierarchy.

Philosophical approach

LDD is not simply a ‘bolt on’ component, but rather a philosophy that must be followed through the whole design and construction process, including seismic resisting & gravity structure, as well as non-structural and contents aspects. It requires the engineer and design team be prepared to agree and document performance with stakeholders, not blind reliance on Codes and Standards.

This approach it may require a difficult conversation with a client stating that low damage performance is not achievable due to:

- The geotechnical performance of the site will be too poor to be practically remediated
- Poor performance of adjacent external factors such as adjacent buildings or sites/slopes
- Events such as Tsunami.

This philosophy does not mean that ‘Low Damage Technologies’ need to be used. Ordinary, structures well designed with redundancy and regularity on good sites can achieve better than code minimum performance.

Proposed content

What follows is a summary of progress to date. It is a work in progress, without final consensus on all issues. Before publication the guidance document will be subject to a review and consultation.

The document is proposed to be split into the following chapters/topics:

1. Introduction
2. Background
3. Scope
4. Overview of LDD
5. Performance Objectives
6. Performance Assessment Criteria
7. Design & Implementation
8. Further Considerations
9. Glossary

Chapters 5 and 6, setting the performance objectives and assessment criteria, are the most challenging. The authors have found it useful to group the questions around performance objectives and acceptance criteria into the following areas.

- Building use and occupancy considerations
- Site considerations
- Business continuity, functionality and reparability considerations
- Financial considerations
- Procurement, construction and maintenance considerations

When considering performance, the default minimum standard is the Building Regulations 1992. These are performance based regulations and compliance is then via the building code and a choice of deemed to comply methods or alternative solutions.

Being mindful of the Building Regulations and the need to use language that is understandable to current stakeholders, a Damage Control Limit State (DCLS) to supplement both the Serviceability and Ultimate Limit States is defined. Further, splitting the building into Primary Structure, Secondary Structure, Non-structural Elements and Contents allows performance to be talked about in a grading system way such as the Arup REDi or US Resiliency Council.

Table 1 below is the start of how some performance objectives might be formulated in a way that is consistent with the Building Regulations.

Table 1. Proposed Performance Objectives

Limit State	Serviceability	Damage Control	Ultimate	Grade Required for:		
General outcome	Fully operational: Superficial only, repairable within days, no disruption to operation.	Limited operation required: Minor damage acceptable provided full operation is possible (either immediately or within hours). Damage may be repaired within normal maintenance periods within a reasonable budget	Repairable, not operational. Shelter possible (contents protected)			Gold/Kōura

Limit State	Serviceability	Damage Control	Ultimate	Grade Required for:		
By Category						
Primary structure:	No significant damage requiring repair.	All damage repairable insitu within normal maintenance cycles or through after-hours work.	Damage acceptable. Building able to continue to resist another 3 events and repairable without full strip-out or de-cladding	Bronze/ Kōuraura	Silver/Hiriwa	Gold/Kōura
Secondary structure:	No significant damage requiring repair.	No significant damage requiring repair.	As primary			
Non-structural elements:	No significant damage.	Minor damage only. All damage repairable insitu within normal maintenance cycles or through after-hours work.	Cladding integrity to be maintained with temp repairs. Emergency systems general operable. More to come, with discussion			
Contents:	No significant damage	No significant damage	Key life safety, emergency systems and valuable contents remain in place.			

Notes:

1. The Limit States are a proxy for the load level against which performance may be assessed.
2. The Damage Control Limit State defines a level at which a building may remain operable and will generally correspond to the SLS2 level as defined in NZS1170.5
3. The Damage Control Limit States described above needs to be considered in relation to the return period factor/Importance Level – ie the load level is not consistent overall occupancy types.
4. Dose LDD need to split Primary and Secondary structure?
5. What happens to LDD philosophy when there is differing design teams for base build/core (owner/developer) and fit-out contents (tenant)? Clearly you can't have a LDD fitout without LDD base build but can you have LDD base build and not contents?

Fitting in with current design terminology/knowledge.

When it comes to performance acceptance it is important to understand the effects of our current 'design tools' on LDD. Below highlights the relationship with LDD not be a precise definition.

Ductility: by definition, this implies a level of damage once the element or system goes beyond elastic behavior. Weather Force or Displacement based design, the level of post elastic behavior will need to be evaluated in terms of the Performance Objectives for LDD.

Redundancy: like ductility a method of providing additional elements or loadpaths. Again, to gain the benefit from redundancy implies a level of damage that will need to evaluated in terms of LDD.
Performance-Based Design: in its current interpretation, it is a way of targeting certain design performance criteria, but tends to be focused on the structural aspects and does not consider the time or cost of reparability or operational requirements.

Next Steps:

Provide more detail in the performance Objectives and Assessment areas prior to finishing final draft. The final draft will be peer reviewed and put through a stakeholder engagement process that deliberately includes owners, developers and users. Once general agreement is reached, a launch that includes both training and industry engagement is planned.

Part 3: International Experience.

The concept of appropriate robustness levels in a country's building stock is not unique to NZ. The following comments are observations from the author of the international effort gleaned from attendance at NZSEE Conference 2017 and SEAOC Convention 2018.

Background:

The US Resiliency Council has paved the way by highlighting the issues in terms of:

Safety: the focus is on the protection of people and allowing them to exit a building.

Damage: where the focus is on physical damage and quantified in monetary costs of repair.

Recovery: where the focus is on reparability and return to service and quantified as a time duration.

Like New Zealand, the building codes sets minimum requirements intended to minimise loss of life and not really limit damage or maintain functionality. This approach can also result in a range of performance for buildings, depending on use, region and owner.

The US has its own set of terminology such as, Life Safety, Collapse Prevention, Immediate Occupancy and Functional Recovery.

Latest News:

In April 2018, an amendment to AB 1857, called AB 1857 (Nazarian) – Functional Recovery Standard for New Buildings. The SEAOC board have fully endorsed support to this 'more than life safety standard'. This has been achieved by working collaboratively with EERI on the subject.

Discussions with SEAOC leads the authors to believe that both NZ and the US are working on the same issue. Further, both countries have agreed to share knowledge going forward.

Conclusions:

Both the people expectation of building performance and the technical aspects of building performance are inextricably linked. Recent experience has highlighted four lessons:

1. Life Safety code based minimum design performance is not universally understood.
2. Engineers have not done a good job at communicating the performance that our designs deliver.
3. The amount of time before normal occupancy resumes is an important factor in decision making.
4. That clarity and ownership of terminology definitions is important.

These lessons strike at the heart of both our profession and the ability of society to withstand and recover from an earthquake. It is the author's opinion that:

1. In the future owners and users will judge success of building performance; not engineers.
2. The issues are universal and information sharing and collaboration is important.
3. We must lead the conversation on resilience and LDD but not set the risk level. That is, it is our job to ensure the owners and occupiers are informed but make their own judgement calls on risk.

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