A practitioner's approach to communicating damage control performance

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ABSTRACT: For all of the technical expertise currently being invested into low damage design, one of the most important areas, communicating expected performance to clients has relatively few formal tools to assist the practitioner. A wide range of end users, from commercial developers to institutional owner-occupiers, from tenants to insurers to the general public have a vested interest in the seismic performance of our built environment. However our expected damage performance criteria are not always conveyed effectively outside the structural engineering industry.

This paper discusses the challenges practitioners face effectively conveying damage control measures to their clients, as well as the challenges the structural engineering profession faces conveying this same information to others in the construction industry and to the general public. It considers the key decision drivers that influence our clients in this regard, discusses some of the ways that practitioners are trying to assist their clients with these decisions, looks at some of the tools currently available, and anticipates the impact of the New Zealand Low Damage Design Guidelines currently under development.

1 BACKGROUND

Over the past six years, a series of earthquakes in New Zealand have heightened the public awareness of the effects of seismic events. In particular, the 2010 Canterbury Earthquake, 2011 Christchurch Earthquake, 2013 Seddon Earthquake and 2016 Kaikoura Earthquake have received widespread public attention, not just of their immediate effects, but also of the longer term impacts of post-earthquake repair, demolition and rebuild.

This has led to developers, landlords and tenants being much more eager to engage with structural engineers. However, we don't as yet have a standardised framework to base such discussions on. This paper examines some of the frameworks that do exist, how applicable they may be to the current New Zealand context, and sets out some of the other techniques being used by engineers in their discussion with clients.

2 THE CURRENT ENVIRONMENT

In the current environment, particularly in the rebuild context of Christchurch, the conversation around expected building performance is, for most non-engineers, tied to *%NBS* (Percent of New Building Standard). *%NBS* has been adopted by the industry as a convenient measure of a building's likely relative strength against the current standards.

However the ubiquity of Initial Seismic Assessments, which contain a (generally rather rough) estimate of *%NBS*, along with legislation that effectively ties repair requirements to *%NBS*, has led to the measure being viewed with particular importance (and often endowed with inappropriate

exactitude) by the general public. This can be seen the market through Real Estate advertising, featuring slogans emphasising ‘Percentage NBS’ as a measure of seismic resilience, such as a recent one from Wellington proclaiming “Solid as a rock – NBS level of over 140%”.

To help address the limitations of *%NBS* and the need for a better industry standard around level of damage and resilience a Low Damage Design Guide is currently being prepared by MBIE and SESOC. It is expected that this guide will cover the technical aspects of implementing Low Damage Design as well as providing some form of overall framework for agreeing a Low Damage design brief with a client. We note that matching the often rather vague requirements of a non-technical clients to engineering parameters can be rather difficult, and this paper can in part be viewed as a commentary on the challenges we expect will be faced in developing a guide that is valuable to practitioners.

The authors would suggest, that like all things in engineering, the information flow must start at the requirements of the end user, and work from there towards the technical aspects.

In particular, for the conversations on this matter to be suitably useful to both the client and the engineer, they typically need to address the following aspects:

- Differentiation between the Three D’s (Deaths, Damage and Downtime)
- Differentiation between damage control and repairability
- Differentiation between potential damage to various aspects of the build (structure, facade, fitout, loose furnishings).

3 CURRENTLY AVAILABLE TOOLS

Although there is not yet an industry standard guide to Low Damage Design, there are some publications that can be useful to the practitioner. While none of these publications are exhaustive, they do collectively provide some useful assistance. Importantly, they can also be used to benchmark a low damage design discussion against recognised industry norms.

3.1 Serviceability Limit States

The authors would recommend that a low damage design conversation uses as a starting reference point the provisions of existing standards. Specifically NZS1170 sets out two damage control design requirements. The SLS1 requirement for the structure and non-structural components to not require repair and the SLS2 requirement that the structure maintains operational continuity.

Some clients, particularly those likely to be interested in low damage design, already may have some level of understanding of the SLS1 and SLS2 concepts. These can serve to act as a codified reference point for the differentiation between damage control design requirements, and strength design requirements. Many clients do not understand that there is not a linear relationship between importance levels and likely damage, and conveying this understanding is an important first step.

3.2 Tolerable Impacts

The concept of Tolerable Impacts was put forward as an expansion of serviceability limit states used in AS/NZS 1170.0:2002 to facilitate project specific additional limit states in a way that ties into those already used. These are effectively a matrix that provides a framework for expected risk and likely performance to be accounted for when developing a building’s design criteria. This matrix incorporates the existing code limit states.

From a practitioner's point of view it is very important to align with existing standards wherever possible. The use of Tolerable Impacts, or a similar code-integrated approach is something that the authors would therefore encourage the Low Damage Design Guide working group to adopt.

3.3 **A Sample Resilience Evaluation Framework - The REDi™ Rating System**

Internationally, other jurisdictions are developing their own guidance around damage control. Both FEMA P-58 and ASCE 41-13 evaluate seismic performance, but we discuss here the REDi™ system, as it is notable for its focus on resilience.

The REDi™ Rating System developed by Arup is an example of recently developed resilience framework. It sets out a series of REDi™ ratings, (Platinum, Gold, or Silver), and requires mandatory criteria for that tier in each of three Resilient Design and Planning categories - Organisational Resilience, Building Resilience, and Ambient Resilience to be satisfied. It also includes systems for verifying its processes.

When viewed in the light of communication with a client, there are two strong selling points of the REDi™ system.

The first is the simplicity and positivity of its rating system. While simple tiered rating systems are almost universally adopted in market facing systems, the REDi™ system is notable for its positivity. It's Platinum, Gold or Silver rating are all immediately recognisable by those outside the engineering industry as tiers of steadily improving rankings, and as positive rankings above 'standard'.

Of particular value with the REDi™ system to the practicing structural engineer is its lucid distinction of the types of resilience - being Organisation Resilience, Building Resilience, and Ambient Resilience. In discussions with clients about structural resilience (effectively "Building Resilience" in the REDi™ system), it is easy to become overwhelmed by other issues such as the appropriate management response to a natural disaster (Organisational Resilience), or risk from nearby hazards such as rivers or cliffs (Ambient Resilience). The REDi™ framework creates clear boundaries around each type, simplifying otherwise complex discussions. This clear differentiation provides a clarity in a otherwise murky area.

In the New Zealand context, the great drawback of the REDi™ system is its US focus. The interpretation between American and New Zealand codes is not something that can practically achieved within the economic constraints of a typical project. Certain aspects of the guidance, particularly direct physical properties such as drift limits, could however be directly adopted.

3.4 **A Sample Rating Overlay - The US Resiliency Council**

In contrast to technically focused guidance such as those given in the REDi™ guidelines or FEMA and ASCE publications, the US Resiliency Council provides a Rating system focused generally towards the non-technical users. As such, it provides insight into the conversation with clients, and potentially provides a pathway for an equivalent New Zealand Interpretation.

The USRC Rating system is market focused, including two types of ratings. A private "Transaction Rating" and a publically available "Verified Rating". This Rating system is perhaps best viewed as an overlay, sitting atop a range of engineering evaluations and using a translation matrix to turn them into a standardised system. Assigning between one and five stars across three categories, Safety, Damage, and Recovery.

Figure 1. USRC sample Verified Rating

For earthquake hazards, the USRC currently uses two engineering evaluation procedures:

- FEMA P-58 Seismic Performance Assessment of Buildings
- ASCE 41-13 Seismic Evaluation and Retrofit of Existing Buildings (along with the Structural Engineers Association of Northern California Expected Performance Rating System (SEAONC EPRS)).

While the USRC Ratings are simple, the underlying FEMA and ASCE documents are both complex and not directly applicable in New Zealand, making direct adoption of the USRC Ratings impractical without significant additional work.

Given that any Rating system requires widespread market uptake, and that the USRC Ratings seems to have made the most progress in this regard, there could well be merit in advocating a New Zealand format adoption. However, we would note that the 'New Zealandification' of this system would be no small task.

3.5 A Possible Local Rating System - QuakeStar

Locally, the Quakestar rating system has been put forward as a New Zealand Building Rating System. This has parallels to the USRC setup, focused on ratings that are understandable by the end user. In terms of implementation, it perhaps has most parallels with a GreenStar type approach, in that is uses a relatively simple evaluation tool to develop a rating. It is carries similar advantages and disadvantages to Greenstar, in that it is a relatively simple process. Given that conversations with clients or tenants are, by necessity, on much more technically simple level than other engineering discussions, the authors' view is that this relative simplicity of the system is a net benefit.

Table 6. Indicative ratings of notional buildings

Building	Design	%NBS	QuakeStar Score	QuakeStar Ratings			External Factors	Comment
				Safety	Damage	Repair		
URM40	1930	40	30	EP	*	*	na	URM with 40%NBS
URM 50	1930	50	40	*	*	*	na	URM with 50%NBS
Pre 65 RC	1960	50	45	*	*	*	na	Pre 1965 Reinforced Concrete with 50%NBS
2015 IL2	2015	100	130	***	**	*	na	New IL2 Design - conventional
2015 IL2 - BI	2015	100	130	***	****	**	na	New IL2 Design - with Base Isolation
2015 IL3	2015	100	170	****	***	**	na	New IL3 Design - conventional
2015 IL3 - BI	2015	100	170	****	*****	***	na	New IL3 Design - with Base Isolation
2015 IL4	2015	100	230	*****	***	***	na	New IL4 Design - conventional
2015 BI IL4	2015	100	230	*****	*****	****	na	New IL4 Design - with Base Isolation

Figure 2. An example of Quakestar ratings for various buildings

For the Quakestar system to be successful, it would require widespread uptake - meaning either market pressure for adoption, or some form of government legislation. There does not seem to be strong government moves to put this into legislation, though the authors would support efforts of NZSEE and other organisations to enable this.

Regarding market pressure for adoption, we would note the relatively low stars achieved by conventional new builds (3 star, 2 star and 1 star for safety, damage and repair respectively). These relatively low star ratings are unlikely to lead to voluntary adoption of the system, as clients tend to only voluntarily adopt Rating Systems where they convey a positive view of the building.

3.6 The Gap in Existing Systems

The existing systems all come from a similar premise - that there is an existing building on which a detailed engineering evaluation can be undertaken, and that evaluation can then be translated into a simple rating. These processes can thus be valuable for assessing a building after key decisions have been made, however they offer little support in assisting clients with understanding the benefits of low damage design at the start of the design process.

The critical decisions about damage control are typically made very early in the design process,

generally at the same time as the overall structural system is being selected. Decision making at this phase is highly subjective, generally relying on the experience of the design team to interpret the desires of a client. The section below discussed some of the approaches used by Beca to assist with this decision making process.

While we expect that a significant part of the New Zealand Low Damage Design Guide will be clarifying the technical design criteria for engineers, we would like to stress the importance of being able to tie these criteria to discussions that a client or tenant can understand. We would suggest that it would wise to build on the existing work of the USRC and QuakeStar in this regard.

4 PROJECT CLIENT DISCUSSIONS

As project engineers navigate through discussions with particular clients on particular projects, they make use of available tools. More often than not however, they must create their own collateral to assist these discussions. This section looks at some of the methods used by Beca to address this issues with their clients.

4.1 Lincoln Hub, Lincoln

The Lincoln Hub project is a major new joint research facility for Lincoln University and AgResearch on the Lincoln University Campus, and represents a major long term investment for both client parties. As owner-operators there was a clear client interest in balancing whole of life benefits against capital costs.

To facilitate the discussions, Beca developed a set of simple collateral images tailored to the project. These included:

- A simple checklist of drivers often influencing the adoption of damage control measures.
- A deaths - damage - downtime matrix
- A cost - resilience - value diagram
- The same cost - resilience - value diagram adjusted to whole of life cost.

The simple checklist was intended to serve as a reference point for the client to measure their project against others in the market. Triggers on this checklist included: Owner/Operator client; Institutions dependant on a physical campus; Contents more valuable than structure; Emergency response function; Immediate post-quake operability expectations; Unacceptability of extended building downtime; Ability to negotiate insurance benefits.

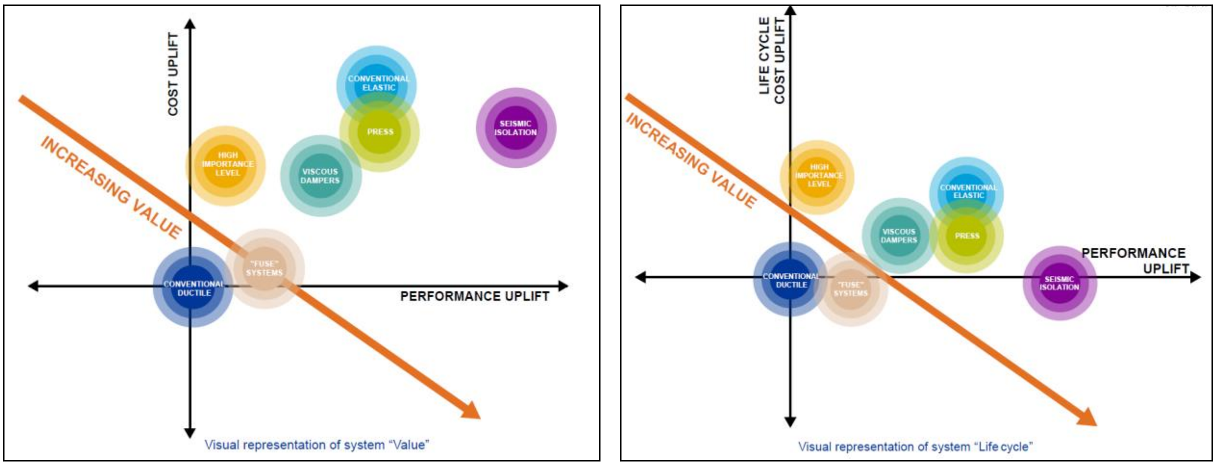


Figure 3. Simplified diagram showing relative cost uplift, performance uplift and value. And a similar diagram adjusted for life cycle costs.

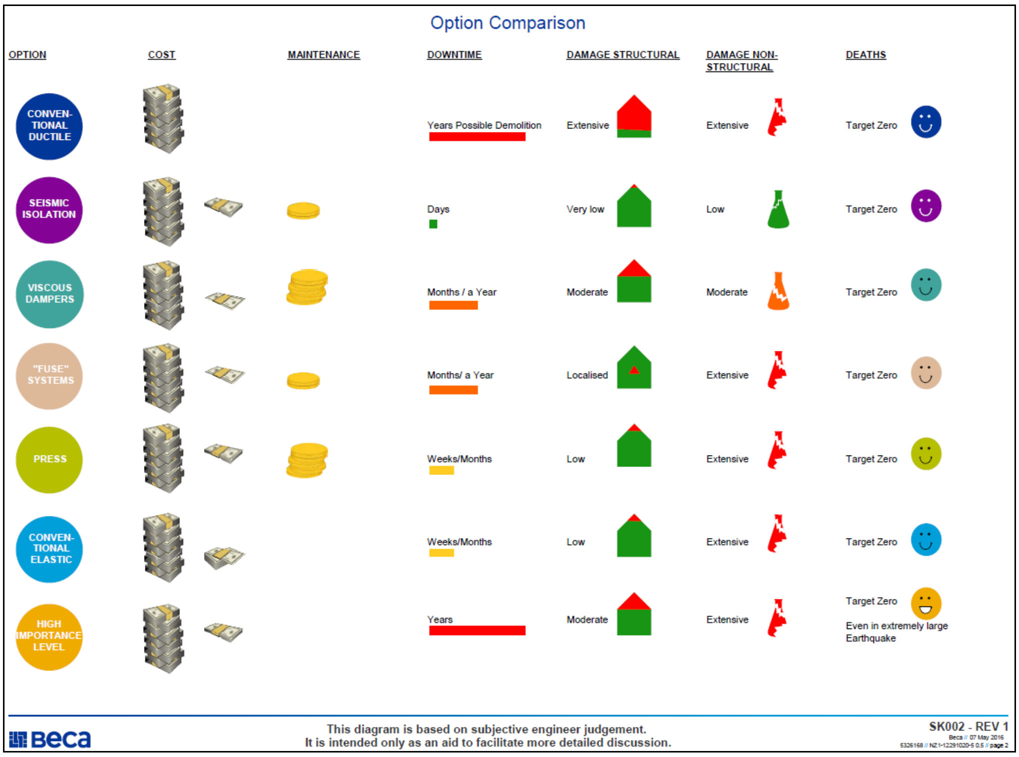


Figure 4. Early project phase matrix providing subjective judgements on impacts of various decisions

These diagrams were the initial prompts for more detailed discussions around the type of structural system to be adopted. They proved useful as a means of applying an amount of tension to the Client's value judgements and giving them a framework by which to correlate their business drivers to the structural design decisions.

Of particular note is their relative simplicity, being useful examples of distilling complicated concepts down to a minimum of information. Their focus is as a client decision making support tool, not as an engineering tool. We note that they will not be applicable to all projects, and that their content is the result of subjective engineering judgements.

4.2 **ANZ Centre, Christchurch**

The ANZ Centre project is a useful demonstration of the way in which tenant activities can influence designing for damage control.

In this commercial development the developer, while sympathetic to good design, was not actively pursuing a damage control agenda. The two major corporate tenants however (ANZ and Beca), were both experienced tenants with access to professional engineering advice. These tenants, following on from the advice of their engineers, both negotiated for their tenancy agreements to include the requirement for the building to have seismic isolation.

As part of the design development, the base build team reviewed all tenancy requirements (including seismic isolation), for their appropriateness for the building form. The existence of a basement in the building made seismic isolation relatively easy to accommodate within the design.

Of note with regards to this paper, is that during the discussions around damage control, the point was put forward by the project cost consultant that "any damage would be covered by insurance". This fundamental disconnect between damage being addressed by design (the engineer's usual view) and damage being addressed by insurance (many developer's, and thus client's views) is crucial to the relatively limited uptake of damage control mechanisms through design.

This disconnect is representative of market failure with regards to the understanding and implementation of damage control in New Zealand buildings. Such market failures are generally

remedied through one of two routes.

Regulatory: In this instance, through the provision of either national level legislation or local government regulations to require damage control in certain areas (such as the extension of an SLS2 requirement to urban centres of national significance).

Market driven: Either through enlightenment of the general public via systems like QuakeStar, or through segment specific interventions like insurance premiums more directly related to building risk.

4.3 New Zealand International Convention Centre, Auckland

The New Zealand International Convention Centre (NZICC) is currently under construction and will be the largest conference, exhibition and entertainment space in New Zealand with its gross floor area of 32,500 m^2, and the largest building project undertaken in Auckland since the Sky Tower in 1997.

The Engineering Brief was a multi-stakeholder agreement with the specific requirement that "Consideration shall be given to the adoption of an appropriate 'low damage' seismic design philosophy in the design of the building structure. This is aimed at reducing the potential for primary structural damage under a seismic event, therefore minimising rectification costs and disruption to the use of the facility."

A visual tool was put together in the initial stages of the design to assist in the early discussions with client regarding the structural design of the lateral load resisting system. The tool consists of a table comparing various potential structural systems to be adopted for the building (Fig. 5). For each structural system the table presents various advantages and disadvantages and an overall judgement (in the form of a smiley/neutral/sad face) with respect to 'Structural Performance' and 'Disruption Avoidance'.

These discussions led to the design approach adopted to meet the "low-damage" design aspiration. This includes:

- The use of Buckling Restrained Braced Frames (BRB)s which can be selectively repaired and replaced in the event the BRBs have been subjected to significant cumulative ductility demand during an earthquake.
- A Capacity Design approach adopted to protect key structural elements to ensure these elements remain elastic (not damaged) in the design level earthquake.
- The primary and secondary trusses that form moment-resisting frames designed to either remain elastic or be able to sustain the ductility demand at the potential plastic hinge zone of the cruciform columns. This also provides some degree of self-centering capacity to the overall system.
- The use of performance-based seismic design and a direct-displacement-based (DDB) design approach, allowing a more explicit consideration of seismic performance of the building for a range of seismic hazard intensities, and particularly giving more explicit way to design to limit inter-storey drift demands.

C. Lateral Load Resisting Systems Options

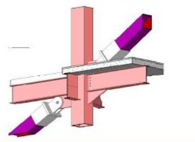
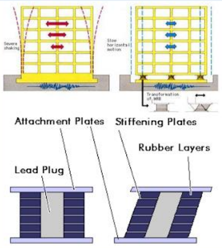
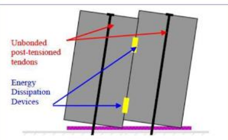
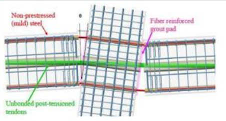
Structural System	Overview	Images	Advantages	Disadvantages	Structural Performance	Disruption Avoidance
Buckling Restrained Braced Frames (BRBF) **(Low Damage)**	▪ Proprietary braced member purchased to order. ▪ Able to dissipate large amounts of seismic energy by yielding in compression and tension without damage. ▪ Inner slender, steel load-carrying core encased in grout. Outer steel tube restrains the steel core against buckling.		▪ Damage in a seismic event to the structural frame is concentrated in the BRB element (effectively acts like a "fuse"). The BRB element can if necessary be replaced after a seismic event. ▪ Relatively smaller steel column and beam sizes. ▪ Fast to construct. ▪ Lower response of the structure due additional effective damping.	▪ BRBs are manufactured overseas. ▪ BRBFs are currently not formally recognised by the NZ Building Code. ▪ BRBFs not a "self centering" system.	 RECOMMENDED	 RECOMMENDED
Base Isolation	▪ Isolation allows the ground to move under the building – minimises transmission of shaking to the building. ▪ Suitable for reinforced concrete or structural steel structures. ▪ More than 1000 isolated buildings worldwide, approximately 20 in NZ. ▪ Lead Rubber Bearing (LRB) system invented and pioneered in NZ. ▪ Concave slider bearings are also widely used.	 	▪ Minimises accelerations to the building, contents and secondary items – thus minimising damage. ▪ Proven technology used worldwide, particularly in post disaster facilities. ▪ Provides the best level of damage control to structure, contents and operational continuity. ▪ Base isolation a self-centring system. ▪ Minimal disruption and unlikely to need any repair even after large earthquake.	▪ A cost premium can be associated with the requirement for flexible connections, hanging lifts/stairs etc. ▪ Allowance needs to be made for independent movement between the basement and superstructure. ▪ The building needs to be set back from the property boundary to allow the building to translate without crossing the boundary. ▪ Alternative Solution Building Code compliance. ▪ ▪		
PRESSS Shear Walls **(Low Damage)**	▪ PREcast Seismic Structural System (PRESSS) incorporates precast concrete walls, vertical post-tensioned cables and energy dissipation devices. ▪ External energy dissipaters (mild steel bars or similar) absorb the energy of the earthquake while protecting the other structural elements. ▪ 'self-centring' following an earthquake with minimal residual deformations.	 	▪ The 'damage avoidance' system leads to minimal close down times and repair following a moderate earthquake. ▪ Some damage to fitout in occasional or larger EQ. ▪ Simple to replace energy dissipaters which may be damaged in a large earthquake. ▪ Self centering capability following a large earthquake.	▪ Energy dissipaters may be visible. ▪ New technology - only 10 to 20 PRESSS buildings worldwide. ▪ Some localised damage to structure in large earthquake. ▪ Can be limiting to the architectural layout. ▪ Non-structural elements need to be detailed for large displacements.		
PRESSS Frame **(Low Damage)**	▪ PREcast Seismic Structural System (PRESSS) prefabricated elements, post tensioned cables & energy dissipation devices. ▪ External energy dissipaters (mild steel bars or similar) absorb energy while protecting the other structural elements. ▪ Post-tensioned cables help 'self-centre' structure following an earthquake. ▪ Concrete, steel or timber	 	▪ The 'damage avoidance' system reduces close down times and structural repair following a large earthquake. ▪ Simple to replace external energy dissipaters. ▪ Self centering capability following a large earthquake.	▪ Two way PRESSS frame building has not been constructed before. ▪ Energy dissipaters may be visible. ▪ New technology – only 10 to 20 PRESSS buildings worldwide. ▪ Some localised damage to structure in large earthquake. ▪ Non-structural elements need to be detailed for large displacements, at a cost premium.		

Figure 5. Selected portion of the visual tool providing comparisons of various structural systems

4.4 Joint Food Science, Palmerston North

The proposed Joint Food Science Facility (JFSF) will be a multi-storey development located on the Massey University campus in Palmerston North. When completed it will be New Zealand's largest agri-food related research and innovation centre and represents a significant collaboration for the project partners: Massey University, AgResearch, and the Riddet Institute.

The original structural brief for the project specifically called for a 'conventional structure' due to budgetary considerations. However, there was an aspiration to investigate options to increase the resilience of the building if possible within the cost plan. We believed that, through good design, we would be able to achieve superior outcomes in areas of particular importance at minimal additional cost. Our concept was to achieve this through a "targeted design" approach, where aspects of particular importance to the client were identified and the overall solution is focused around these objectives.

During our initial discussions with the client, the correct Importance Level to apply to the building became key to defining the structural design. The client's understanding of importance level implied that increasing the level of importance of the building would increase level of shaking at which damage occurred. We provided explanation around damage occurrence in relation to importance level. Key to this was an understanding that although an IL3 building would have 30% more capacity for an associated uplift in cost, it would not have a comparable beneficial effect on the business continuity resilience of the facility. As a compromise, we recommended that the Serviceability Limit State (SLS) be increased. Through good detailing of movement joints and other critical details, we aimed to double the SLS design criteria. This could be achieved for a relatively modest increase in capital spend, but would make a marked difference to business continuity in relatively moderate earthquake events.

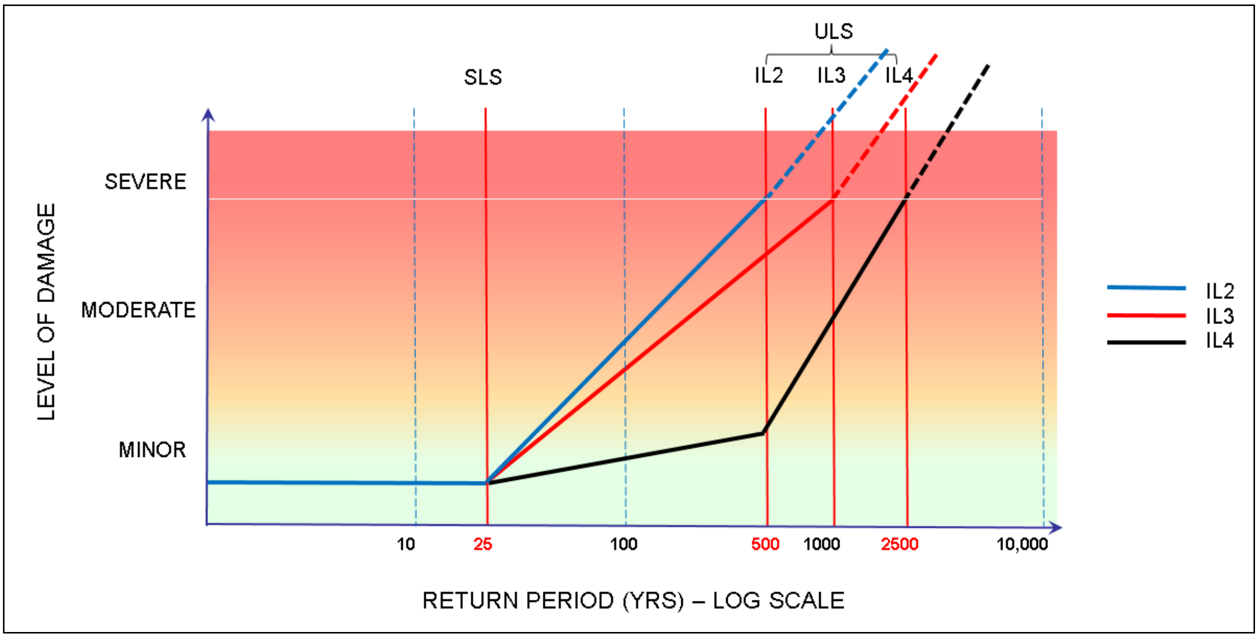


Figure 6. Visual Representation of expected damage levels for different return periods

Although a specific low damage design was not adopted for the project, the discussions with the client around Importance Level and the serviceability limit state design were vital in ensuring that the client understood the likely performance of the finished building and achieved as resilient a facility as possible within a tight budget.

4.5 **The Ballet Building, Wellington**

The Ballet Building, located on Courtney Place, is part of the heritage listed St James Theatre Complex and whilst the majority of the building has been rebuilt, the front facade, along Courtney Place, is a heritage listed asset and forms part of the Wellington cultural fabric. Currently listed as earthquake prone, Wellington City Council intends to bring the building's seismic performance above 67*%NBS*.

The effects of the Christchurch earthquake in 2011 on heritage buildings were considerable. Over 150 heritage listed buildings suffered significant damage causing either collapse, or the requirement for post earthquake demolition. The concept of low damage design as an option for the seismic retrofit of heritage buildings is therefore an attractive one for key stakeholders. However, the inevitable question of building performance needs to be addressed as part of the concept development. Whilst the majority of seismic strengthening targets a life safety level of performance, when strengthening heritage buildings, there is an underlying aspiration to protect the heritage fabric.

The Ballet Building's performance is limited by the capacity of the floor diaphragms due to limited lateral load resisting structure in the transverse direction. As a result, a structural concept was developed to introduce new bracing frames to the front and rear facade to restrain the diaphragms. This initial concept included BRB frames to the first two levels on both facades.

As the concept was developed further, issues around retention of heritage were discussed internally within Beca, with the client and with Heritage New Zealand. During these discussions, the opportunity to use viscous dampers in place of the BRB frames was proposed for investigation. There are a number of advantages using a low damage, viscous damper solution, which were presented to the client during initial discussions. These include:

- Controlled drift limits.
- Reduction in base shear demands.
- Reduction in overall cost of retrofit due to reduced accelerations and demand throughout the

building.

- The ability to control the drift leads to the ability to tune the building movement. This can mean a more easily repaired and reused building post event.
- The use of the dampers enabled an overstrength foundation system to be implemented, limiting damage to the superstructure.

In order to determine the benefits to the project, without risking abortive work, we proposed a staged study to assess the benefits of using the dampers with minimal additional cost to the client. Our methodology included the following stages.

Stage 1 - Limited Feasibility Study - An initial study, primarily using some high level hand analysis was used to investigate the feasibility and potential benefits of the damper system. The results of this were discussed with the client with a recommendation on the next steps.

Stage 2 - Full Feasibility Study - The next stage, to reduce the uncertainty in the modelling, involved spreadsheet analysis to further define the solution and estimate the reductions in the overall demand through use of the dampers.

Stage 3 - Concept/Preliminary Development - Finally, 2D simplified ETABS modelling was undertaken to confirm the likely base shear and acceleration reduction. This was then fed into the preliminary design to redefine the scope of the seismic retrofit required.

On completion of the concept/preliminary design stage, we undertook a cost comparison to determine the economic benefits of the dampers vs the BRB system. This indicated a saving of around 20% on the capital works for the retrofit project through reduction in scope. This was in addition to associated programme benefits.

However, it is important to note that despite the use of a so called ‘Low Damage solutions’, there is still the likelihood of damage occurring. The dampers require movement in order to generate the increased damping. This can lead to frame cracking and the risk of pounding related damage. Whilst not significant damage concerns, these aspects still required communication to the client and heritage stakeholders, along with proposed mitigation solutions.

The economic benefits, in addition to the ability to better control the damage throughout the building, led to the damper solution being adopted. The staged approach taken to proving the damper solution provided the client with a low risk opportunity to investigate innovative solutions without having to invest significant amounts of design effort until the benefits could be quantified.

5 CONCLUSION

There are a number of international (and some local) systems intended to capture the resilience or damage control aspects of a project. All of these, in various ways, try to distill the complexity of an engineering evaluation down a much simpler system (generally a star rating) for a client, tenant, or the general public.

Each of these systems also suffers from two particular challenges - the sometimes very significant effort to achieve such a distillation, and the current lack of market drivers to encourage adoption of those systems.

These systems also generally do not cover the essential concept phase collateral than can help a client decide the extent of damage control that they may want to adopt. A series of such concept phase discussions has been set out here with the intention of highlighting some of sorts of information that we consider clients are most looking for.

The authors would encourage the writers of the New Zealand Low Damage Design Guide to focus at least as much effort of the client-side discussions as may be given to the technical discussion, and in particular to assist with a framework for discussion that can be applied at concept stage.

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