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Challenging Current Design Standards – Seismic Design in Australia

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Abstract

Australia is generally accepted as being a region of low seismicity and low risk, though with a potential for high consequence, with associated design practise and standards tailored to suit. Australia's earthquake loading's standard AS 1170.4 and material standards AS 3600 and AS 4100 have been updated over recent years with amendments in relation to seismic design. These standards follow a typically prescriptive and 'deemed to comply' approach, with simplifications oriented around this low level of seismicity. This approach is perhaps generally appropriate in lieu of the much more detailed international standards adopted in areas of high seismicity such as New Zealand and parts of the United States.

The engineering profession is in a challenging time as design and construction methods continue to evolve. Clients are technically more aware with increased focus on sustainability, re-purposing and retaining existing assets, whole of life and building behaviour.

This paper discusses aspects of current prescriptive design standards and their applicability to design, and how improved education and knowledge of underlying principles could aid structural engineers in obtaining an increased appreciation for building behaviour. This would assist with understanding what happens should a rare large earthquake occur 'the big one', the shift towards performance-based design and changing technologies, and when assessing existing buildings.

This paper also discusses the need for guidance on assessment of existing structures for earthquake loading, and assisting clients with understanding associated risks. Commentary is included in application of the principles of New Zealand assessment guidelines, amended as necessary to suit Australian requirements to recent projects in Australia.

This paper presents the experiences and insights of practising engineers, on current seismic design standards in Australia as applied to both new structures and assessment of existing.

Keywords: earthquake loading, engineering principles, building behaviour, assessment, education.

1 Introduction

We 'accept' a road toll of ~1200 deaths over an average 12-month period. But what would society say if a catastrophic earthquake occurred in one of our heavily populated capital cities, or elsewhere in Australia, resulting in significant loss of life and damage to buildings and infrastructure?

Societal expectations are typically that structural engineers design buildings and infrastructure which are safe and able to withstand design loads including from earthquake events. This includes **new** structural design and, without knowing otherwise, **existing** structures to be 'just as good' effectively meeting modern design standards.

Australia is a wholly intraplate seismic region and although generally accepted as having low seismicity it can experience quite large earthquakes. These large earthquakes happen much less frequently than fault induced earthquakes (like those of our neighbours New Zealand, Papua New Guinea and Indonesia). Earthquakes above magnitude 5.0, such as the destructive 1989 Newcastle earthquake, occur on average every one-to-two years, and about every ten years Australia experiences an earthquake of magnitude 6.0 or more.

In recent times internationally, Turkiye-Syria, Japan, New Zealand, Afghanistan and Haiti have had significant earthquakes, and locally in the past two years Australia has experienced Woods Point (M5.9), Otway Rangers (M4.7) Sunbury (~M4.0) and others. Woods Point occurred on an **unknown** fault, Sunbury is also thought to have occurred on an unknown fault line. While the underlying seismic hazard likely hasn't changed, from a designer's perspective this increased knowledge has had consequences, prompting seismic assessments and also informing reviews to the 2018 National Seismic Hazard Model (prepared by Geoscience Australia). Due to a limited history of earthquake records, there is some uncertainty with our seismic hazard design factor and a (albeit low) risk remains of a large earthquake occurring.

In addition to projects associated with recent events, the authors have been involved in seismic assessments for projects ranging from relatively small modifications through to assessment of significant infrastructure structures. This has comprised high-level qualitative assessment through to numerical or quantitative assessment.

Engineers, clients and the public are becoming more cognisant and knowledgeable in relation to earthquakes. "Australia doesn't get earthquakes? What are the risks to our structures?".

Australia's earthquake loading's standard AS 1170.4 *Earthquake actions in Australia* and material standards *AS 3600 Concrete structures* and *AS 4100 Steel structures* have been updated over recent years reflecting latest local knowledge along with that internationally as applicable to Australia. These standards are largely prescriptive in nature, generally aligning with Australia's low seismicity.

This paper discusses the following:

- Seismic engineering principles. How well are these understood and transparent in our profession? What about uncertainty and the risk of a 'big one'?
- Aspects of Australia's standards when designing new structures. What is their role, what should the profession be doing to improve knowledge of structural engineers?
- Seismic assessment of existing structures, with a shift towards appreciation of actual building behaviour and performance-based design.
- Encouragement of structural engineers to think beyond linear elastic software analyses.

2 The basics of structural engineering in an Australian seismic context

A detailed in-depth knowledge of earthquake engineering is perhaps not considered necessary in Australia, and a good understanding and appropriate application of **basic engineering principles** may be sufficient for most design activities.

Structural engineers' typical design fundamentals comprise having design actions (demands) derived using loadings standards and resistances (capacities) from material standards. We ensure capacities are greater than demands which is generally black and white. We have traditionally happily based this on what is prescribed in standards which fall under the NCC/BCA, and place increasing reliance on software to do the design for us.

NCC/BCA and individual States prescribe minimum requirements for the important 'demand' side telling us what minimum loads to design for including earthquake loads, snow and wind, alongside live loads.

When it comes to assessing existing structures, it can be less black and white and a greater understanding of **building behaviour** under earthquake loading becomes more important. **This is much more interesting** and provides structural engineers an opportunity to free themselves from prescriptive standards and their clauses, and think about the physical reality of structural systems and what happens when they are subject to earthquake loading or '**pushed**' horizontally. Understanding basic engineering principles in relation to load paths and seismic hierarchy and being able to think past linear elastic behaviour is a prerequisite for seismic assessment, performance-based design - and for design in general.

AS 1170.4, AS 4100 and AS 3600 (and other loading and material standards) are all fairly prescriptive. When designing for earthquake loads engineers typically select ductility and Structural Performance factors from material standards (or AS 1170.4) depending on their selected structural system and **anticipated** level of detailing and **inferred** inelastic behaviour. How well are these understood and considered when undertaking design?

2.1 Some key principles in seismic design

Widely acknowledged key principles of seismic design include:

- Clear and simple load paths
- Regularity and symmetry of structure
- Consideration of seismic 'strength hierarchy' – strength and ductility
- The three 'Rs' of resilience, redundancy and robustness

The first two are relatively self-explanatory to structural engineers, the last perhaps an output of the former. Regularity of structures is 'nice to have' but occasionally out of engineer's control.

Seismic strength hierarchy, or 'capacity design', is a concept developed in New Zealand in the 1960s and 1970s by John Hollings and Tom Paulay, and now used worldwide. In simplest terms, using Professor Paulay's words 'tell the structure what to do'. Ductile mechanisms are identified and detailed accordingly, with brittle failure largely suppressed.

Consideration of seismic strength hierarchy is relevant in both new design and assessment of existing structures. As outlined previously, while Australia is generally considered an area of low seismicity, the risks of large earthquake events is real and the consequences potentially significant. Due to the uncertainty with prediction of earthquakes, it is inherent in modern design that structures should be able to withstand larger events than those nominally designed for. This is perhaps described more directly in international standards than in Australia. This is discussed in the supplement to NZS 1170.5 *Earthquake actions – New Zealand* in relation to designing for a nominal **500-year return** period event (ULS = Life Safety) there is considerable margin against collapse, and if the same structure is subject to say a Maximum Credible Earthquake of **2500-year return period** a small margin against collapse is maintained. This aspect is less quantified in Australian standards, with the commentary to AS 1170.4 simply acknowledging a 'reasonable' margin against collapse for ULS.

Having a good understanding of these principles helps in more traditional design and will also assist with designing for new construction materials, when considering alternative construction technologies and in performance-based design. The authors consider there is an opportunity for the Australian engineering profession to embrace and enhance its understanding of seismic principles inherent, or intended, in design standards. 'Deemed to satisfy' prescriptive provisions, including nomination of ductility and Structural Performance factors, are considered to have limitations and perhaps should not be taken too literally. We encourage engineers to improve their knowledge of building behaviour, and the profession to provide its support.

3 The role of Australian standards in seismic design

Figure 1 summarises the prescriptive nature of Australian standards in design of a structure.

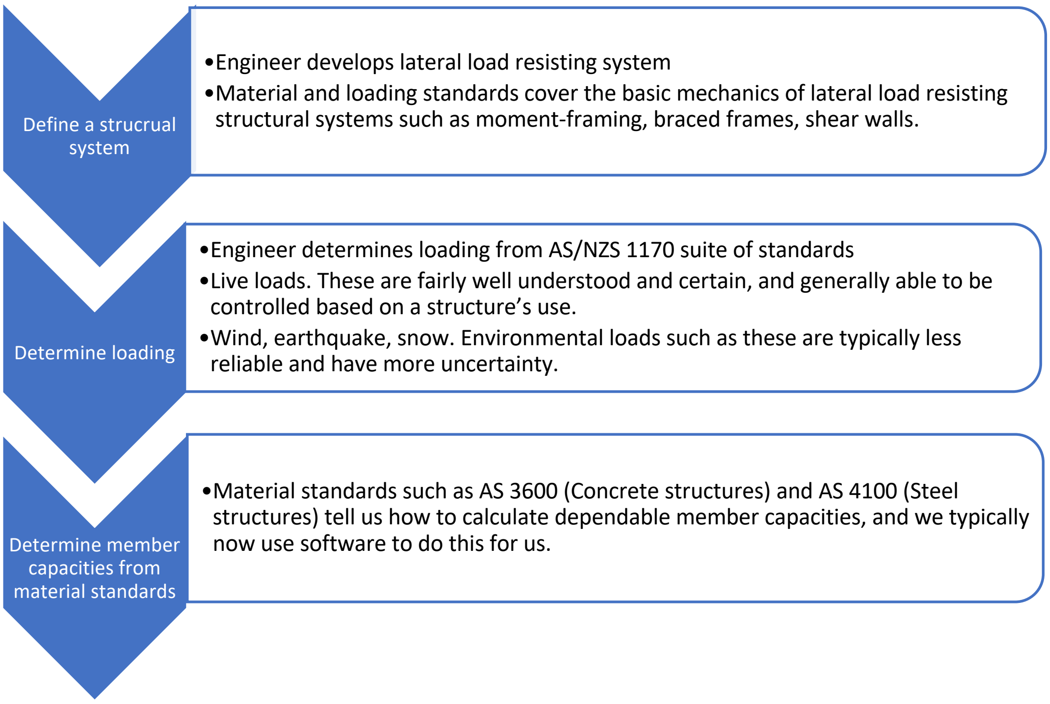

Figure 1 – Prescriptive nature of Australian standards in seismic design

The 2021 commentary to AS 1170.4 is an excellent document covering a range of topics and background to the design of structures for earthquake engineering in Australia. It includes a section on basic principles and an entire section dedicated to capacity design. The authors recommend structural engineers read this document.

The authors offer observations in relation to some aspects of current Australian loading and material standards. These have often come up during the design process resulting in reverting back to **basic principles** and consideration of **strength hierarchy**. This is where the authors consider adequate education and improved knowledge are beneficial, which may then inform structural engineer's appreciation of building behaviour and strength hierarchy, and when undertaking seismic assessments of existing structures. While some aspects of these are perhaps a result of low seismicity and low drift demands for the majority of Australia, and reflecting a level of design and detailing commensurate with low seismicity, improved awareness would be beneficial. These observations primarily relate to seismic hierarchy and building behaviour – 'pushing' the structure. We acknowledge it may not always be possible to design ductile systems due to the low seismicity and potential dominance of gravity loads and/or wind.

An overarching question then is, what is the role of design standards to 'upskill' engineers? An appropriate balance appears necessary between what is contained within 'design standards' and the knowledge an engineer gains elsewhere. The profession could consider mandating advanced earthquake engineering courses during university education. This may lead to graduates and engineers entering the profession having a more in-depth knowledge of seismic design principles and building behaviour. Further focus on training and informative guidance notes would also assist practising engineers. Design standards certainly have a role, they are generally cited by the NCC/BCA after all, and we consider there is a need to ensure they are suitably clear and concise.

3.1 AS 1170.4 General topics

AS 1170.4 was reconfirmed in 2018 and we understand is currently undergoing further revision. Comments have been made by our respective organisations' structural (and geotechnical) engineers in relation to AS 1170.4, of which the 2021 commentary has provided some clearer guidance.

- Australia's low seismicity means buildings designed to AS 1170.4 may only have a **few lateral load resisting elements** resulting in structural systems with low redundancy and resilience.
- The commentary discusses Ultimate Limit State performance and having a reasonable margin against collapse. It also addresses the known issue of low seismicity regions having a greater risk of collapse during a rare larger earthquake compared to high seismicity regions. This is evident in NSHA 2018, where for example, some capital cities have probability factors, 'kp' much greater than 1.8. These are perhaps balanced by nomination of a minimum design hazard factor 'Z' of 0.08 for simplicity. When it comes to understanding building behaviour and opportunities to go outside prescriptive design methods, including for assessment purposes, it would be useful to improve clarity on underlying performance 'targets' for Life Safety and Collapse Prevention.
- For the design of diaphragms, AS 1170.4 notes inertia forces in lower floors of multi-storey buildings are to incorporate higher mode effects. International design practise for diaphragm design is quite different to what is prescribed in AS 1170.4. Perhaps this is appropriate enough for Australia, but a useful reference for diaphragm design is NZS 1170.5 and pESA (pseudo-equivalent static analysis) which provides a minimum design requirement for lower floors (peak ground acceleration).
- Design of transfer structures, discontinuous core/shear wall structure. Transfer structures are typically not discussed in any detail but would be expected to follow seismic hierarchy principles.
- Commentary on how foundations should be designed in relation to strength hierarchy would be useful. AS 3600 has a sentence about this for shear walls but otherwise standards are relatively silent. This relates back to enabling engineers to develop a more holistic 'big picture' of strength hierarchy and building behaviour.
- A 1.5 factor (Clause 6.5 of AS 1170.4) is applied to design spectrum when using a displacement-based approach. The commentary provides some reasons for this factor including allowances for uncertainties. The commentary also indicates the capacity curve is to be determined using mean material strengths (in lieu of characteristic strengths). Some clarity around allowance for the rare, larger earthquake events and how this section relates to achieving reliability and appropriate margins would help engineers understand this design approach.

3.2 AS 4100 Steel structures

AS 4100 was revised in 2020 but doesn't appear to be significantly different to its previous revision in relation to earthquake design. A couple of clauses in AS 4100 are raised in the context of this paper and the extent standards convey underlying principles of seismic design (maintaining a strength hierarchy) and the importance of understanding building behaviour. An updated commentary to AS 4100 with a similarly aligned level of detail in relation to designing for earthquake loads as is available for AS 3600 would likely clarify these.

- Clause 13.3.5, limited ductile ($\mu = 2$) structures, states connections for bracing members expected to yield are to be designed for the full member capacity, and also states there are no additional requirements for moment framing. This may be due to the generally modest displacement demands in Australia at the design level (ULS), though we consider it should be appropriately applied to avoid an undesirable mechanism forming, and if loads are larger. Both types of structures can be checked relatively easily for elastic $\mu = 1.0$ levels of load using analysis and design software. For braced frames (including moderately ductile $\mu = 3$ to Clause 13.3.6.2 which also primarily only addresses connections) this would enable engineers to satisfy themselves collector struts and columns remain elastic and premature failure of those key elements is suppressed, though we note this could still result in an undesirable strength hierarchy. A similar exercise can be undertaken for moment framing structures which enables engineers to understand where weak 'links' are. Are these clauses consistent with the commentary to AS 1170.4's discussion on capacity design?

- It is generally assumed tension/compression bracing falls within concentric bracing clauses of the standards. This may also fall out due to low displacement demands but in mixed bracing systems compression braces designed for □ = 2 or even □ = 3 would likely reach their compression buckling limit before their tensile capacity. Under reverse cycle loading, this would appear to increase the risk of column overload.

How diligently is a strength hierarchy achieved followed through in design when considering the above example prescriptive clauses?

3.3 AS 3600 Concrete structures

The 2018 revision to AS 3600 included significant upgrades in design for earthquake loading and it also has a detailed commentary.

On a recent project, a generally non-preferable column sway mechanism was not able to be pragmatically suppressed due to dominant gravity loading actions. Reinforcement was generally adequate for □ = 1.0 elastic earthquake loadings and the provision of additional transverse/shear reinforcement in potential column plastic hinge zones was minor. A non-linear force-displacement pushover was then carried out, including pushing to 1.5 times a factored up **2500-year** spectrum. Subject perhaps to interpretation, an engineer using AS 3600 would not have had to consider this level of design detail. Does this meet the intent of collapse margins and risk of overload? Refer earlier comments in relation to ULS, Life Safety and Collapse Prevention.

As part of the 2018 revision, capacity design and detailing requirements were introduced. There remain some gaps or clauses open to interpretation where engineers can adopt □ and S_p values without understanding the actual failure mechanism.

4 Seismic assessment of existing buildings

4.1 Why and when

Currently, seismic assessment of an existing building may only become necessary or mandatory if triggered as part of upgrading, alterations, change of structure or change of occupancy or use. We note building surveyors may also have an opinion when assessment is required.

Seismic assessments are also becoming increasingly relevant in whole of life considerations, our era of **sustainability** and responsible urban development, combined with basic **risk awareness**.

Seismic assessments inform clients, building owners, and other stakeholders about their building's vulnerabilities. These assessments may be for strength, serviceability, ability to recover rapidly following an event, risk management, social responsibility, commercial considerations or other reasons. This is arising from clients' growing interest in sustainability, re-purposing and retaining existing assets, 'old' buildings not designed for earthquakes, implications on building use and operations, along with meeting societal expectations and social responsibility. Perhaps earthquakes of recent years are also influencing this.

Seismic assessments, for whatever the reason, provide insights into building vulnerabilities, enabling informed decision-making and risk management.

4.2 Recent examples

A range of seismic assessments have been undertaken by Beca and Arup for various purposes including:

- 'Detailed' seismic assessments to understand vulnerabilities and risk. This included numerical assessment of details and vulnerabilities, and percentage comparisons against AS 1170.4 loading demands.
- High-level qualitative assessments for international investors wishing to understand their potential exposure as part of due diligence.
- 'Initial' seismic assessments involving identifying lateral load resisting systems, studying detailing and reviewing potential building behaviour and brittle mechanisms.
- Heritage projects for building certification – modification of existing heritage structures where parts of the structures that served post-disaster functions were strengthened to 100% of current AS 1170.4 earthquake loads. The remaining structures were strengthened to achieve 34% of current AS 1170.4 requirements (for Importance Level 3), adopting a performance-based solution an approach advised to the client and accepted by the building surveyor.
- As a result of modifications to existing structures and increased loading.

4.3 The need for guidance

As the NCC/BCA is primarily focussed on 'new' buildings, there is little guidance on assessment of existing buildings in Australia. AS 3826-1998 *Strengthening Existing Buildings for Earthquake* which provided guidance on assessment and strengthening existing buildings was withdrawn in 2019.

A review of current Australian loading and material standards provides the following information:

- AS 1170.4 does not contain any clauses.
- Appendix B in the AS 1170.4 commentary suggests using New Zealand's guidelines for assessment of existing buildings. Appendix B also provides some guidance on risk appetite and suggested levels of compliance with AS 1170.4 demands.
- AS 3600, Clause 1.3 states 'The general principles of this Standard shall be applied when evaluating the strength or serviceability of an existing structure'. It acknowledges the potential for non-conformance to current standards.
- AS 4100, Clause 1.5.2 has similar wording to AS 3600 and also states to use 'actual material properties' and includes references to AS 5100.7 *Bridge design Part 7: Bridge assessment* and AS 5104 *General principles on reliability for structures*.
- AS 5100.7 is dedicated to assessment of existing bridge structures.

Some Australian States have basic documents regarding assessment though these appear to be more qualitative than quantitative. The Government of South Australia's 'Ministerial Building Standard MBS 001 Upgrading health and safety in existing buildings' includes useful flow charts and qualitative assessment or consideration of building vulnerabilities.

Other than AS 1170.4, the remaining standards listed are perhaps more relevant for non-earthquake assessment of existing structures. As the risks are different for seismic assessment, use of AS 3600 and AS 4100 clauses would likely result in conservative findings.

4.4 Building behaviour, not compliance

Seismic assessment generally allows for relaxation of some requirements that would apply to new building design – inherent conservatisms in new building design are inappropriate when assessing existing buildings. As outlined in Section 2, new building design is fundamentally based around a predetermined outcome using generally prescribed inputs, while assessment focusses more on building 'behaviour' under lateral loading. This is distinct from 'compliance' and whether a building notionally has sufficient 'strength' to resist AS 1170.4 prescribed lateral loads and is detailed in accordance with current material standards. Many older buildings in

Australia were not required to be designed for earthquake loading at the time of their construction, and the materials and detailing adopted may not meet the requirements of modern **material** standards – but this doesn't necessarily mean they are immediately of risk.

When assessing existing structures, a greater understanding of building behaviour under earthquake loading is necessary. Understanding load paths and seismic hierarchy, including ductile and brittle mechanisms, and being able to think beyond linear elastic response, are important for seismic assessment where more realistic estimations of building behaviour are increasingly relevant. Penalising a building due to its 'non-compliant' deficiencies without assessing what they mean is too simplistic an approach.

Seismic assessments are typically undertaken by engineers experienced with how buildings respond to earthquake loading and includes the need to be able to use engineering judgement, as the black and white aspects of new building design become less applicable. A 'big picture' understanding is required including the ability to think beyond the first point of 'failure' and in a non-linear fashion. As raised earlier, is this the role of prescriptive design standards or more a need for increased education and knowledge development within the profession?

Equally important, or perhaps more so, is then being able to articulate to clients, building surveyors, community and stakeholders what the assessment findings mean in lay-persons terms such that informed decisions can be made.

4.5 Application of New Zealand assessment guidelines to Australia

New Zealand has had formal guidelines for seismic assessment of existing buildings for many years. The latest revisions are known as '*The Seismic Assessment of Existing Buildings: Technical Guidelines for Engineering Assessments (the Guidelines)*'. This suite of documents includes detailed procedures for the seismic assessment of existing buildings and is specifically referenced by the updated commentary to AS 1170.4.

Recent seismic assessments for clients in Australia have been undertaken generally following the New Zealand Guidelines and amended as necessary to incorporate requirements from applicable Australian Standards. Earthquake loading has been determined based on the requirements of AS 1170.4.

Key features of New Zealand guidelines, and means of application to Australia, include:

- The fundamental objective of seismic assessments is to understand structural load paths and likely behaviour of a building during earthquake shaking. This includes identifying a building's failure hierarchy and evaluating the capacities of details, elements and systems in the critical mechanism.
- Use of 'probable' capacities when determining strength and deformation of a member, an element, a structure as a whole or founding soils. Structurally, capacities are determined using 'mean' material strengths (or from sampling and testing) and adopting a capacity/strength reduction factor of 1.0. The use of capacity reduction factors of 1.0 differs from, for example, AS 3600 prescribed factors of 0.6-0.85 for flexure and 0.7-0.75 for shear.
- A design earthquake in accordance with AS/NZS 1170.0 and NCC/BCA for the applicable importance level and design life (e.g., IL2 50-year design earthquake with return period of 500 years for ULS).
- Ultimate Limit State – Life Safety. The Guidelines primarily focus assessment on life safety which is consistent with AS 1170.4 and use of Ultimate Limit State design and the 500-year return period event noted above. While there is no need to consider explicitly performance beyond the prescribed 500-year return period event in new building design, seismic assessment typically considers this in a qualitative manner.
- The output from a detailed seismic assessment is typically presented as a rating as a percentage of New Building Standard '%NBS' along with commentary around the building's assessed behaviour.

Seismic assessment is interesting in that it can be considered more as 'real engineering' and understanding how a building acts under earthquake loading. Engineers can gain a greater insight into building behaviour across a range of loading scenarios (along with consideration of %NBS ratings) which can then inform subsequent activities with clients and stakeholders.

4.6 Conveying assessment findings and risk

'That's great, what does it all mean? We don't have earthquakes in Australia!'.

A key part of seismic assessment is the ability to convey risks to the community, clients and stakeholders, such that informed decisions can be made. Structural engineers are by profession technical people, and there is a skill to conveying technical matters to non-technical people without resulting in head scratching.

Some relevant aspects in relation to assessment findings, what they mean and how they can be communicated are:

- Seismic assessments are useful for identifying vulnerabilities which can then inform retrofit and improvement. They are less definitive in determining '**failure**' of a building.
- The '%NBS' metric is an assessment of **relative** seismic risk, comparing an existing building to a compliant New Building (e.g. to AS 1170.4 and the NCC/BCA) – refer Figure 2. It is not a predictor of building failure in any particular earthquake.

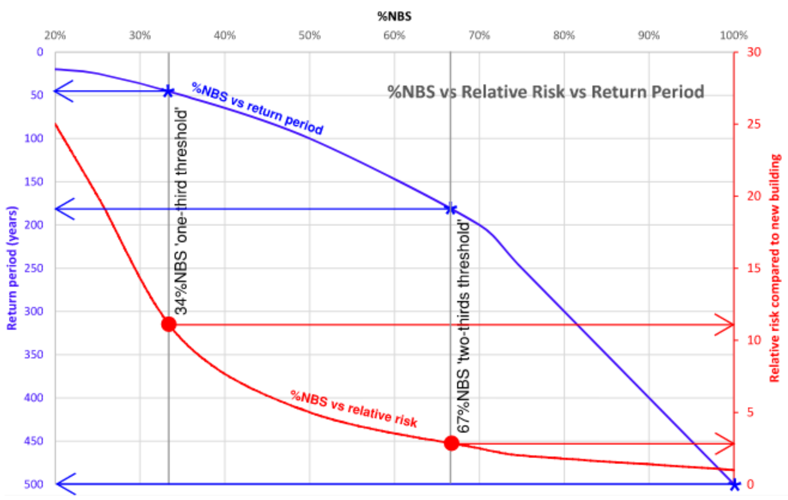

Figure 2 – % New building standard, relative risk to new building and indicative return period

- A low %NBS rating can serve as a trigger for planning and implementing a seismic upgrade to address identified vulnerabilities and mitigate seismic risk.
- Seismic risk can never be eliminated and needs to be **managed**.
- There is no precise means of predicting a specific 'site' response (ground shaking) or how a building will behave or respond to ground shaking. Uncertainties exist for both 'demands' (earthquake shaking) and building 'strengths' or capacities. Seismic assessment represents 'a range of scenarios'.
- Comparisons can be made to more common everyday risks such as motor accidents, falls at homes, work related fatalities. The risk of death due to earthquakes is generally considered low compared to other causes of death, however, the exposure can be high (number of fatalities possible in a single event). The authors' experience is not all clients find this a useful comparison. Perhaps back-calculating an equivalent return period and annual probability of exceedance is more useful – refer Figure 2.
- What is an acceptable level of risk? Appendix B (informative only) in AS 1170.4's commentary provides some guidance in relation to %NBS values and residual building design life. Ultimately this would likely come down to a Client's risk appetite, commercial decisions, and perhaps the building surveyor.

4.7 Challenges

Potential challenges with seismic assessment of existing buildings in Australia include:

- What triggers the requirement for seismic assessment? Client, stakeholder, NCC/BCA, State regulations, Building surveyor?
- A lack of guidance for seismic assessment itself, plus decision making in relation to subsequent levels of risk.
- Low seismicity and a view ‘Australia is not New Zealand, we don’t get earthquakes’. People may have forgotten Newcastle and other, more recent, events.
- A client or stakeholder’s ‘risk appetite’. While this generally comes back to ‘doing the right thing’, having some basic guidance available would be beneficial.
- Role of NCC/BCA building surveyors in ‘compliance’ to 100%NBS or some other threshold, relative risks, commercial decisions, pragmatic ‘sweet spot’ balancing of risk and retrofit/strengthening cost. Upgrade or retrofit requirements can be dictated by building surveyors which may lead to unnecessary commercial expense. Who should decide – Client or building surveyor?
- Perhaps simply retrofitting/mitigating the risks specific vulnerabilities a building may have instead of targeting a specific %NBS or threshold is adequate.
- Limited experienced earthquake engineers? Education?
- Peer review. Appropriate level of expertise to enable peer review to be undertaken, both at project level plus where necessary from the building surveyor.
- AS 1170.4’s commentary sets an interesting precedent and clients potentially perceive this as a reference that should be complied with – though it is only informative.

5 Concluding remarks

Having a good understanding of engineering principles when undertaking seismic design helps in more traditional new-build design and when undertaking seismic assessment. The authors encourage engineers undertaking earthquake design to understand building behaviour and performance-based design approaches in lieu of the prescriptive nature of design standards.

Design standards generally adopt a prescriptive and ‘deemed to satisfy’ approach. These provisions perhaps should not be taken too literally by engineers.

There is a need for guidance on seismic assessment of existing buildings with clients’ increased focus on sustainability, re-purposing existing assets, and building behaviour and risk awareness. Understanding and conveying risk is an importance aspect of seismic assessment, and also new building design.

Structural engineers should take the opportunity to review and provide comment on standards when drafts are released for public comment.

It may be time to include advanced earthquake engineering courses more widely as part of university studies to assist those entering the engineering profession. The profession could also consider mandating these advanced earthquake engineering courses. This may lead to graduates and engineers entering the profession having a more in-depth knowledge of seismic design principles and building performance. Opportunities to advance in performance-based design seem unlikely to be obtained from prescriptive design standards.

Further focus on training and informative guidance notes would also assist practising engineers. This requires engineers to participate when provided the opportunity.

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