EBSS

Evidence Based Seismic Strengthening

Don’t mention the law

Review of the new seismic strengthening regulations and methodology

February 2017

Contents

About EBSS

EBSS is a society established to:

- Improve the quality of the debate on seismic strengthening policies
- Produce research and discussion documents on seismic strengthening issues
- Lobby central and local governments to implement evidence based seismic strengthening policies
- Take legal action, or assist parties to take action, when there has been a breach of the law
- Provide information to building owners who are unfairly affected by the implementation of seismic strengthening policies
- Provide assistance to building owners who may have received poor advice from engineers on seismic strengthening matters.

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A word on our title

For those who are not familiar with the Faulty Towers TV series, our title is a reference to Basil Fawlty's famous "Don't mention the war". In a cringingly uncomfortable skit, Basil could not stop himself from mentioning the war to his German guests.

As uncomfortable as it might be for MBIE's Chief Executive, David Smol, we will be mentioning that his new Earthquake Prone Building methodology ignores settled law. The Supreme Court[1] has been clear that the earthquake that defines an earthquake prone building, is a moderate earthquake, not any earthquake of an engineer's choosing, as Mr. Smol seems to think.

Our choice of title is perhaps also apposite because the Earthquake Prone Building methodology is something that 'could well' have come out of a Fawlty Towers skit, with the hapless Mr. Gardiner playing Manuel, David Smol as Basil Fawlty, and Rob Jury, Sybil (who really calls the shots).

[1] https://www.courtsofnz.govt.nz/cases/university-of-canterbury-v-the-insurance-council-of-new-zealand-inc/@@images/fileDecision

Part one: Introduction and Overview

"It is difficult to get a man to understand something, when his salary depends on his not understanding it."
Upton Sinclair

The Ministry of Business Information and Employment (MBIE) is currently consulting on the regulations and the earthquake prone building (EPB) identification methodology required under the Building (Earthquake-Prone Building) Act 2016.

The purpose of this document is to set out our view on the most important issues raised in the consultation documents, and in the Engineering Assessment Guidance (EAG) documents that cover the substance of the EPB identification methodology.

The big issues

The big issues are:

- The definition of ultimate capacity, which sets the trigger point for identifying earthquake prone buildings.
- The application of the EPB test through the MBIE Chief Executive's methodology.
- The inadequate assessment of how the new framework will work in practice.
- The cost of the building assessments process.
- The way building seismic risk information is to be conveyed to the public.
- Only a narrow group have contributed to the process.
- Seismic fundamentalism.

Definition of ultimate capacity is acceptable

The definition of ultimate capacity as the point at which a building loses gravity support (i.e. it is close to collapse) is broadly acceptable and lawful.

The law will be flouted

On the second point, it seems clear that there is no intention of applying the ultimate capacity exceedance test in practice. Rather, engineers will go on largely applying the old ultimate limit state based regime, which sets a trigger point of 34%NBS to separate earthquake prone from non-earthquake prone buildings.

This is fundamentally different from the 'exceedance of ultimate capacity' test. All the 34%NBS test means is that a building has failed a compliance test, which is set so it is very unlikely to collapse. It will, however, capture a much larger number of buildings. It also obvious the moderate earthquake test has been completely ignored despite the 2014 Supreme Court decision that found that a moderate earthquake was a hard limit.

Further, engineers have been instructed, in writing, not to use the actual capacity of a building" in their assessments.[2]

The legal test is that buildings will come close to collapse in a moderate earthquake, or will actually collapse. Wellington had a moderate earthquake in November 2016. Of the nearly 700 'earthquake prone' buildings, only two had any structural damages and none collapsed. However, the WCC website claims that EPBs can be **expected** to collapse in a moderate earthquake.

No assessment of how the system will work

There has been no analysis of how the assessment methodologies will work in practice. It is reasonable to expect, with a regime that is likely to cost billions of dollars that the new methodologies would have been tested across sample of building types, and that there would have been blind tests that would check whether practicing engineers could assess buildings consistently.

The term 'Chief Executive's methodology' is something of a misnomer. Other than some high level process guidance the Chief Executive has not developed a methodology as such; rather he has referenced the Engineering Assessment Guidance (EAG) documents, which is a bag lot of analytics, prescriptions, suggestions and philosophy. Depending on the inclination of the user, very different outcomes can be generated.

MBIE has stuck to its 2012 assessment that there are around 20,000 EPBs in New Zealand, but really has no idea how many will be designated. The engineers who are really running this process are on a mission to designate as many buildings as they can, so the number affected could well be much higher than 20,000 and the costs much more than $10 billion. Even taking a cautious view on seismic risks (multiplying by a factor of more than three) the benefits are unlikely to be more than $300 million. MBIE has put the benefits at $24 million.

There are much cheaper options that will address the risks that should be a concern. Wellington and Blenheim are addressing the material risks with unreinforced masonry buildings at an estimated cost of $9 million. An appropriately targeted nationwide programme could deal with the real risks for around $100 million.

[2] Document Part A Version SB 3 June 2016. Draft for Sector Briefings

Cost of the assessment process

While classes of buildings that will not have to be automatically assessed have been identified, the list is too limited. Assessment costs alone could unnecessarily cost more than a billion dollars. Much cheaper options that would be as effective in identifying at risk buildings have been ignored.

Only a narrow group have contributed to the process

The methodology development has been dominated by the large engineering firms. GNS Science's absence is notable and concerning. GNS Science is the centre of risk engineering excellence in New Zealand. There was no input from lawyers and economists and other relevant disciplines. With one possible exception there were no dissenting engineers. There appears to have been no serious effort to obtain independent external validation.

The public is being mislead

Perhaps the most important issue we address is the way risk information will be conveyed to the public through the NZSEE risk grading system. The legislation prescribes how a % NBS is calculated, and that it be publicly reported. The rating does not make much sense as a way to understand seismic risk, but there is not much we can do about that, given that is entrenched in legislation.

The important issue is the NZSEE risk grading framework, which describes buildings as high risk, and very high risk, when the reality is that the great bulk of those building are extremely low risk. Being in an EPB in Auckland could be 4000 times safer than flying, and flying is widely regarded as very low risk.

The NZSEE risk descriptions have the effect of frightening and misinforming building owners and users, and that is their purpose. The only 'defence' of the approach, in the EAG, is a statement that it would be difficult to provide actual risk information. This is an evasion. Risk engineers have been building quantitative risk models for decades and the basic information exists for New Zealand. Conceptually, it is a straightforward matter to produce simple measures of building and life safety risk that can be understood by the public.

The high/very high risk descriptions are not 'protected' by legislation, and we believe their use is an offence under the Fair Trading Act. Engineers are in trade and subject to the Act's provisions. The Act provides that no person shall, in trade, make a false or misleading representation concerning the need for any goods or services, or make unsubstantiated representations.

EBSS will be making a complaint to the Commerce Commission under the Act.

Seismic fundamentalism

We have been struck, after four years of dealing with the seismic strengthening issues, with just how little evidence, logic and analytics seem to matter to the coterie of engineers who are effectively running the seismic strengthening regime.

One might think that evidence that the regime will impose costs that outweighs the benefits by a factor of a 100, or the Christchurch evidence that showed that older reinforced concrete buildings performed extremely well in a very severe earthquake, would have given them reason for pause. But not at all, the latest incarnation of the seismic evaluation framework (the EAG) is if anything an even more virulent in its pursuit of 'bad' buildings than its predecessor.

Our experience has lead us to the realisation that on the big picture issues we are not always dealing with 'rational' professionals, to whom the evidence and arguments matter, and who want policy decisions to emerges from an open and reasoned debate. Rather, what we are dealing with here is a form of fundamentalism, which we call **seismic fundamentalism.** These people know the truth on the right balance between cost and risk, and are the sole source of the truth. The key tenets of seismic fundamentalism are:

- The justification of a seismic strengthening policy is the reduction of losses and the improvement of safety. The extent of any such improvement and its costs are largely irrelevant. It is enough that there will be some improvement.
- Earthquake engineers are above the law. NZSEE 2006 simply ignored the exceedance of ultimate capacity and likely to collapse tests in the law and the EAG similarly ignores the 2014 Supreme Court ruling.
- The balance between of costs and benefits implicit in the methodology is just the right balance. This (lengthy) dictum should not be seriously questioned and does not have to be justified.
- Accentuate the negative, eliminate the positive. Rare instances of failure are talked up. Positive evidence on building performance is often ignored. If your theory and reality clash – reality is wrong.
- Scientific work on the probability of seismic events is to be distrusted, and if possible undermined.
- Seismic risk management is solely an engineering problem and should only be managed by engineers. Engineers know how to make buildings safer, so it naturally follows that they should be left to get on with the job. The laity do not know their own best interests so they have to be shielded against information that might sow doubt.

Seismic fundamentalists are not a readily defined group. It is a mindset and a culture, and at times, there is collusion to promote the cause. The core drivers are in the large engineering firms and if there is a high priest, it is probably Rob Jury of BECA.

The seismic fundamentalists have effectively commandeered the policy development process and have been adept at packaging their message in the post Christchurch environment to secure political support for their program. They also effectively dominate MBIE, although it is not clear how many true believers there are there. Seismic fundamentalists probably also dominant many local authority engineering offices and will be implementing the Act. The Wellington City Council is a seismic fundamentalist hotbed.

Not all engineers are seismic fundamentalists. Many have spoken out against the seismic strengthening regime. Most practitioners, no doubt, are just content to just follow the rules (and have little choice but to, or risk professional censure), without fully understanding what underpins them. If they have doubts, they are content to turn a blind eye. Money is an effective salve.

The seismic fundamentalists' behavior is not just explained by ideology. Engineers respond to incentives like everybody else. And those incentives often push them to very conservative assessments.

- They want to protect their backsides. Our 'some-one must be at fault' mentality and health and safety legislation gives engineers a perception that they will be at risk if a building that is not designated subsequently fails. It is safer to declare it to be earthquake prone.
- They have a two billion dollar plus fee income golden goose. They don't want to give it up. Large businesses are strongly motivated by the economics.
- They have gone too far to turn around now. An admission of past errors might have legal consequences, and naturally no one likes to admit to errors.
- It places local authority bureaucrats in a position of great power. This is seductive to some.

Structure of the document

Part two sets out our key conclusions

Part three provides context to the more technical discussions. It explains how we have arrived at where we are today. We have also explained some of the key developments in the test case as it covers some of the same territory as the consultation document.

Part four discusses the definition of earthquake prone building and explains why the proposed methodology does not give effect to the legal definition. We propose a requirement that we think would increase the likelihood that engineers and local authorities will give effect to the law.

Part five covers the risk rating framework and why we will be making a complaint to the Commerce Commission.

Part six discusses the cost of assessments and the role of the profiling.

Part seven discusses the IEP.

Part eight addresses a number of mostly more technical issues. These include:

- Joint buildings
- Building pounding
- The Reinforced Concrete Building document C5
- The Unreinforced Masonry building document C8
- The timber framed building document C9
- Validation and testing.

Part two: Key conclusions

MBIE has appropriately defined the key term in the definition of earthquake prone building

Ultimate capacity has been defined as the point at which a building has lost gravity support and so is close to collapse. The problem is that the definition has been effectively ignored in the Chief Executives Methodology, which is used to identify earthquake prone buildings.

MBIE has wilfully ignored the Supreme Court

In a landmark decision in 2014 the Supreme Court found that earthquake prone buildings should be assessed against a moderate earthquake. The methodology is riddled with explicit and implicit tests against undefined severe earthquakes.

Engineers have been directed to understate buildings' seismic capacity

In a methodology document provided to engineers they were told that the assessed seismic rating should **never** match the actual capacity of the building. Put bluntly, engineers are being told to rig the results.

Engineers should be required to attest that EPBs meet the legal test

The attestation could read (for an Auckland property): 'I Bill Smith, engineer, attest that the building at xxx will lose gravity support when subject to peak accelerations of 0.043g in a moderate Auckland earthquake'. Councils should make the same attestation before a building is declared to be earthquake prone.

Wellington's 2016 earthquake shows claims about EPB risk grossly overstated

The Council's website states that earthquake prone buildings can be **expected** to collapse in a moderate earthquake. The Wellington quake was moderate, but only two of nearly 700 earthquake prone buildings had structural damage, and none collapsed. If the Council's claim was correct hundreds of buildings should have been badly damaged, or should have collapsed

The NZSEE risk grading framework is grossly misleading

Extremely low risk buildings are being identified as high risk, and very high risk, when there is very strong evidence that they pose extremely low life safety risks. We believe that engineers have breached the Fair Trading Act by making misleading statements about the need for services, and making unsubstantiated statements about earthquake risk. EBSS intends to make a complaint under the Act.

The methodology is a mess

It is full of inconsistencies and vague statements. It is difficult to understand what it means let alone have any confidence in the outcomes. The methodology is open to manipulation that will deliver more EPBs.

There has been no testing of the models

We have no idea of the economic impact because no one knows how the earthquake prone building methodology will work in practice. We have previously put the cost at $10 billion, but it could be considerably higher. There can be little confidence that it will deliver consistent results. The model development process falls well short of minimum testing and validation standards, let alone best practice.

The Initial Evaluation Procedure evaluation should be honestly calibrated and applied

The IEP is much cheaper than a full engineering assessment and is better fit for a mass-screening regime. It has been calibrated so it often generates absurdly low assessments. This should be fixed so it is a real option for building owners who are forced to get an assessment.

Policy development process has been captured by private interests

The large engineering firms that have played the critical role in the development of the Chief Executive's methodology have an obvious conflict of interest that has not been managed by MBIE.

The evidence that reinforced concrete EPBs actually perform very well has been ignored

From a life safety perspective, older reinforced concrete buildings performed as well as modern buildings, in the Christchurch earthquake. This was inline with the performance in other earthquakes. This evidence has been ignored and these building are being assessed even more conservatively.

Simple low cost interventions that will deal with the worse risks have been ignored

The focus has been on a grandiose national assessment programme that will have little impact on life safety. The recent Wellington/Blenheim proposals to address the worst risks in 300 unreinforced masonry buildings is expected to cost $9 million. A national rollout of an effective programme in medium and high risk areas could well cost less than $100 million.

Government should contribute to save our architectural heritage

A start of sorts has been made in Wellington. It would not cost much to protect towns such as Whanganui, which could be decimated by the regime. Earthquake strengthening of all buildings in low risk areas, and reinforce concrete buildings in all areas is mostly a waste of money. The Minster released figures in his 2015 speech showed that significant delays in building strengthening would not cost a single life.

Call an implementation halt

No framework should be implemented until it has been properly tested. The experience with 'modern' buildings in Wellington should be a major concern, and we should not proceed until the event is fully understood and any implications for seismic risk management has been worked through. A delay could also be used to work out a more timely but measured response to the unreinforced masonry building risk issues.

Get independent advice

A fresh perspective is needed. MBIE and the earthquake engineering profession are inevitably wedded to a regime that will not deliver good results for New Zealand.

Part three: How did we get to where we are today?

Before we start with the technical issues it is helpful to put the discussion in context. How did we get to the point where we will be spending unknown billions on seismic strengthening for very little benefit, when it is well known that almost all of the benefits can be captured by focusing on just the ‘low hanging fruit’ (unreinforced masonry (URM) buildings in high and medium seismic risk areas)?

We have also included a description of aspects of the ‘test case’ because some of the analysis, evidence and debate that came out of that process is very relevant to our discussion of the new regulations and methodology.

The recent policy development history

Widening the coverage

There is a long history of the regulation of the seismic capacity of buildings in New Zealand, which is summarised in MBIE, and other, documents, but for our purposes the story starts with the NZSEE reconnaissance reports (of large overseas earthquakes, mostly in the 1990s). Prior to the introduction Building Act 2004 seismic strengthening only applied to unreinforced masonry buildings. The key lesson from the foreign experiences, or so it is claimed, was that reinforced concrete and steel framed buildings constructed after the introduction of modern seismic design techniques performed well in severe earthquakes, but earlier buildings did not. Hence it was necessary to extend the New Zealand seismic strengthening regime to reinforced concrete, wood and steel framed buildings. Looking back this claim was always tenuous.

We have read the reconnaissance reports, and while they were informative they did not, in themselves, present an overwhelming case for a major extension of the seismic strengthening regime in New Zealand. Not a single other country drew the lesson that existing older reinforced concrete buildings had to be mandatorily strengthened.

Second, nearly all of the events were major earthquakes (typically beyond the Wellington design strength earthquake level), not moderate earthquakes. So the lessons were not necessarily relevant to an understanding of performance moderate earthquakes (one third as strong as a design strength earthquake), which is the legal standard. Indeed, we have never seen any discussion of moderate earthquake impacts in the New Zealand engineering literature. This is extraordinary given its centrality to the legal compliance standard.

The New Zealand evidence

At the time the extension to the regulatory regime was being pushed, a major study of the performance of reinforced concrete buildings in the 1931 Hawke Bay earthquake had been completed and the results published. The studies showed that not one of around 100 reinforced concrete buildings suffered material structural damage in what was a severe earthquake.

However, to our knowledge no attempt was ever made to reconcile this evidence with the apparently more negative outcomes coming out of the reconnaissance reports. It has simply been ignored by the engineers who were lobbying for a broader application of seismic strengthening requirements.

The 2004 Act

In the event, MBIE’s predecessor in the regulatory field was convinced that something had to be done and the extended coverage found its way into the Building Act 2004.

Important aspects of the new framework were the EPB trigger point and the pace of implementation. In the latter respect the regime was not necessary threatening. Local authorities could devise their own policies and most decided on a passive approach, which would require strengthening only when a building was undergoing a change of use.

On the trigger point, the New Zealand Society of Earthquake Engineering (NZSEE) had the idea that 33 percent of the new building standard was the ‘right’ number.

A supportive cost benefit analysis?

From a cost benefit perspective there appeared to be a justification of sorts for the 33% figure. A cost benefit analysis[3] prepared for the Department of Internal Affairs appeared to show that there was a net benefit in implementing a 33% regime. The total costs for the 6 largest centers (Auckland, Hamilton, Dunedin were $542 million and the benefits $802 million for a benefit/cost ratio of 1.48. For Wellington and the Hutt the numbers were strongly positive – ratios of nearly 3. However, the ratios for Auckland and Dunedin at .04 and .08 respectively, showed that there was no value in strengthening in low seismic risk zones.

After the passing of the Act the new regime attracted relatively little public attention. The Wellington City Council, (driven by a small group of bureaucrats, who from our reading of the files really didn’t understand what they were doing) became something of a hotbed of seismic fundamentalism and climbed into the project with zest, but most other local authorities took a more relaxed approach.

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[3] David Hopkins and George Stuart 2008 ‘Improving the Performance of Existing Buildings in Earthquake Proposed Legislation in New Zealand’ 13th World Conference on Earthquake Engineering

The Christchurch earthquake and its consequences

Then came the Christchurch earthquake. As with any disaster the political imperative was to be seen to be doing something. A Royal commission was convened and went about its business. MBIE (then the Department of Building and Housing) started to pull together the analysis that would underpin a review of the regulatory framework. A critical part of that was a cost benefit study, which was put together by GNS Science and Martin Jenkins.

Critique of the Hopkins study

It was about that time that we (Ian Harrison) first came involved with the seismic strengthening issue. In the context of understanding the consequences of earthquakes for insurance risk Harrison came across Hopkins/Stuart cost benefit study. It was immediately apparent that there were serious shortcomings in the study that grossly overstatement the ratio of benefits to costs. In particular, the assumption that benefits should be a multiple higher because of wider 'social and economic costs' didn't make sense. The authors had confused the overall social and economic costs that earthquakes might impose with the **marginal** difference that an increase in building capacity to a minimum of 33 %NBS would make. That marginal difference is very small.

There were also some straightforward technical errors. For example it was assumed that buildings were occupied 24 hours a day, 365 days a year; a high building occupancy assumption implied that Wellington had 400,000 occupants in commercial buildings. Both assumptions substantially increased the life safety benefits of seismic strengthening.

Harrison wrote a note on the matter and sent it to the DBH. At that point they were working on the cost benefit analysis so they arranged for a meeting, which was attended by DBH and Martin Jenkins staff. All were in full agreement that the social and economic arguments in the cost benefit analysis were grossly oversold.

This thinking found it way into the cost benefit report which showed that the cost of reaching the 33%NBS standard would be around $1 billion but the benefits only $25 million. It is likely if that report had been produced for the Department of Internal Affairs back in 2000 then the earthquake provisions in the 2004 Act would have been very different. The seismic fundamentalist lobbying for an expanded coverage could easily have been rebuffed.

Responding to the Royal Commission

The Royal Commission's report did not come out until the end of 2012, and prior to that there was a fear in the bureaucracy that they would recommend that the EPB trigger point be increased to 67% in line with the NZSEE recommendation. In the event they stuck with the 33%, but were unable to provide any serious justification for ignoring the MBIE cost benefit study.

So when the Ministry's consultation report came out at the end of 2012, the thrust was to support the Commission's recommendations. MBIE was under orders to produce an immediate and positive response. They did not accept some of the sillier recommendations, but the 33% target and the accelerated time frame had to be supported. So the Ministry had to resort to an array of spurious arguments and invent mysterious 'social and economic costs' (that they knew were nonsense) in an attempt to justify its preferred options.

We responded to the consultation document pointing out their lack of logic, and identifying a major problem. The NZSEE was ignoring the law and imposing a much higher trigger point than the law permits. We were ignored. MBIE claimed that the issue was outside the scope of the review, which wasn't true.

Responding to the proposed Bill

Subsequent to the consultation we then dug deeper into the issues and in '*Error Prone Bureaucracy*[4]' we explain just how little effective political governance and consultation there was when the changes in the Act and subsequent regulatory provisions were slipped past Parliament and the public. We also re-examined the MBIE cost benefit analysis. While it was basically sound, it understated the scale of the cost. On our estimates the cost was in the vicinity of $10 billion. MBIE officially responded negatively, but our private feedback was that it was supported by MBIE staff who understood the issues, but it that was about the money, and the big engineering firms were calling the shots.

We submitted the document to the Select Committee.

The negative reactions to the first Bill (on our count more that half of the specialist engineers and many councils were opposed), led to a partial rethink by the new Building and Housing Minister and he responded by increasing the time allowed for remediation work in medium and low seismic risk areas. It was explained (on the basis of the MBIE cost benefit numbers) that this would save over $300 million in remediation costs, but there would be no loss in benefits. It was expected that not a single person would be killed over the next 100 years because of the sometimes lengthy strengthening delays.

Adjusting for difference in seismic risk

Prior to the second Select Committee hearings on the amended bill we produced a document[5] that looked at the way the NZSEE framework adjusts for seismic risk in different localities.

Because the new building standard varies by the seismicity of each locality, the existing building standard also varies. The effective trigger point for low risk Auckland is about one third as high as high risk Wellington. It is argued that this adjustment compensates for seismic hazard differences, and by implication %NBS figures represent a comparable level of

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[4] Tailrisk Economics 2014 'Error prone bureaucracy'

[5] EBSS 2015 'The Flaw in the Score'

risk, no matter the location of the building. The current Minister has been impressed by the argument and has cited it when responding to claims that the regime had a one size fits all approach

The problem is that the claim is wrong. First, for Auckland the new building standard is not based on Auckland's measured seismicity. Instead an artificially higher earthquake is used. The effect, and this was almost certainly the intent, is to reduce the %NBS multiplier from about 4.5 to 3 capturing a swath of buildings that would otherwise be above 34%.

Second, we calculated relative risk using GNS science data and found that the NZSEE methodology overstated the relative risk in low seismic areas by a very wide margin (by a factor of perhaps 50-100). The logic and calculations were presented in *The Flaw in the Score*. We provided a copy to the NZSEE for review. They said they would get back to us with their comments. They never did. Several engineers have read the documents. None have taken issue with the basic premise that the NZSEE have got the relative risk measure wrong.

What did we learn from Christchurch?

Christchurch was a very strong earthquake with peak horizontal ground accelerations of around 0.60 - 0.80g being recorded in the CBD. Not surprisingly, given the unusually strong vertical accelerations, several URM buildings collapsed. However, the important learning was just how well the stock of older reinforced concrete (RC) buildings performed. There was just one failure, the PGC building. The CTV building was a flawed modern building.

Jury and Kam [6] summed up the RC performance as follows.
*"An assessment using force-based linear analysis would suggest a large number of the buildings in Christchurch should have collapsed under the recorded seismic loads, which were **2 to 6 times** (our emphasis) the calculated 'design' capacity. Explanations are offered regarding, for example the relatively short duration of shaking in this particular earthquake, but the fact remains that similar observations have been made after every earthquake affecting a region that has had some historical earthquake resistant design requirements."*

And they went on.
"While it might be expected that nominally ductile structures subjected to shaking levels significantly in excess of design levels might perform poorly, there is no evidence from Canterbury earthquakes to suggest that they perform, in general, any worse than highly ductile buildings proportioned for very low levels of strength."

The benchmark survey of the relative performance of older and modern RC buildings in Christchurch is Kam et al.[7]They concluded, on the basis of damage stickers (green - safe,

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[6] Kam W.Y., Jury R. (BECA) 'Performance-based Seismic Assessment: Myths and Fallacies' 2015 NZSEE Conference

orange - limited occupancy and red - unsafe) that older RC buildings performed worse than newer ones. But the measured difference in performance was quite small (55 percent stickered vs. 44 percent) and was exaggerated by their methodology. They lumped together the orange and red stickered buildings as poor performers. We redid the numbers based on just the unsafe buildings. The older building performance was almost exactly the same as the modern building performance (actually just slightly better).

Wellington 2016

Performance of EPBs

In broad terms the Wellington earthquake could be described as moderate.
Of the nearly 700 EPBs just two, we understand, suffered structural damage and none collapsed. Many of the buildings must have been subject to forces approaching and beyond moderate earthquake levels. The general level of performance was as we expected for a moderate earthquake (see below). The WCC claim, on their website, that the EPBs could be **expected** to collapse in a moderate earthquake. If that was true hundreds of buildings would have been badly damaged or would have collapsed. The website information is misleading and should be withdrawn.

Modern buildings

The big news was the partial collapse of the modern Statistics Department building and the apparently poor performance of several other modern buildings. It is now acknowledged that there is a design flaw in many modern buildings that have used precast concrete elements, but beyond that it is too early to draw strong conclusions about the relative performance of 'non-flawed' modern, and the older reinforced concrete buildings. The earthquake sequence was unusual, and the distant earthquake 'suited' the older shorter rigid buildings better than modern tall ones. It would be a different story if Wellington where to be hit by a close severe earthquake.

Lessons

Nevertheless, Wellington did reinforce what should already have been known. First, there is no such thing as a completely safe building. Earthquakes interact with actual buildings in complex ways that cannot always be understood and modelled ahead of time, and there is always the chance that that a particular earthquake will have a particular building's number. This has to be acknowledged, and short of tearing down the entire building stock and starting again, accepted. The issue comes down to the risk and the only way to make risk decisions is on the best quantitative evidence.

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[7] Kam, W.Y., Pampanin, S. and Elwood, K. (2011). Seismic Performance of Reinforced Concrete Buildings in the 22 February Christchurch (Lyttleton) Earthquake. *Bulletin of the New Zealand Society of Earthquake Engineering, Special Issue* **44**(4): 239-279.

Second, the NZSEE's pronouncements on the relative risk of buildings sits on even shakier ground. If tall flexible modern buildings are relatively more vulnerable to (the more frequent) distant earthquakes, then it is difficult to say whether they are a lower risk overall let alone assert that they are 10 or 25 times less risky.

The test case - testing the legality of the 34% trigger point

The NZSEE regime is not only economically irrational, it is unlawful. There is no legal requirement that defines an EPB as having a less than 34 %NBS. The legal requirement is that a building must exceed its ultimate capacity, and be likely to fail in a moderate earthquake. It is patently obvious that for most EPBs this is not true.

At the end of 2014 we decided to test the law by seeking a determination from MBIE that two test case buildings were not earthquake prone because the Wellington City Council had not applied the right legal test.

The main argument

Our case was built on two main arguments. First, we presented a NZSEE Executive Officer's explanation[8] that at the 34 % trigger point a building had a very low probability of failure. Second we presented GNS Science and US Geological Survey based analysis that put that a probability of a collapse, in a moderate earthquake for the relevant building class at 10,000-40,000 to one. Thus, obviously, it is not likely that the building will collapse in a moderate earthquake.

We produced a cost benefit analysis for one of the buildings. The cost to strengthen the building to 34%NBS according to one engineering assessment was $4 million. We assessed the life safety benefits at a little over $20,000.

The use of the IEP

The Council's designation was based on an Initial Evaluation Procedure (**IEP**) assessment. We argued that the Council could not be satisfied that the buildings were earthquake prone based on a procedure that was just a screening device. The Council puts a caveat on its IEP assessments that they are only a screening device and should not be used by anyone for any other purpose. This caveat was removed from the IEP that was provided to MBIE.

The Supreme Court Decision

At that point the Supreme Court had delivered its decision in the Insurance Council v Canterbury University case. The issue was whether the legal test was that a building was

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[8] Clark W. and O'Rouke H. 'Review of the Hastings Opera House Redeveopment Project 2004-2008 and Subsequent Assurance Reviews commissioned by the Hastings District Council

likely to collapse in a **moderate** earthquake, or in **any** earthquake. If it was any earthquake then a Council could impose a higher %NBS test.

The Court was very clear that the test was a moderate earthquake and that this was a constraining limit. The Court also dismissed the argument that a higher limit could be justified by reference to the general purposes of the Act.

It was always obvious that the Act posed a moderate earthquake limit, and that the NZSEE 'interpretation' that the likely to collapse test was just a general aspiration had no merit.

The Determination process

We were not really expecting an honest response from MBIE. If we succeeded we could effectively bring the regime down, and MBIE was committed to defending the regime.

MBIE deliberately delayed the process. It was required by law to complete the Determination in 60 days. It did not bother to even ask the WCC for relevant documents until that time was up, and had to be pressed by our lawyer to make a start.

The Manager of Determinations, John Gardner, who did the determination, had an irreconcilable conflict. He was involved with development of the new methodology with the WCC manager of Seismic Resilience, Steve Cody, who was managing the case, and with Rob Jury who was the Council's engineering advisor. We were not aware of the extent of the conflict at the time, but there was a perceived bias and we wrote to the Chief Executive of MBIE to complain. MBIE attempted a legal defence of their decision to retain Gardner rather than use an independent party. They argued that Gardiner's involvement did not meet the perceived bias test.

Despite the importance of the issue, the WCC did not make a submission until after Gardner's draft determination had been sent to the parties. The Council obviously knew that the answer would be favorable and that they didn't need to bother submitting. However, when they saw that Gardner's draft decision (which was based on not much more than a statement of faith that the methodology could identify critical structural weaknesses and that you can't trust empirical evidence) they realised it was completely inadequate. They were then energised to come to his defence with something that at least attempted to address our submissions. Rob Jury was the Council's engineering advisor, and he attended the Determination hearing.

It wasn't an impressive effort from the Council, and we had to deal with enough red herrings to fill a good sized fishing quota, but the nub of their position was as follows.

The Council's arguments and our responses

The first argument was is that it is not possible to accurately model when an individual building will fail. Hence the only option is to use the Ultimate Limit State test. This argument is at the heart of the seismic fundamentalist philosophy.

We were initially nonplussed by this argument. Of course it is not possible to exactly model when a particular building will fail, even if the earthquake is precisely specified. Buildings are complex systems, so all building assessments must necessarily be based on a probabilistic model. The regulatory task is to make an assessment on whether the building is likely to collapse in a moderate earthquake, which is a probabilistic concept. As it is obvious that the ULS calibration is not right for a collapse test it needs to be adjusted. It is relatively straight forward, conceptually, to recalibrate the model so that it better predicts collapse. This could be done at the model coefficient level, and in particular by using empirically predictive ductilities, or simply by a big enough adjustment to the structural performance coefficient.

At the hearing we put this response to Jury. He agreed that you could do that (which sunk his argument that the ULS test had to be used unchanged), but said that that is not what that they have telling people they are doing, or how engineers were operating. He didn't seem to grasp that our point was that they shouldn't be doing what they are doing as it was not lawful.

The second argument was that the existing building standard, used probable strengths not design strengths, hence the conservative buffers in the new building ULS measure had been removed. The problem with this argument is that there are many more conservative buffers in the ULS than just material strengths.

The third argument was that the severity of a moderate earthquake was not just defined by its maximum acceleration, but also by its duration – which was defined to be the same as a design strength earthquake. The suggestion was that the full definition provided for a more severe earthquake than one based on force alone, because a design strength earthquake is longer than a moderate.

However, it turns out that the duration element is something of a dead letter because duration is not typically used in the design of buildings, and even if it was, moderate earthquakes are empirically, on average, longer than design strength events. The reason is that moderate earthquakes in a particular locality tend to be more distant, and their waves have had time to spread out, and so take longer to pass.

We presented a robust data [9]set that demonstrated this effect empirically. The moderate earthquakes median was about 39 seconds while the design strength duration was 16. Jury responded with an excerpt from the Encyclopedia of Seismic Engineering from decades ago, that purported to show a positive relationship between duration and earthquake severity. The problem was that neither earthquake size and duration were defined and the analysis rested on guesses from descriptions of historical events, and a couple of very dated studies.

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[9] Raghunandan M and Liel A.B. (2013) 'Effect of Ground Motion Duration on Earthquake-induced Collapse' Structural Safety Vol. 41 pp 119–133

There was no reliable relationship in the figure and the Council, eventually, in the context of the appeal, withdrew from its defence of this position.

Gardner was undaunted. For him the duration question was his get out of jail card. If our empirical evidence on the relationship between earthquake severity and collapse rates, did not relate to both a moderate earthquake on g-force and design length duration then it did not count, despite the duration empirics being the exact opposite of what his 'theory' required.

We have laboured this point a little because it is obviously important to be precise about the definition of moderate earthquake, because that is what underpins the law.

Jury on the probability of collapse

Despite Jury's arguments on duration and the lack of a conservative buffers, he actually agreed with our assessment of the numbers on the probability of collapse, when it came to it in the hearing. The reason is that he had come to the same conclusion in his own analysis.

In the Kam/Jury paper there is an estimate of the probability of collapse in a moderate earthquake (one chance in more than ten thousand) that was presented to the group developing the Chief Executives methodology. This admission obvious undercuts the argument that the conservative buffers had been removed – if that were the case we would expect the likelihood to be around fifty percent.

The relevant section of the table is presented below.

	Seismic Rating			
Level of Ground Shaking/Return Period	**34 *%NBS***	**50 *%NBS***	**67 *%NBS***	**100 *%NBS***
50 year return period *(One-third ULS loading?)*	*None* AALAN ≥*Minor* AALAN ≥*Moderate* unlikely ≥*Major* unlikely *Collapse* exceptionally unlikely	*None* likely ≥*Minor* unlikely ≥*Moderate* unlikely ≥*Major* unlikely *Collapse* exceptionally unlikely	*None* very likely ≥*Minor* unlikely ≥*Moderate* unlikely ≥*Major* extremely unlikely *Collapse* exceptionally unlikely	*None* almost certain ≥*Minor* unlikely ≥*Moderate* extremely unlikely ≥*Major* exceptionally unlikely *Collapse* exceptionally unlikely
100 year return period *(One-half ULS loading?)*	*None* very unlikely ≥*Minor* almost certain ≥*Moderate* AALAN ≥*Major* unlikely *Collapse* unlikely	*None* AALAN ≥*Minor* AALAN ≥*Moderate* unlikely ≥*Major* unlikely *Collapse* exceptionally unlikely	*None* likely ≥*Minor* unlikely ≥*Moderate* unlikely ≥*Major* unlikely *Collapse* exceptionally unlikely	*None* very likely ≥*Minor* unlikely ≥*Moderate* unlikely ≥*Major* extremely unlikely *Collapse* exceptionally unlikely

What does likely mean?

As the empirics were settled then the case should have turned on whether odds of 1:10,000-40,000 is 'likely'.

The Council argued that likely is equivalent to 'could well occur', drawing on the language used in a dangerous building case. So the logic is that a collapse 'could' occur; 'could' means 'could well occur'; 'could well occur' means 'likely'. Hence 'could' means 'likely'.

However, in the article Jury presented an engineer's perspective on the meaning of likely. In his view it refers to a probability of >67-90 percent.

(2.2 times ULS loading?)	*≥Minor* almost certain *≥Moderate* almost certain *≥Major* very likely *Collapse* very likely	*≥Minor* almost certain *≥Moderate* very likely *≥Major* likely *Collapse* AALAN	*≥Moderate* AALAN *≥Major* unlikely *Collapse* unlikely	*≥Moderate* AALAN *≥Major* unlikely *Collapse* unlikely

Suggested Descriptors/ Categories

Damage:

None; Slight (damage to non-structural items only);

Minor (damage to structural items that can be repair easily);

Moderate (damage to structural items that can be repaired with significant effort)

Major (damage to structural items not worth repairing)

Collapse

Likelihood:

Almost certain >95%

Very likely >90-95%

Likely >67-90%

About as likely as not (AALAN) ≥34-67%

Unlikely >1-34%

Very unlikely >0.1-1%

Extremely unlikely >0.01-0.1%

Exceptionally unlikely <.01%

The Supreme Court Decision

Jury admitted that the Council had not considered the likelihood of collapse in their assessment. He also said that the Council had not made any changes to their policies in the light of the Supreme Court decision.

The Determination outcome

Gardner did not take issue with our empirical analysis at the hearing, and presumably was also aware of the Jury analysis. But when he came to write his determination he simply ignored or misrepresented anything he found inconvenient, and unsurprisingly, found that the building was earthquake prone. He buttressed his decision by finding (in the final Determination – he did not raise the point in the many proceeding months) that only evidence from an engineer counted as evidence. Section 186(c) of the Act states that he must '*receive any relevant evidence, whether or not it would be admissible in a court of law;*

The Appeal

The Determination has been appealed to the District Court as provided for in the Act. There is no provision for an appeal of the District Courts decision.

Part four: Identifying earthquake prone buildings

In this section we first explain what the key terms in the definition on an earthquake prone building, a moderate earthquake and ultimate capacity means, and critically examine MBIE's proposed regulatory definition. We then show that in practice the law will be ignored and that buildings will be subject to much more severe tests than is lawful.

The legal definition of earthquake prone building

The Amendment Act (section 133AB) defines an earthquake-prone building as one that:
"Having regard to the condition of the building or part and to the ground on which the building is built, and because of the construction of the building or part –

*(a) The building or part will have its **ultimate capacity** exceeded in a **moderate earthquake** and*

(b) if the building or part were to collapse, the collapse would be likely to cause – (I) injury or death to persons in or near the building or on any other property; or (ii) damage to any other property".

Moderate earthquake definition

A moderate earthquake has the same meaning as in the current regulations. It is defined as follows:
in relation to a building, an earthquake that would generate shaking at the site of the building that is of the same duration as, but that is one-third as strong as, the earthquake shaking (determined by normal measures of acceleration, velocity and displacement) that would be used to design a new building at the site.

G-force/z-score

As discussed above, the duration element in the definition is a dead letter, so a moderate earthquake can be defined in terms earthquake force alone. The standard way of doing this is reference to the maximum acceleration, which is expressed in term of the force of gravity or g. The g force is sometimes referred to as a z-score.

For Wellington the design earthquake is 0.40g and one third of this is 0.133g. Auckland has a g of 0.09 but for new building code purposes is assigned the minimum of 0.13. This means that a moderate earthquake in wellington has a z-score of 0.13 and in Auckland 0.043
More than half of New Zealand population, and from the 2012 MBIE estimates, a good proportion of the earthquake prone buildings are in the low seismic areas (with a moderate earthquake of below 0.05g).

Effects of a moderate earthquake

Risk engineers know, in broad terms, how buildings generally behave in different sized earthquakes. The US Geological survey has produced a table that shows the relationship between g and the Modified Mercalli (described as instrumental intensity) index, which is a measure of the severity of an earthquake based on how it is perceived and its effect on the built and natural environments.

Figure 1 relationship between g and MMI

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

From the table 0.05 g is associated with MM V and light damage. And light really means very light. It is described on the GNS website as follows:

People

Generally felt outside, and by almost everyone indoors. Most sleepers awakened. A few people alarmed.

Fittings

Small unstable objects are displaced or upset. Some glassware and crockery may be broken. Hanging pictures knock against the wall. Open doors may swing. Cupboard doors secured by magnetic catches may open. Pendulum clocks stop, start, or change rate.

Structures

Some windows Type I cracked. A few earthenware toilet fixtures cracked.

Buildings on very soft ground will generally experience more vigorous shaking in the same earthquake event, but even if that effect were enough to push them up to the next, MMVI grade - quite a big adjustment- it would not be enough to cause damage that would be consequential from a life safety perspective. MMVI is the kind of damage that would be expected in a Wellington moderate earthquake. And that is pretty much what happened to the older, EPBs in the 2016 earthquake.

MM6 outcomes read as follows:

MM 6	**People** *Felt by all. People and animals alarmed. Many run outside. Difficulty experienced in walking steadily.* **Fittings** *Objects fall from shelves. Pictures fall from walls. Some furniture moved on smooth floors, some unsecured free-standing fireplaces moved. Glassware and crockery broken.* *Very unstable furniture overturned. Small church and school bells ring. Appliances move on bench or table tops. Filing cabinets or "easy glide" drawers may open (or shut).* **Structures** *Slight damage to Buildings Type I. Some stucco or cement plaster falls. Windows Type I broken. Damage to a few weak domestic chimneys, some may fall.*

Deceptive information on earthquake risk

It is obvious that it is highly unlikely that a building will fail (or exceed its ultimate capacity) in a moderate earthquake in Auckland. In Wellington the likelihood is still extremely low as discussed in the test case evidence. But that is not what is being presented to the public.

The Auckland City seismic strengthening website presents the following information on performance in a moderate earthquake.

For the purpose of consistency, there exists a theoretical 'design-level earthquake' that as a standard all modern buildings must be built to endure. When assessing the performance of older buildings, they are deemed 'earthquake-prone' if ,during an earthquake of only one-third the intensity of that standard, ***they can be expected to suffer partial or complete collapse,*** *causing injury or death to people or damage to another property.*

The inference is that only buildings that can be expected to suffer partial or complete collapse have been or will be identified as earthquake prone in Auckland. This is complete nonsense. Thousand of buildings that won't fail will be designated. Auckland City probably doesn't understand this, but the engineers who prepared the website information should.

The Wellington City Council website has an identical statement which is also grossly misleading. However, the Wellington seismic unit does not have the excuse of ignorance. It is well aware, from the test case, that collapses in moderate earthquakes are very rare, not expected.

The definition of Ultimate Capacity

To understand what ultimate capacity means it is essential to clearly understand the difference between Ultimate Limit State and Ultimate Capacity. The two have often been confused and conflated.

There is a useful explanation of the difference on the Wikipedia site (note that the term ultimate state rather than ultimate capacity is used but the two are synonymous).

A clear distinction is made between the Ultimate State (US) and the Ultimate Limit State (ULS). The US is a ***physical situation*** *that involves either excessive deformations* ***leading and approaching collapse*** *of the component under consideration or the structure as a whole, as relevant, or deformations exceeding prepared values. It involves of course considerable inelastic (plastic) behavior of the structural scheme and residual deformations. While the ULS is not a physical situation but rather an* ***agreed computational condition*** *that must be fulfilled, among other additional criteria, in order to comply with the engineering demands for strength and stability under design loads.*

So the fundamental distinction is this. ULS is an agreed computational condition, ultimate capacity is an actual physical state leading and approaching collapse.

The ULS philosophy as applied to new building design is explained in NZS 1170.5. It sets a test that is designed to ensure that if it is met, the probability of collapse in a design strength earthquake is very low (although the probability is not articulated). It does not, and does not purport, to represent a state at which the building is near to collapse.

ULS not appropriate for legal test

The problem arises when the ULS methodology is applied to existing buildings where a particular test is required in law. The ultimate capacity test relates to what is, in principle an **objective fact** (a physical situation) about the actual performance of a building in a moderate earthquake. It is not a test that can be met by just any 'agreed computational condition'. The computational condition must be calibrated to the near collapse objective.

The legal test is that a building **will** exceed its ultimate capacity in a moderate earthquake. The significance of the word 'will' was discussed in the test case. The lawyers on both sides agreed that it signifies a relatively high probability of exceedance.

As also discussed above, it is a conceptually straightforward to convert ULS based calculations to be a better fit for the ultimate capacity test. The use of probable material strengths is a start, but much more is required. The coefficient values in the models, could be reassessed, realistic ductility estimates could be used, and as a last resort the default Structural Performance factor could be set a level that better reflects the known performance of reinforced concrete buildings.

MBIE's proposed definition of Ultimate Capacity

It appears that the definition of ultimate capacity discussion is just a piece of window dressing, and that MBIE has no intention that it be applied in practice. The fact that they are only now consulting on a possible definition is a bit of a give-away. Defining key terms is an essential first step in building a methodology, not the last.

The ultimate capacity definition

It is proposed that ultimate capacity be defined as follows:
Ultimate capacity means the building's probable capacity to withstand earthquake actions and maintain gravity load support calculated by reference to the building as a whole and its individual elements or parts.

The proposed definition is reasonable. It is consistent with both a natural and ordinary meaning legal interpretation, and engineering logic. The following is the definition MBIE (John Gardner) used in a 2012 Determination.

The term ultimate capacity is not a specific structural engineering term, and I am therefore of the view that I should consider the natural and ordinary meaning of the words ultimate capacity. "Capacity" is defined as 'the maximum amount that something can contain' and "ultimate" in a structural sense is defined as 'denoting the maximum possible strength or resistance beyond which an object breaks'. In *my view, the reference to the ultimate capacity of a building is therefore a reference to the point at which the building fails in a structural sense and could collapse.*

No material change from 2004 Act

In practical terms the proposed definition means that the legal test for an EPB has not materially altered from the 2004 Act. The current Act posed two tests.

(a) It will excced its ultimate capacity in a moderate earthquake; and

(b) It is likely to collapse in a moderate earthquake

If a building has lost gravity support (exceeded its ultimate capacity) then it will be at a point where collapse is highly likely. Probabilistically, the ultimate capacity test is a little stronger than the collapse test, because there will be buildings that have lost gravity support but do not actually collapse, but this is balanced by the use of the word **will** in condition (a).

The basic similarity of the two test was probably in MBIE's mind when it prepared the 2012 Cabinet paper that presented the proposed amendments to the 2004 Act. It said that condition (b) was being dropped because it was redundant.

MBIE reverts to ULS test

Having defined Ultimate Capacity MBIE then 'forgets' its implications for the EPB test and revert to the %NBS trigger point test in the rest of their discussion. And the ULS test is used in the methodology documents. There are two arguments for this approach.

First, it is suggested that Ultimate Capacity is the same as Ultimate Limit State in the new building code, once the latter is adjusted for the use of probable (actual) material strengths. This is the same argument used, but abandoned, by Jury in the Detemination hearing, and is simply not true. In practice, there are multiple conservative factors in the model.

Second, MBIE says they considered calibrating to a collapse standard (implying that this is the first best test) but that was not a practical possibility. They recite the logic for the ULS in the new building standard (NZS 11705).

Given the current state of knowledge of the variables and the inherent uncertainties involved in reliably predicting when a structure will collapse, it is not currently considered practical to either analyse a building to determine the probability of collapse or base a code verification method around a collapse limit state.

And they add

Submissions during the development of the Amendment Act also supported that the collapse point of a specified building cannot be reliably assessed and should not be included within the definition of 'ultimate capacity'.

For these reasons, the proposed definition of ultimate capacity is not linked to the risk of collapse of the building.

As discussed above this is just a recitation of Jury's test case argument that he conceded didn't hold up . It is possible to adjust the ULS calibration to a Ulimate Capacity standard. It is no harder than multiplying the current %NBS number by a factor such as three. The art is in selecting the factor(s). That would be part of the methodology, engineers would not do it on a case by case basis.

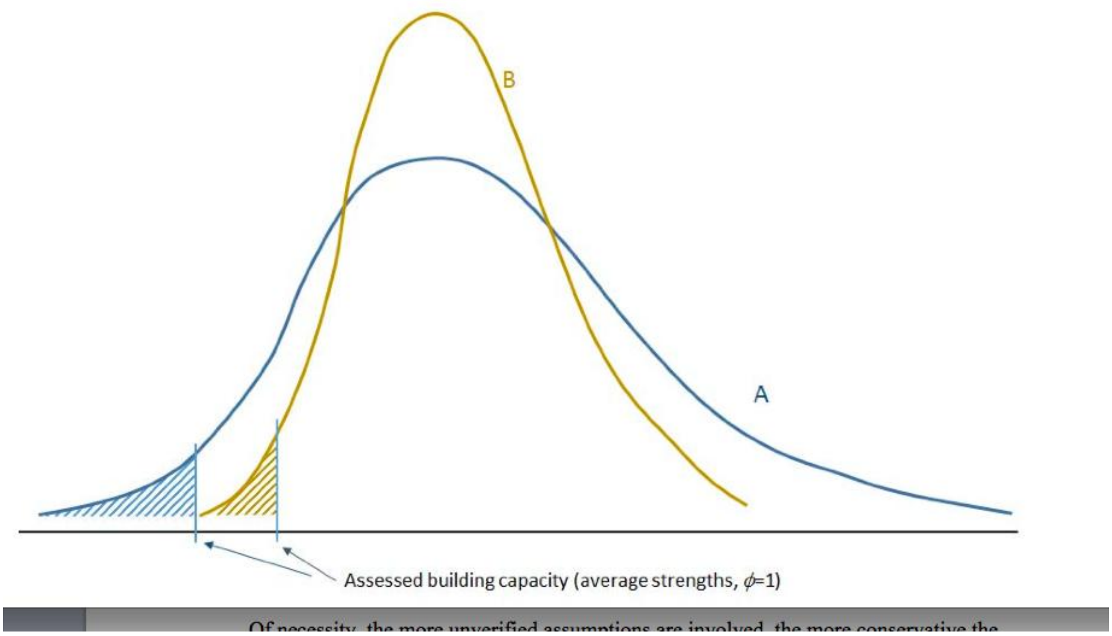
What engineers have been told

If there could be any doubt that the ultimate capacity test will not be applied in practice this is put to rest by the following statement in Document A of the EAG. It appeared in the first version of the paper used to brief engineers. It was removed, perhaps not surprisingly , from the subsequent public draft.

*The assessed seismic rating should **never** (*their emphasis*) match the actual capacity of the building. Although the assessment may use probable (average) material properties instead of lower characteristic values and no capacity reduction factors, there are other factors that introduce an element of conservatism, notably in the algorithms that are used to calculate capacities and in the displacement and rotation limits that are used to assess building elements.*

To emphasise: The assessed seismic rating should **never** match the actual capacity.

There is also the following graph which makes it clear what is meant to happen. In the graph the peak of the distribution of possible outcomes is the mean or probable capacity. In law the 'will exceed its ultimate capacity' test means that the targeted calibration should be to the right side of the curve. But what is being targeted (from the vertical lines) is very much a low estimate of capacity.



Assessments against stronger earthquakes

In the EAG there are several instances where it is clear that severe, not moderate earthquake assessments are being made. For example, the part on geotechnical assessment makes it clear that the moderate earthquake test is completely ignored. Instead it is more or less required that the assessment be at least the design level and is strongly suggested that engineers go to twice this level. Other instances are identified in the next section.

Geotechnical analysis for new design is typically undertaken assessing behaviour (e.g. liquefaction analysis, slope displacement) at a specific shaking level. For a detailed assessment it is appropriate to relate the scoring of a geotechnical issue against this level but also have due regard for the effect of larger levels of shaking. The indication is that the majority of the life safety risk for typical (i.e. IL2) new buildings results from shaking between ULS shaking and twice this level.

MBIE knows the difference between ULS and Ultimate Capacity

It is not as if MBIE is not aware of the difference between the ULS and Ultimate Capacity. In a paper presented to the 2008 14th World Conference on Earthquake Engineering, the Chief Engineer and others said:

5.1 Definition of earthquake-prone building
The definition of earthquake-prone in the Building Act requires that the ultimate capacity of the building be exceeded and that it would be likely to collapse causing injury, death or damage to other property. Difficulties were expected in determining engineering criteria defining "ultimate capacity" and "collapse". ***Even if it is accepted that "ultimate capacity" means attainment of the Ultimate Limit State (ULS) used in many design standards, the definition of "likely to collapse" poses difficulties****.* ***The difference between ULS and collapse states can be considerable*** *depending on the configuration, integrity and ductility of the structure. It is possible that engineers representing building owners will argue that collapse will occur at a much higher level than the ULS commonly used in assessment of structural performance.*

There was pressure from design engineers to add regulations giving detailed definitions of how to assess the collapse level. The Department took the view that it would be easier to resolve such issues on a case-by-case basis. If a building owner does not agree with a TA's view that a building is earthquake-prone, either party is able to refer the case to the Department of Building and Housing for a "determination". …….It was recognised that the lack of closer definition could give rise to requests for a "determination", but the Department considered that these requests would be few in number on the basis that most owners of buildings with a ULS below or around the one-third threshold would not argue the finer points of ULS versus collapse. Rather, they would recognise the merit of strengthening work. If the Department receives many requests for determinations on this question, the need for regulations will be reviewed.

We think that this admission is extraordinary. MBIE knew that the NZSEE interpretation of the Act was dubious, to say the least, but actively promoted it in the preface to the NZSEE guidelines as 'authoritative'. The idea that a critical legal issue could be dealt with case by case is simply bizarre. The law applies equally to all building owners not just to the few who might work out that their Council's designation methodology was unlawful.

The fact that no engineers raised the issue does not reflect well on the profession. Some of them knew that the way the Act was being implemented was adversely affecting their clients. They said nothing.

The Methodology in practice

An element/part based approach

One of the controversies between engineers with the implementation of the current regime has been over an element/part versus the holistic approach. With the element based approach the %NBS structure is determined by the lowest element score. A holistic approach considers the performance of the structure as a whole. The two approaches can generate very different %NBS assessments.

It has now been decided that the approach will be element driven. Part C1 states

The global probable seismic capacity of the primary structure will be limited by the member/element with the lowest probable capacity; ***provided the failure of that element would result in a significant hazard to human life****. The capacity of elements that do not fulfill this requirement should be set to a residual value (or zero if appropriate) and the analysis repeated until the lowest scoring member/element is identified that would result in a significant life safety hazard.*

This will tend to reduce % NBS assessments and introduce a large element of subjectivity. This is partially admitted.

What is considered to constitute a significant life safety hazard is discussed in Part A. In summary, it is a hazard resulting from the failure of a member/element of the primary or secondary structure or of the supporting ground that would lead directly to collapse of the building as a whole or to a part of it and that could reasonably affect a number of people.

What does and what does not constitute such a hazard will rely to some extent on the judgement of the assessor. Therefore, it is important that the decision making process for this is recorded in the DSA report. Further guidance on this issue is intended to be included in the EPB Methodology.

'To some extent' is an understatement to say the least. One of the fundamental tenets of the philosophy is that it is not possible to model how a building will collapse. Now it is argued that an engineer will be able to tell us that the exceedance of the ultimate capacity (really the ultimate limit state) of a particular building element will lead to collapse.

The 'life safety' test may place some sort of constraint on some of the silly assessments made under the current regime where minor shortfalls would see a building identified as earthquake prone.

But overall the test is intended to be only weakly constraining.

- The test of the life safety effect is vague. At one point it only has to be judged that the 'weakness' **could** lead to a life safety event. Thus, even the slightest possibility could qualify the element. At another point the test is that it be **likely**, but likely is not defined. Is it 1:10,000 or is it the 60-90% probability?

- The 'reasonably affect a number of people test' is not defined. Is it 2 or 20? Significant life safety test is not defined by MBIE.
- The test is that there be a life safety risk in **earthquakes** not in a moderate earthquake. Thus, it is always possible for an engineer to imagine some extreme earthquake (even if the geophysics suggest that it is almost impossible for it to occur) that could lead to a building collapse. Given the emphasis the documents give to the consideration of gravity support, it is likely that many engineers will find that any element with a pillar could generate a failure.

The EAG make it clear that the methodology is **not** calibrated to a moderate earthquake.

'Although the assessment of SWs in these guidelines is focused on the demands at ULS levels of shaking (or a proportion thereof when %NBS is less than 100) ***the expectation is that a building will be able to continue to perform to a satisfactory level in shaking much higher than this to meet the overall performance objectives****. The provisions of these guidelines (acceptance criteria, treatment of SSWs and the like) have been set at a level to provide confidence that this will be achieved. Therefore, it is not the intention that higher levels of shaking are specifically addressed in the assessment process'.*

What the authors don't seem to grasp is that the regulatory purpose of the Guidelines is to provide a methodology that will identify buildings that are legally earthquake prone, not achieve some ill-defined 'overall performance objectives'.

The logic of the Act tells us that the test should be a moderate earthquake. While the structure of the new Act is not exactly the same as the 2004 Act, the question at issue is the same that the Supreme Court settled in 2014.

MBIE on parts

If we look at what MBIE has to say on the element/part vs. holistic assessment it is a little difficult to deciper.

It is intended that parts of buildings are considered for buildings identified as potentially earthquake prone. It is not intended that parts within buildings that are not potentially earthquake prone are identified and addressed.

It is difficult to read the double negative. What they are saying is that **it is intended** that parts within buildings are identified and addressed.

This is not consistent with the story that was sold to Parliament. Parliament was led to understand that 'parts' referred to nonstructural elements such as parapets, that could pose a higher life safety hazard than the building structure. Parliament would not have been aware that 'parts' would have been used in a way that could significantly affect the assessment of the building structure.

At another point in the MBIE documents it is stated:
*Some examples of parts that may have a significant life safety hazard in **moderate earthquake** shaking if not adequately restrained or supported include URM parapets, precast cladding panels, heavy items of plant and heavy partition walls.*

They don't mention parts of the structure at all when these are the most important parts.

The significance of the above statement is that it is acknowledged that the life safety test is against the building's moderate earthquake performance. It is not consistent with the methodology as explained in the EAG.

Of course, we don't expect this admission to make any difference. MBIE is a myrmidon in this game. We expect they will ignore, what is probably an inadvertent slip into an honest interpretation, and it will be the EAG interpretation that will rule.

But that is not the law. What the Guidelines do, properly interpreted, is to introduce the likely to collapse test into the methodology. And the test is a matter of fact of whether a building will collapse in a moderate earthquake, not any earthquake.

We should always remember that exceedance of an engineering standard does not kill people, it takes the actual collapse of the building.

A new role for the term 'critical structural weakness' (CSW)

In the current regime, a critical structural weakness is a reference to a particular building characteristic (such as a vertical irregularity) that could be expected to increase the probability that a building might collapse in a severe earthquake.

Under the new methodology (but not in the IEP where a CSW apparently retains its old meaning), a critical structural weakness simply means a building element or part that has the lowest % NBS rating in the building. If the critical structural weakness is fixed, then the next lowest % NBS then becomes a critical structural weakness.

Presumably the point of this nomenclature change is to impress or frighten building owners. They are increasingly aware that the %NBS calculations are hit and miss and that may not mean much that the building is 25%NBS. But it sounds much more impressive, and frightening, if the building has a 'critical structural weakness'.

There is no need for a pejorative term that psychologically manipulates engineers' clients. The term should be removed from use and replaced with the term 'lowest %NBS' element.

Manipulation of model inputs to generate lower %NBS

Input manipulation has been going on subsequent to Christchurch, as engineers seek to manage their own perceived risks by making more conservative assessments. The most important of these is the ductility assumption. We were told by the late Ian Smith that a relatively small group of engineers had got together and had effectively imposed much more conservative maximum limits. For older reinforced concrete buildings the limit was 1.25. This compares with the input of 2 that had been previously used in the IEPs (which would have been a conservative figure. In Wellington the limit is effectively enforced by the manager of Seismic Resilience (a former building inspector who takes his guidance from Rob Jury), who will not accept any engineering assessments that do not comply with the Council's limits.

There is no justification for these limits in terms of what happened in Christchurch. As is well known, reinforced concrete buildings performed extremely well, suggesting if anything, engineers should use high ductility inputs.

The manipulation of the ductility assumption has had the effect of substantially increasing the effective %NBS trigger point. A reduction in the ductility coefficient from 2 to 1.25 increases the effective target by 60 percent. What has been going on is not the exercise of engineering (or bureaucratic) judgment; it is the manipulation of the system for personal ends.

It is not as clear what role global ductility will play in assessments in the new Guidelines, but we can be pretty sure that the calculation can be manipulated to secure the same sort of conservative outcomes.

Severe structural weaknesses

Severe structural weakness explained

'Severe structural weakness' (SSW) is a new concept that can be used to reduce a building's measured %NBS. The logic behind the concept is spelt out in EAG document A. (A3.3.4)

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

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

However there are some systems that experience indicates have little structural resilience, are susceptible to a sudden reduction in their ability to continue to carry gravity load as the earthquake shaking increases beyond a particular value, and are difficult to quantify based on current knowledge or inability to analyse. These are referred to in these guidelines as Severe Structural Weaknesses (SSWs). If SSWs are present they require careful assessment and a process that ensures that there is sufficient margin against them causing system failure.

Another obvious breach of the law

What is going on here is that if engineers don't like a particular type of building, but it still comes up with a %NBS of more than 34%, its rating can be marked down (by 50 percent for each structural weakness - a building with a 60%NBS, but found to have three structural weaknesses will then be assessed at 7.5%NBS). The SSW assessment is made by implicitly testing against severe earthquake forces. The objective to 'meet the overall objectives set out in the building code' implies a new building test. Again, this is obviously wrong in law. The assessment must only address performance in a moderate earthquake.

It is a further instance of a flagrant disregard of the Supreme Court decision.

Will it be used sparingly?

It appears on a reading of Document A that the Severe Structural weaknesses should be used sparingly.

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

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

However, it appears that the criteria will not be as restrictive as they appear. Part C2 appendix C2G discusses some of the identified SSWs.

Non-ductile columns

The first is Non-ductile columns with axial-shear failure. This could be read to apply to large numbers of older RC buildings that don't have modern detailing, despite the fact that that this will almost certainly be implicit in the assessed ductility of the building. This looks to be double counting.

Nor does the logic behind the SSW assessment make sense. No account is made for redundancy in the element based assessment of the shear wall so there is no need to make an adjustment for the lack of it. If the desire is to distinguish the relative capacity of buildings with redundancy from those without, then this could be done as a judgmental overlay in a holistic assessment of building capacity. So it two buildings are assessed at 35 percent on the capacity of their elements, then one would be uprated to say 50 or 60 percent because of the additional resilience that redundancy provides. Instead it is proposed that the %NBS of the building without redundancy is reduced to 17.5 percent.

Loss of support due to complex slope failure

It appears that a building will have its capacity reduced if it is on a slope or near a cliff. Again this is a bit of nonsense. A lower %NBS could require the building to be strengthened, but It will not help if the ground gives way. The building will still fall over.

Part five: Seismic Ratings system and risk education

The risk grading requirement

The Act provides for buildings to be assigned an earthquake rating which is defined as *'the degree to which the building or part meets the requirements of the Building Code that is its %NBS rating.*

It is argued that this earthquake ratings provide a way to classify buildings according to the standard they achieve and therefore how well they might perform in an earthquake.

And that *Publishing the earthquake rating of a building on the EPB register and placing this information on building notices will place additional incentives on owners to address the highest-risk earthquake-prone buildings.*

This is a 'relative risk' approach. The rating is an assessment relative to a new building. The alternative is the absolute risk approach, where risk is presented in terms of the probability of an adverse event.

Basic flaws in the relative risk approach

Does not consistently rank in terms of relative risk

It is implied that the %NBS ratings consistently rank buildings in terms of their risk. That is not true. Buildings with the same %NBS in different seismic areas have very different risk because the NZSEE methodology, as explained above, does not correctly adjust for geographical differences in seismic risk.

Provides no useful information

The second serious problem with the relative %NBS approach is that it does not provide any useful information about the actual risk of the building. All it tells you is that the building has so much less seismic capacity, than a new building, but without an understanding of the risk of the new building this is quite meaningless and useless from a risk assessment perspective.

It is highly relevant to building users as to whether a particular building has; say a one in 10 or a one in 1000 chance of collapsing in a benchmark earthquake. Information about the expected frequency of seriously life threatening earthquakes is also highly relevant. It is one thing that big event can be expected to occur once every 100 years, but quite another if it is once every 5000 years. All of can be presented quite simply to the user, in terms of a probability of building collapse measure (that is the probability that the building will collapse in a given year) and most, usefully, in terms of the life safety risk (say 1 chance of being killed in 100,000 years).

Description of risk grades

The NZSEE risk rating system goes further than the %NBS measure and the associated grades. It quantifies the difference in relative risk compared to a new building (i.e. 3 times, 10 times etc. 25) and describes the risk grades in qualitative terms.

Less than 20% NBS very high risk
20-33% high risk
33%-67% medium risk
More than 67% low risk.

This 'relative risk' approach can only be described as a nonsense. It will not better inform the people or result in better risk decisioning. Rather it is intended to frighten and mislead the public and results in suboptimal decision making. This obvious purposes are:

- To induce owners to upgrade their buildings to 67%NBS and above. In commercial markets 100%NBS has almost become the only viable option.
- To put pressure on owners to strengthening early. The intention is to unwind, as much as possible, the time to strengthen provisions in the Act that were intended to lessen the impact of strengthening requirements in low and medium seismic risk areas.

We believe that engineers who use or promote the framework may be committing an offence under the Fair Trading Act. We intend to lay a complaint under this Act.

The reason we will take this action is that give a completely misleading picture of seismic life safety risk. To illustrate, we have calculated the life safety risk of buildings in Auckland, New Plymouth and Wellington that are likely to be defined as high risk and very high risk. We have used the data that was provided to MBIE by GNS Science for their 2012 review. Of course these estimates should be not taken literally. There is significant uncertainty around the GNS estimates, but even taking a more conservative view of the risk (say by increasing the probability of quakes to the 84% percentile), the broad picture of building life safety risk is very robust.

	Odds of death over one year 40 hours occupancy	**EBSS risk rating**
Auckland Unreinforced Masonry Building (defective)	1 in 60,000,000	**No effective risk**
New Plymouth URM (sound)	1 in 9,000,000	**No effective risk**
Wellington URM (sound)	1 in 300,000	**Very low risk**

As a point of comparison, flying has similar characteristics to earthquakes. There is a very small chance that there will be a catastrophic event that results in death. The chance of being killed, per hour, when flying is 4000 times greater than being in a typical Auckland 'earthquake prone' building. For New Plymouth buildings it is about 600 times greater, and for Wellington 20 times.

We fly because we know that flying is very safe. But the Auckland, New Plymouth and Wellington buildings will be shunned because they will be falsely identified as 'very high risk' or 'high risk' when there is overwhelming evidence that they are not. It is absurd to say that a building with a life safety risk of 1:60,000,000 is very high risk.

Where did the relative risk numbers come from

The other issue is the 'times riskier' numbers. Our understanding is that they were essentially just made up. Apparently, they were selected because on the basis of the numbers in some damage curves, (which plot a relationship between the severity of earthquakes and the amount of damage to buildings). This is not the same as the relationship between a buildings %NBS and the amount of damage.

MBIE promotes the EAG earthquake rating system in their documents so we asked them to provide any documents they had on what was behind the 'times riskier' numbers.

Their response was as follows*:*

The Ministry does not hold any information about how the ratios were calculated, or analysis and discussion about the methodology used for calculating the ratios, as the Ministry has relied upon the 2016 document "assessment and Improvement in Earthquakes " for these numbers. For these reasons, part two of your request is refused under section 189e) of the OIA, as the information requested does not exist.

There is nothing in the 2016 document about the methodology. The Ministry's lack of interest in understanding a performance metric that they place a good deal of weight on, is discomforting, but not unexpected. As MBIE has repeatedly taken things that the NZSEE says on faith alone. The problem here is not just that there is no information in the MBIEs files, there is probably no information anywhere, because the numbers were just made up.

The EAG response

We criticised the 'relative risk' approach to risk education in *Error Prone Bureaucracy* and we know that a number of engineers are also highly critical of the approach.

The EAG authors are aware of these criticisms and present a defence of their position in part A of the EAG. We have repeated in here, in its entirety, together with our comments.

Observations from actual earthquakes indicate that the performance of even quite similar buildings in reasonable proximity can vary over a considerable range and, therefore, any prediction must be associated with considerable uncertainty. This uncertainty arises from a lack of current knowledge but *also the inability to predict, in advance, the considerable variability in the way in which the earthquake waves propagate from their source to the building, the way in which the building responds to the shaking due to the complex nature of building structures, involving the interaction of many elements, and the way in which the complex nature of the ground on which the building is sitting affects the building response.*

Therefore, it is unreasonable to believe that seismic performance can be predicted in absolute terms, and this means it should always be communicated within a probabilistic framework. This is however not easily done.

For these reasons, the approach taken in these guidelines is to assess how the building will perform compared with a new building that just meets the minimum seismic standard for life safety defined by the Building Code.

In the first statement, what they probably meant to say is that, it is unreasonable to believe that collapse can be predicted, using a deterministic model – which is true. The implication that performance must be measured in a probabilistic framework also naturally follows. But this is not an argument for not working in a probabilistic framework or that it is not possible to calculate probabilities. It is possible to calculate probabilities. Risk engineers have been doing it for decades. So what the argument comes down to that it is not easy to communicate probabilities to the public. We think this is also wrong. We have had little trouble in communicating risk concepts to the public. After all we are mainly dealing with building owners, who are generally numerate. And so is much of the New Zealand public. After all they teach probability at primary schools.

The argument then goes on

By adopting a measure of relative performance against a minimum acceptable level, it is possible to avoid the need to quantify the actual expected performance of the building.

So it is argued that it is alright to avoid providing useful information, providing you have given the public useless or misleading information.

The real reason for the lack of quantification, of course, is that the seismic fundamentalist do not want the public to be informed. If they were, they would see the NZSEE risk framework and their recommended 67% NBS minimum for the nonsenses that they are.

Fair Trading Act offences

We believe that the NZSEE risk grading system is a representation that constitutes an offence under the Fair Trading Act. Engineers are in trade, and are subject to the Act.

We have not set out detailed legal arguments here, but they are fairly obvious. There have been unsubstantiated representations, and misleading statements have been made with respect to the need for good and services. For convenience, we present the relevant sections of the Act in Box 1.

Misleading and deceptive conduct
9 Misleading and deceptive conduct generally

No person shall, in trade, engage in conduct that is misleading or deceptive or is likely to mislead or deceive.

11 Misleading conduct in relation to services

No person shall, in trade, engage in conduct that is liable to mislead the public as to the nature, characteristics, suitability for a purpose, or quantity of services.

Unsubstantiated representations
12A Unsubstantiated representations

(1) A person must not, in trade, make an unsubstantiated representation.

(2) A representation is **unsubstantiated** if the person making the representation does not, when the representation is made, have reasonable grounds for the representation, irrespective of whether the representation is false or misleading.

(3) This section does not apply to a representation that a reasonable person would not expect to be substantiated.

12B Court must have regard to certain matters
(1) In proceedings concerning a contravention of section 12A, and in assessing whether a person had reasonable grounds for a representation, a court must have regard to all of the circumstances, including—
(a) the nature of the goods, services, or interest in land in respect of which the representation was made:
(b) the nature of the representation (for example, whether it was a representation about quality or quantity):
(c) any research or other steps taken by or on behalf of the person before the person made the representation:
(d) the nature and source of any information that the person relied on to make the representation:
(e) the extent to which the person making the representation complied with the requirements of any standards, codes, or practices relating to the grounds on which such a representation may be made, and the nature of those requirements:
(f) the actual or potential effects of the representation on any person.

False representations
13 False or misleading representations
No person shall, in trade, in connection with the supply or possible supply of goods or services or with the promotion by any means of the supply or use of goods or services, —

(h) make a false or misleading representation concerning the need for any goods or services

We also believe that the breaches of the Act rates highly on the criteria the Commerce Commission considers when deciding whether to take an enforcement action. The relevant criteria are as follows:

Extent of Detriment

Detriment is assessed by applying both quantitative and qualitative measures to determine the impact and consequences of the alleged contravention. The greater the likely level of detriment arising from the conduct in question, the more likely it is that the Commission will take or continue with enforcement action.

In assessing detriment, the Commission considers the following questions:

Are consumers or businesses likely to suffer and to what extent:

- *Increased costs?*
- *Loss of property?*
- *Impaired choice?*
- *Are the more vulnerable targeted by the behaviour?*
- *Are a wide range of consumers or businesses likely to be affected?*
- *Is competition in the relevant markets likely to be adversely affected?*
- *Are excess profits likely to be gained?*
- *Is the behaviour likely to have significant adverse national or regional impact?*

Seriousness of Conduct

The more serious the conduct, the more likely it is that the Commission will begin or continue enforcement action.

In assessing the conduct, the Commission considers the following questions:

- *Is the conduct deliberate, reckless or very careless?*
- *Is the conduct repeat or ongoing behaviour?*
- *Is there a serious departure from expected lawful commercial behavior?*
- *Is the conduct/information difficult to detect by businesses or consumers?*
- *Can the conduct be undone?*

In the Public Interest

The Commission must have regard to a number of factors in the wider public interest. In assessing public interest the Commission considers the following questions:

- *Is there likely to be widespread public interest in the issue?*
- *Would a decision not to commence or continue enforcement action likely undermine public confidence in the law?*
- *Is it more appropriate for the Commission, rather than another agency or an affected party, to address the issue?*
- *Are there any mitigating or aggravating features involved?*
- *Do the personal circumstances of the parties involved argue for or against enforcement action?*
- *Is there a significant need to clarify the law?*
- *Is it necessary to reinforce the application of the legislation?*
- *Are the issues timely?*

Part six: Cost of Assessments

There are about 80,000 pre-1976 buildings in New Zealand, which could be potentially subject to earthquake prone tests. Post-1976 buildings can also be subject to assessments. All it requires is a suspicion in the Territorial Authority (TA), that the building might be earthquake prone. We don't know how many of these newer buildings could be affected as it depends on the attitude of the TA. In that respect the signs are not encouraging. For example, recently Auckland Council bureaucrats created a new concept of 'brittle building' and unlawfully place this designation on LIM reports to bully building owners into obtaining a DSA. This was part of the post Christchurch reaction, over the CTV building, and who knows what panics will arise in future.

Total cost of 'extreme vetting'

If all buildings were to require a Detailed Engineering Evaluation[10] (DEE) then that will be very costly. MBIE has been reluctant to put much effort into investigating these costs because the numbers are obviously embarrassing given the very low benefits. Prices will probably go up with the pressure on resources, so an average cost of, say, $20,000 is probably low. With, say, 100,000 buildings potentially affected the total cost of the 'extreme vetting' option would be $2 billion. Most of this would be in low and medium seismic area where strengthening will have near zero to very low benefits.

Cost reduction options

Obviously this cost should be reduced. The first best option would be to remove classes of buildings from coverage. The obvious candidate is reinforced concrete building. That is not an option right now. The other options are the effective use of profile categories, and to maximize the use of the IEP rather than use the DEE.

Profile categories

Profile categories are those categories of building that TAs can consider to be potentially earthquake prone and that must be identified within the time frames in the Act. If a building is not in a profile category it does not mean that it may not be assessed and found to be earthquake prone. It just means that it is less likely to be assessed at an earlier date. A Council can assess any building at any time.

However, Councils can use the profile category framework to effectively exempt non-profile category buildings because they don't, in law, have to assess them. They could take the view that they are in medium or low risk seismic zone and that these buildings do not pose a

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[10] The terms Detailed Seismic Assessment (DSA) and Detailed Engineering Assessment (DEA) have been used previously to describe the same process.

material risk. Or they could take the view that the implementation of the methodology is not lawful and that they will try to minimise the extent of the harm, without having to resort to a frontal attack through a judicial review.

Setting the profile categories

The profile categories were identified after a technical team examined the Wellington City Council EPB assessments. They calculated the proportion of buildings that were found to be earthquake prone by IEP where that assessment was confirmed by a subsequent detailed seismic assessment. They found that for wooden and low-rise (1-2 stories) reinforced concrete buildings the proportion was low. It was assumed therefore that the chance that these buildings would have a %NBS of less than 33 was low and that the class could be excluded from mandatory consideration under the time frames under the Act. Unfortunately, we do not know how much difference this will make to the total number of building that will requiremandatory assessment.

Unfortunately this process missed an obvious further step, %NBS is a function of geographical area z-score, and it would have been a straightforward matter to adjust the Wellington information to apply to other cities. They could have taken the Wellington DEE %NBS scores, and uprated by the ratio of the scores (i.e. Wellington z/ Hamilton z). If a high proportion of buildings pass on the adjusted DSA then the building class would fall out of the profile category for that area.

Ingham[11] used this methodology (see section 7) to make an assessment of the number of earthquake prone URM buildings in New Zealand based on an assessment of a sample of Auckland URM buildings.

We suspect that a large number of buildings, especially in Auckland, would fall out of the profile categories if this approach were taken. Which is probably why it wasn't done.

IEP vs. DEE

IEPs are cheaper, and more conservative than DEEs, so they should always be accepted that a building is not earthquake prone if the %NBS is great than 33% by a TA. The role of the DEE should be just to provide the building owner an 'appeal' right. This is essentially how the system works at present.

Our concern is that the tone of the IEP document (Part B) is that the IEP is something of a second-class option, with the inference that TAs should really be using the IEP for EPB decision making.

[11] Ingham and Russell (2010) 'Prevalence of unreinforced masonry buildings in New Zealand'

The Initial Seismic Assessment (ISA) is the recommended first step in the overall assessment process. It is intended to be a coarse evaluation involving as few resources as reasonably possible and it is expected that an ISA will be followed by a Detailed Seismic Assessment (DSA) where important decisions are intended that are reliant on the seismic status of the building. Such decisions might include those relating to pre-purchase due diligence, arranging insurance, confirming the earthquake-prone status and prior to the design of seismic retrofit works. An ISA completed with a high level of information available may be sufficient to confirm the earthquake prone status of a building at the discretion of the assessing engineer.

This text should be amended to make it clearer that an ISA is a legitimate final assessment. It should be used to confirm that a building is earthquake prone, but it can be used to confirm that it is not.

It is important to remember here that a DEE is a poor predictor of building performance so TAs should not be concerned that they are not using the 'best' available methodology.

Part 7: The IEP

General issues with the IEP

It is acknowledged that there have been many issues with the implementation of the IEP including disparate results and often absurdly low scores. This is largely put down to the quality of the assessors and it is recommended that IEPs be undertaken or at least supervised by experienced engineers. The IEP is described as a largely qualitative procedure, but it is not really. Most of it is very mechanical and the some of the flaws are embedded in the structure of the IEP model. No attempt has been made to fix these problems.

Where judgement is required problems can arise with the attitude of the assessor and the culture of the assessment team. If that is to find critical structural weaknesses at every turn, then absurdly low scores can be generated.

Given the role the IEP can play in reducing unnecessary high assessment costs it is important that the structural and 'cultural' issues are addressed.

Key structural problems

The base %NBS scores.

It is said that these are only 'slightly' conservative but we are not told how conservative. Is it 10 or 20 percent, which is acceptable, or is it 50-60 percent which is too high. The EAG needs to spell out how the base parameters were derived and there should have been an assessment of how accurate these have been compared to subsequent DSA assessments. This was not done despite the wealth of accumulated experience since the IEP was calibrated in 2000.

The role of pounding in the model

We discuss later that impact of pounding on building failure has been grossly over stated. However, pounding impacts on %NBS in a mechanical fashion and the calibration means that it can have an absurdly large impact. The %NBS can be reduced by up to 84 percent. So a score of say 50 percent falls to 8 percent to take account of a factor, which hardly ever causes building failures. This cannot be reliably mitigated by the subjective assessments that feed in the F factor. This is limited to a 50 percent uplift for buildings of over three stories, which would just role back the %NBS to 12 percent, even if the assessor believed that pounding was not a material risk. This would also mean that there would be no room left to take positive factors into account.

The pounding adjustment factors should be scrapped. If an engineer truly believes that pounding is an issue, then this can be captured through the F factor. The engineer would have to justify their quantification of the impact. The default, as for the DEA, should be that there be no pounding adjustment.

Limits on %NBS 'uplifts'

The maximum uplifts of 150% for buildings of up to 3 stories, and only 50% for buildings of more 3 stories is arbitrary and has not been justified. There is no need for any limit providing the engineer can justify his assessments. If there is a limit then the gap between the two high classes should be much smaller.

Ductility factor

The ductility factor is critical. Realistic, not very low assessments should be used.

Failure to assess against a moderate earthquake

Critical structural weaknesses are assessed against their impact in a severe earthquake. On the face of it this represents a more conservative approach than in NZSEE 2006 where the test was purported to be the design strength earthquake. However, this wasn't true, because no attempt was made to calibrate to differing design strength earthquakes. The implicit test was always some unquantified severe earthquake.

The 'severe' earthquake test is unlawful. Engineers must make their assessments on a moderate earthquake test.

Test case building example

Many of the problems with the IEP are illustrated in the IEP assessment of one of the test case buildings by the Wellington City Council

%NBS assessment absurdly low

The building was assessed at 2.8%NBS. A moment's thought should have suggested to the Council that something was seriously wrong. What the results were indicating is that the building would be likely to collapse in an earthquake 2.8% as strong as the Wellington design strength earthquake. That is the z-score is 0.012g. Given the relationship between g. and the New Zealand Modified Merclalli Intensity Scale discussed above, 0.012g is equivalent to the passing of a light truck. The building has been passed by light trucks, heavy trucks, and buses for decades. It has never collapsed.

Technical reasons for low score

Pounding 'vulnerability' reduced the score by 72 percent. An attempt was made to mitigate this through the F factor uplift of 1.5 but this had only a small effect. Multiplying a small number by 1.5 still gives a small number.

The building was found to have severe vertical irregularity, because the ground floor was 3.6 metres high and the other floors 3 metres. This resulted in a reduction of the %NBS of 60%.

However, the engineer had not looked at the plans, which showed that the upper floors were about 3.3 metres high. A subsequent DSA found no vertical material irregularity. The Council's review document stated that the assessment was checked against the plans. That statement was false. The Council admitted at the Determination hearing that they had not reviewed the plans. They undertook to come back to the Determination to explain why the review had not taken place. They never did. We suspect that falsification of the review documents might have been systemic and not something the Council wanted to talk about. We will be pursuing the matter.

A short column effect resulted in another 30 percent reduction.

The engineer classified the building as standalone, when it should have been clear, even from a cursory visual inspection that it was structurally joined to the next building (which had a %NBS of more than 34). No pounding potential was identified at that point so the engineer must have concluded that there was a common wall.

The building was identified as been designed pre-1935. But it had been strengthened (in1995), when there was change of use to requirement to meet the code requirements. This strengthening was ignored despite the Council's policy that there was a prima facie case that the building should not have been earthquake prone, and despite the IEP requirement that the code the building was strengthening to, be identified.

Council strategy and culture

The Council had an incentive to accept low %NBS scores because it did not want to spend money on assessments, so they skipped critical parts of the process, particularly the plan inspection. A very low % NBS was an advantage to them because they could claim to be satisfied (as required in law), that the building was earthquake prone, despite the lack of proper process. The score was so low that the building just had to be earthquake prone.

Another completely unacceptable aspect of this affair was that at the time of the Determination hearing we were not aware of the significance of the change of use strengthening (due to the negligence of the engineers who had recently done a DSA for the building). The Council knew, and had a duty to disclose that to us. Instead, they held off giving us the strengthening file until days before the hearing, no doubt to secure a tactical advantage.

Under the new regime engineers will be engaged by the building owner to do the IEP. This should be an advantage. The engineer should have has an obligation to his client, and hopeful we will see more professional IEP assessments.

Unreinforced masonry buildings IEP

Unreinforced masonry building can be assessed using an attribute scoring methodology. The best score on each of the 13 attributes is 0 for the best assessment and the worst is 3. The overall score can range from 0 to 39.

The methodology appears to have been calibrated so a large number of buildings, even in the lowest seismic areas, will be designated as earthquake prone. To get above 34%NBS , in a low risk area, requires a score of between 10 and 15. For medium risk area it is 5-10 and for high seismic areas a score of 1 for every attribute except 2. It only takes one material transgression to fail.

There is no justification for the calibrations. In particular, there is no explanation of why %NBS scores of 5 and 10 percent have been assigned to critical attribute bands. Nor is or any evidence that the system has been tested to ensure that the outcomes are sensible and will generate consistent results.

This methodology is unreliable and should not be used for IEP assessments.

Part eight: Technical and other issues

Joint buildings

The section on joint buildings correctly points out that buildings that sit astride legal property boundaries (typically with a common wall) have to be considered as a whole in the assessment. That is sensible, as it is an engineering nonsense to make an assessment for one half of the building, as if the other side didn't exist.

Where this section goes adrift, however, is in the subsequent ratings of the buildings. If one half of the building is 30%NBS and the other side 50%NBS then both sides are rated at 30%. There is nothing the owner of the stronger side can do to improve the rating of his building. This doesn't make sense. Providing the owner's %NBS calculation takes account of its connection to the other property then the 50%NBS is the relevant assessment.

Building Pounding - Engineering alternative facts

Pounding importance grossly overstated

The section on pounding is a case example of 'accentuating the negative and ignoring the positive'. The representation of the literature is misleading and the importance of the pounding factor is grossly overstated.

This may not be so important with DEEs where engineers can exercise more judgement and where the default position is that pounding should be ignored, but an IEP is much more mechanical and the exaggeration of the pounding effect can have a significant impact on the reported %NBS.

The discussion and analysis of pounding risk is in the Appendix C2B. It begins:

Numerous pounding damage surveys and numerical and analytical pounding studies have been undertaken in recent years, especially after the 1985 Mexico City earthquake (Bertero, 1986) which caused an unusually large number of building failures. In the 2011 Littleton (Canterbury) earthquake, seismic pounding was also observed to cause significant damage in a number of URM buildings (Cole et al., 2011).

The authority in this area is Anagnostopoulos. In a 1998 article[12] he carefully examined 11 major earthquakes (9 reported in a previous article) where pounding had been reported, to

[12] Anagnostopoulos S.A (1998) Building Pounding re-examined: How serious a problem is it' Paper no. 2108 Eleventh World Conference on Earthquake Engineering

assess the significance of pounding for building damage. He noted that there were at least as many major earthquakes where pounding was not cited as a problem He concluded:

"The number of buildings that have suffered stuctural damage due to past earthquakes is a minute percentage of all buildings that were in contact with each other.

The Mexico City earthquake in the 1980s is often cited as a case when pounding has been a significant cause of collapse. He found that this was overstated.

"pounding could have been a significant factor for damage in only 3% to 4.5 % of the total number of buildings that suffered serious damage or collapse. Therefore, even in this case, this percentage is quite small and becomes insignificant if one considers the total population of buildings that were subject to pounding." [13]

There is no reference to key Anagnostopoulos papers in the references. With respect to Christchurch the Cole paper concluded only that pounding only might have contributed to building collapse in just two cases, both URM buildings. There was no evidence that it was a material contributor to structural damage to RC buildings.

Anagnostopoulos concludes that pounding is only an issue when there are large differences in mass and heights. However, despite acknowledging that the analytical studies do not produce conclusive results, the appendix takes a much more expansive view of the evidence and sets out six typologies that are at material risk.

From observations of earthquake damage, six critical building configurations have been identified as vulnerable to seismic pounding (Jeng and Tzeng, 2000; Cole et al., 2011; Kasai et al., 1992).

This statement is misleading. The Jeng and Tzeng article did not look at empirical damage at all. They undertook a theoretical assessment of uncertain robustness. The abstract of their article is presented below.

Taipei City, with its high seismicity, soft soil condition, and many tall buildings without proper seismic separation, is vulnerable to seismic pounding destruction similar to that occurred in Mexico City during the 1985 earthquake. A survey of the seismic separation is performed to reveal the current status and identify the buildings susceptible to pounding damage. Dynamic pounding analyses of model frame structures are also conducted to obtain the story shear amplification. From the computed story shear amplification, the measured gap, and the relative position of the buildings, a damage index is assigned for each building and compared with a proposed damage criterion based on story shear amplification to define its damage level. The conclusion is that pounding mitigation is urgently needed for a large number of existing buildings.

[13] Anagnostopoulos (2008) cited in EAG bibliograpjy

Cole 2011 (Darfield) found that there was little pounding damage and sometimes no damage where it was expected to occur. It is more a refutation rather than a confirmation of the typology.

We were unable to access the Kasai article, but it is unlikely that they would have been able to base a typology on empirical evidence when we know that there is so little where pounding had a material effect.

Finally, the statements about the high vulnerability of URM buildings to pounding is not consistent with the discussion in C9 on URM buildings. It reads:

The effect of pounding damage to masonry buildings is generally less than for a frame or rigid diaphragm building as it tends to be more localised. Because of the high stiffness and often low height of these buildings, the impact forces are high frequency and associated with small displacements, and therefore carry less energy. Façades and other walls in the same alignment pound in their strong direction. Pounding between parallel walls where the pounding energy is dispersed over a large area will have a smaller effect than localised punching. In addition to the above, most URM buildings have timber floors which have little mass to cause pounding. Similarly, with flexible diaphragms the impact energy is absorbed over a larger displacement.

Timber framed buildings (C9)

The evidence

The section on timber frame buildings says that in general low-rise timber framed buildings have performed extremely well with regard to life safety in large earthquakes.

A 2008 survey of observed damage to timber framed buildings caused by eight significant earthquakes in the USA, Canada, New Zealand and Japan concluded that two-storey timber framed buildings largely met the life safety criterion required by design standards. The fatalities recorded in timber framed buildings were predominantly in larger (three-storey to four-storey) buildings as a result of external hazards such as landslides. When subject to peak ground accelerations in excess of 0.6 g some Californian two-storey timber buildings exhibited soft-storey behaviour and suffered partial collapse; while in Kobe, Japan, minimal damage was observed.

Similarly, a study of timber framed housing in the Christchurch earthquake of 22 February 2011 showed that they performed extremely well for life safety (Buchanan). The only recorded fatalities in timber framed residential buildings were attributed to rockfall.

The performance of engineered timber buildings was also reviewed by Buchanan et al. (2011b). The authors noted that these buildings generally performed well both for life safety and serviceability.

The document also reports on experimental testing of New Zealand school buildings and housing corporation two story multi-unit buildings. These tests found that the NZSEE models grossly understated the actual capacity of these buildings (by factors of 5 or more).

The empirical evidence and testing relate to events well in excess of moderate earthquakes, and generally in excess of Wellington design strength earthquakes.

The paper concludes that in general timber framed should not be found to be earthquake prone '*unless a particularly vulnerable aspect is present and, even then, this would need to be one which would lead to a significant life safety hazard in the event of failure'.*

Response to the evidence

The methodology makes some concession to the evidence. A structural performance factor[14] of 0.5 can be used (this has the effect of doubling the measured % NBS compare to a factor of 1) but it is not much of a concession compared to the standard Sp of 0.7 typically applied in IEPs.

However, the way is left open for engineers, if they are of mind to, to find enough 'weakness' to unwind the 'concession'.

Ductility

The default ductility assumption, which scales the reported %NBS, is extremely conservative.

For a force based assessment of a timber building it is generally acceptable to use a structural ductility factor where a ductile mechanism can be identified and the factor can be justified. If the mechanism(s) cannot be identified with certainty, the mechanism should be assumed to be brittle and the structural ductility factor limited to 1.25.

At a ductility of 1.25 it is assumes that the building is brittle, and behaves much like a brick building. A higher factor has to be justified by the existence of an alternative load path. Some engineers won't bother, or won't find an alternative load path, and taking the most conservative approach, or make only a limited adjustment despite the very strong evidence that timber framed buildings are ductile.

One of the comments in the document states:

The general good performance of timber buildings in earthquakes is considered to be due, at least in part, to their relatively low supported mass ***and ability to deform considerably (via deformation in the connections (****our emphasis***)** *without loss of gravity load support.*

[14] A structural performance factor is a judgment factor that can be used to increase or decrease the %NBS outcome.

There is no reference to alternative load paths here, but load paths is the only criterion for a higher ductility. The ability to deform in the connections is a test of ductility.

We note the following comment in the document 'bracing demands given in NZS 3604:2011 are derived from μ = 3.5 and Sp = 0.70,' which raises the question of how does the default ductility value of 1.25 relate to the 3.5 value?

Other possibilities for downgrades

The document states:

Assessors should consider any particular vulnerabilities or weaknesses within the structure and use their engineering judgement to consider the effects of these.

Some likely issues include: horizontal irregularity, vertical irregularity, heavy roofs and masonry veneer claddings, building condition, foundations and slope considerations, geotechnical hazards, and stairs. These are discussed below, together with suggestions about how to alter the recommended ductility and structural performance factors accordingly.

This is despite, in all of the empirical analysis there is almost no evidence (with the possible exception of soft story development) that any of these factors have played a role in life threatening collapse of timber framed buildings, in strong earthquakes, let alone moderate earthquakes.

On vertical irregularities, an engineering favourite has been the identification of glass window shopfronts in narrow timber buildings as a critical structural weakness in the IEP process. We are unaware of any evidence that this configuration has led to building failures.

The possible exception to this is slope conditions. That may be relevant to the risk of the building. It may be vulnerable, but, as noted above where does it get you in terms of whether the building should be strengthened?

Failure to test the methodology

Again there has been a failure to test the methodology (or at least report that this had been done). An obvious test would have been against the buildings that had undergone destructive testing. If they did not receive a high %NBS score then the model should have been revisited. Blind testing of various building types should also have been done. Though we note here that blind testing may not necessarily to a good guide to eventual behaviour in the field. An engineer may be on his 'best behaviour' in a test environment, and put out higher ratings, but may revert to type in a commercial environment. And as always council's attitudes will be critical. If there are of a mind to impose 'high standards' then we could still get a swath of 'earthquake prone' wooden buildings. We have come across examples where timber framed buildings have recently been rated as earthquake prone.

Reinforced concrete buildings (C-5)

This part updates NZSEE2006 for recent technical developments. What is misleading is the way it presents the lessons of the Christchurch earthquake.

Recent experience has highlighted a number of key structural weaknesses and failure mechanisms, either at an element level or at a global system level. It has not only ***confirmed that pre-1970s RC buildings – as expected – have a potentially high inherent seismic vulnerability***,(our emphasis*) but also that some modern (e.g. post-1980s) RC buildings can be expected to perform poorly. In some cases, this has led to catastrophic collapses or "near misses". This has been a wake-up call as it has identified a "new generation" of potentially vulnerable buildings that need to be scrutinised with care*.

What we are not told is that the pre-70s RC buildings were subject to forces that were around **10 times** the Christchurch moderate earthquake levels, and two to three times the design strength levels. As we discussed above the older buildings did not perform any worse than the new ones.

What seems to be the test of 'poor performance' here, is not that the buildings failed, but that they were damaged - hence the string of pictures of earthquake damage in a few buildings. This is interpreted as evidence of high 'inherent' seismic vulnerability. The point that should have been emphasised is that they did not collapse in a severe earthquake.

What Christchurch demonstrated was that that NZSEE model is hopelessly miscalibrated. But this evidence has been ignored. The pretense is maintained that a 33% NBS building will exceed its ultimate capacity in a moderate earthquake.

Unreinforced masonry buildings (C8)

The section on unreinforced masonry buildings provides a new set of analytical techniques and guidance, but in the end a good deal is left to the engineer's discretion because URM buildings do not lend themselves to simple calculations that generate a precise %NBS number.

The general tenor of the discussion is that because URM are more vulnerable than reinforced concrete frame buildings a more cautious approach should be taken in the analytical work.

We suspect that in practice engineers will interpret the advice that pretty much all URM buildings regardless of the seismicity of where they are located will be found to be earthquake prone.

In legal terms this will be plain wrong. If we exclude the very weakest buildings (or weak parts such as parapets and decorations), then it is highly unlikely that a URM building, in a low seismic zone, will have its ultimate capacity exceeded in a moderate earthquake. There is a huge wealth of evidence that URM buildings do not collapse when subject to a force of 0.043g.

So how could the EAG come to the conclusion that that they will.

First, they do not address the legal test at all. There is no evidence in the document that they systematically considered the evidence of URM building performance in any earthquake let alone a moderate earthquake.

Second, they set up a relative seismic capacity test. However, there is no new building standard so one is invented for the occasion. The problem here is that there is no discussion of how this new building standard has been calibrated. It matters as to whether it has been set to an expected value standard or to a very low probability. If the latter, which we strongly suspect, then a building may be 'earthquake prone' because it is less than one ninth the capacity as the 'new building'. As there is no extant new building standard it is a simple matter to calibrate the ersatz standard to increase the denominator in the %NBS calculation so that nearly all URM buildings are captured.

As the new URM methodology has not been tested at all we don't know how it will work in practice, and neither, we suspect do the authors of this section.

Third, critical structural and possibly severe structural weakness will be identified to justify a downgrading of an initial %NBS.

Mitigating seismic hazard

From the discussion of seismic hazard (C8.12) it appears that mitigation is expected to be required for pretty much all URM buildings.

The overarching problem is that New Zealand's URM building stock is simply not designed for earthquake loads and lacks a basic degree of connection between structural elements to allow all parts of the building to act together (Goodwin et al., 2011).

The basic approach to improving the seismic performance of URM buildings is to:

- *Secure all unrestrained parts that represent falling hazards to the public (e.g. chimneys, parapets and ornaments)*
- *Improve the wall-diaphragm connections or provide alternative load paths; improve the diaphragm; and improve the performance of the face-loaded walls (gables, facades and other walls) by improving the configuration of the building and in-plane walls*
- *Strengthen specific structural elements, and consider adding new structural components to provide extra support for the building.*

What this ignores is that particularly in low seismic areas a URM building can have weaknesses but still comply with the moderate (and even the design strengthen) earthquake test. There is some acknowledgement that seismicity matters, but not necessarily too much and the suggested response is very vague.

When you are developing strengthening options, note that differing levels of seismic hazard will mean that a solution advised in a high seismic area could be too conservative in a low seismic area. Also note that even though a building may have more than 34%NBS seismic capacity, if that is limited by a brittle mode of failure and/or the failure mode could trigger a sequence of failure of other elements, the risk of failure of the limiting element should be carefully assessed and mitigated.

Evidence on the earthquake prone status of URM buildings

If most URM buildings will be caught, then this will be stark contrast to the estimate in a 2010 paper[15].

To calculate the number of EPB URM in New Zealand the %NBS of 58 Auckland buildings was calculated using the IEP. The results (mean and standard deviation) were then applied to other locations by adjusting for relative Z-scores.

For Auckland, the mean %NBS was 60, and only a small number would have been earthquake prone (under 34% NBs). On the other hand mean %NBS outcomes in the seismically active areas were in the lower 20s and a high percentage would have been earthquake prone. Overall it was estimated that 35% of URM buildings would be earthquake prone. Further this estimate was thought to be conservative.

*It must be recognised that the analysis presented here is essentially qualitative in nature and can be expected to **overestimate** the number of poorly performing URM buildings, primarily because of the conservative nature of the IEP. Nevertheless, as an informative estimate of the nature of the vulnerability of New Zealand's URM building stock, this analysis is considered robust.*

Talking up the risk in a low seismic area

Quite by chance we stumbled across an example of engineers talking up the risk of buildings. It is a 2014 report to the Whangarei District Council[16]. The purpose of the report was to give guidance on the expected seismic performance of an existing building, with URM and RC parts, and an estimate of the cost of strengthening work.

There is a cursory description of the building, the general inadequacy of URM buildings are described and it is claimed

Virtually all URM buildings are likely to be earthquake prone unless they have already been strengthened.

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[15] Ingham (2010) op.cit.

[16] Extra-ordinary Whangarei District Council 12 November 2014 Seismic Costing Assessment

It was concluded *"Based on the age and type of construction it is expected that this part of the building would be Grade E, classified as potentially Earthquake Prone and a very high life-safety risk."*

The reinforced concrete building was described as high risk.

What is not explained is that Whangarei is a low seismic risk area and that this would effect the EPB assessment. The claim that the building parts were a very high/high life-safety risk was a gross exaggeration.

The report was not based on a DSA or even an IEP. The engineers spent two days on the report so it is difficult to understand why an IEP was not produced. It would have taken no more than 30 minutes to do so. It is likely that IEPs would have shown that neither building part was earthquake prone.

Validation and testing

There is no evidence of the kinds of validation and testing processes that we would expect to see in the development of methodologies that will have a multi-billion dollar impact on New Zealand. There is a mention that there was some low level external validation but there is no reference to any actual report.

Overall, the development of the framework has been unprofessional.

This is not necessarily a comment on the technical competence of the engineers who have contributed to individual analytical pieces. It is a comment on how all of the pieces fit together to provide a risk based seismic risk management framework that has been properly tested and validated.

FEMA example

The contrast with the processes that the US Federal Emergency Management Authority (FEMA) went through in the development of their next generation model is stark. The FEMA approach is described in Heinz 2014[17]

Extensive quality assurance measures were undertaken to validate the basic methodology and products as part of the Phase 1 developmental process. These included:

(1) independent review of the underlying theory and methods by a validation and verification team;

[17] Heintz J.A., Hamburger R.O., Mahoney M. (2014) FEMA P-58 Phase 2 – 'Development of performance-based seismic design criteria'. in 10th US National Conference on Earthquake Engineering – Frontiers of Earthquake Engineering, Anchorage Alaska July 21-25 2014.

(2) review of the component fragility development process by teams of engineers and researchers familiar with the seismic performance of structural and non-structural components;

(3) detailed review of the quality of data and consistent application of procedures by a panel of experts knowledgeable in structural reliability theory;

(4) independent review of the calculation algorithms embedded in the supporting electronic materials; and

(5) a series of performance evaluations conducted on representative building types to explore the rationality of results.

Legal signoff

Because the New Zealand Guidance documents describe how Local Authorities will ensure compliance with a legal standard there should also have been a legal sign-off that the documents give effect to the law. It seems obvious that there has been no legal input, let alone a sign-off.