

Helping clients visualise seismic risk

J.N. Horsfield, H.M. Ferner & W.Y. Kam

Beca Ltd, Auckland



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ABSTRACT: Following the 2010/2011 Canterbury Earthquakes, there has been a renewed interest in seismic risk. And, more than ever, structural engineers are required to communicate highly technical information to those with an interest in buildings.

The structural engineering profession is littered with jargon and technically complex principles. Therefore, it is important we understand the way we communicate among our peers must be very different from the way we communicate with our clients, even though we are essentially talking about the same thing.

With specific reference to seismic risk in buildings, this paper presents a selection of examples of visual communication techniques designed to explain relatively complex technical principles in an engaging and easy to understand way.

The paper also aims to encourage structural engineers to focus on their consulting skills as a means to lift standards within our profession and positively influence the perception of structural engineers in our community.

1 INTRODUCTION

Following the 2010/2011 Canterbury Earthquakes, there has been a renewed interest in seismic risk. And, more than ever, structural engineers are required to communicate highly technical information to those with an interest in buildings, including owners, facility managers, and tenants, that is our clients.

This is made particularly challenging given the uncertainties that exist in the seismic performance of buildings, the probabilistic nature of seismic risk assessment, and the more deterministic legislative requirements that exist under Earthquake Prone Building requirements of the New Zealand Building Act.

Through a series of illustrative examples, this paper shares some of our lessons learnt in communicating the complex and technical concepts of seismic risk to our clients and various stakeholders.

2 HELPING CLIENT TO UNDERSTAND SEISMIC RISK JARGON

2.1 Peer to peer communication

In the structural engineering profession we enjoy countless opportunities to exchange knowledge with our peers. We attend conferences and seminars, read journals and blogs and have the opportunity to learn from each other in a myriad of ways. And, much like any other industry, such as computing, or the medical and legal professions, our industry is littered with jargon that means an enormous amount to us and our peers, but very little to those not directly involved in structural engineering. Therefore, it is important to understand that the way we communicate in these circles must be very different from the way we communicate outside them, even though we are essentially talking about the same thing.

So whilst a peer-to-peer conversation is able to rely upon jargon to convey a message, the way we speak about issues such as ductility, structural irregularity, plastic hinges, critical structural weaknesses and the like must be tailored appropriately to the audience we are addressing. We have to alter our peer-to-peer communication styles so that our non-technical clients understand very technical information, and, like everything else in our industry, this takes practice.

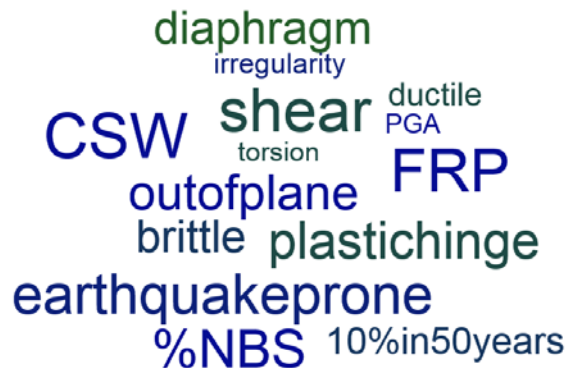


Figure 1. Technical jargon associated with seismic assessment and performance of existing buildings.

2.2 Consultant to client communication - The carrot and the coat hanger

The terms ductile and brittle are well understood by structural engineers, especially those practising in a seismic environment. These terms are often not well understood by our clients. To help our clients gain an appreciation of the meaning of these terms, we use an analogy that they are able to understand. A fresh carrot exhibits classic elastic behaviour when subjected to modest bending. When the bending action is released the carrot returns to its original un-deformed state. Obviously, when the bending is increased the carrot snaps. The wire coat hanger behaves in a similar manner to the carrot when subjected to modest bending actions, but rather than snapping, deforms permanently when subject to increased bending; a process that can be repeated several times without the coat hanger breaking. This simple experiment may seem trivial to the seasoned structural engineer. However, our clients find it enlightening and it underpins our seismic performance communications with them.

3 HELPING CLIENTS UNDERSTAND SEISMIC RISK

3.1 Concept of seismic risk

Catastrophic events heighten the perception of risk and can lead to irrational behaviour. Aeroplane crashes exemplify this, where a very rare but catastrophic event is able to invoke, what is to many, an irrational fear of flying. Major earthquake events have a tendency to invoke a similar response, and often at a societal rather than individual level. The Canterbury earthquake sequence earlier this decade has arguably induced this response in New Zealand.

Our client's understanding and perception of risk posed by buildings in earthquakes can vary significantly. The majority of clients prefer a deterministic outcome from seismic assessment. They want to know does their building 'pass or fail'. Few understand the structural behaviour of buildings in an earthquake and the probabilistic nature of seismic engineering.

Many clients do not understand risk, and often confuse risk and hazard. It is important to help clients understand the difference so that they are able to begin the process of making informed decisions.

$$\text{Risk} = \text{Hazard} \times \text{Vulnerability} \times \text{Consequences}$$

This formula defines risk as a function of seismic hazard over which our clients have no control, the vulnerabilities that exist in their building stock over which they do have control, and consequences which they can assess.

3.2 The wider spectrum of risk

It is helpful to consider the wider spectrum of risk posed by natural disasters. The following diagram illustrates, broadly speaking, where a large urban earthquake sits relative to other events. A large urban earthquake may be expected to occur on average in New Zealand once in a life time.

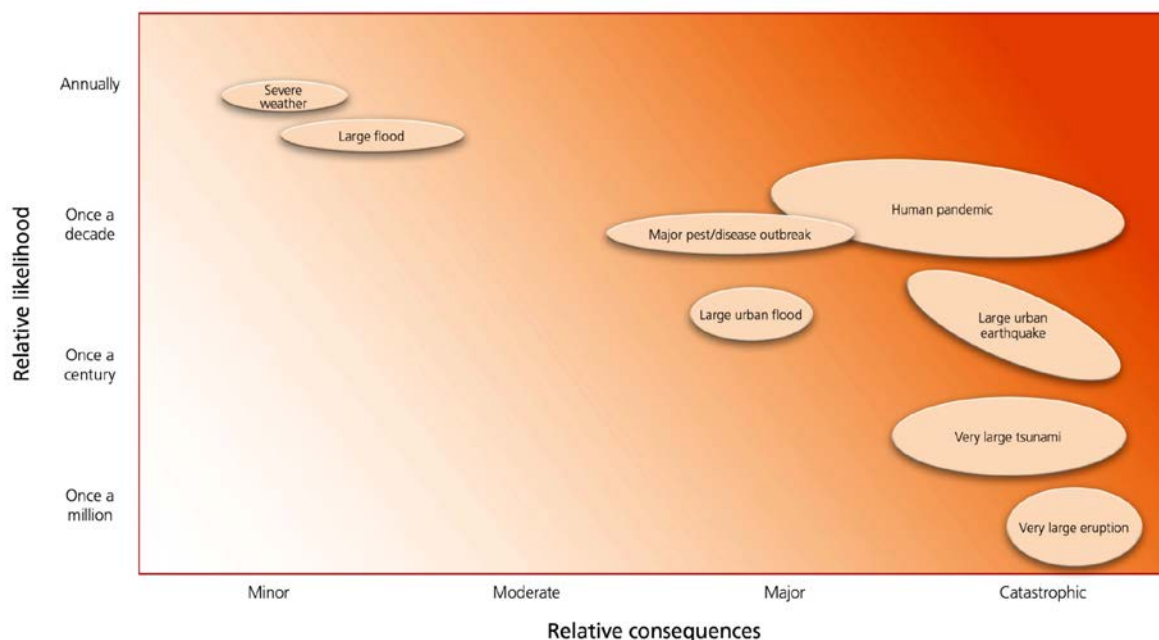


Figure 2. Natural Disaster – Wider Spectrum of Risk.

This helps clients to understand where a large urban earthquake sits in relation to other naturally occurring events in New Zealand.

3.3 Comparing seismic risk with other activities

Clients find it helpful to compare seismic risk with other activities in which they may engage. This provides a perspective from which they can begin to frame their own appetite for risk. The following table compares the risk of fatality for a range of common human activities and compares these, roughly speaking, to the risk posed by an Earthquake Prone Building.

Table 1. Relative risk a variety of human activities.

Activity	Indicative risks/Fatality risk per year
Smoker: 20 cigarettes per day	1 in 250
Drinkers: 1 bottle of wine per day	1 in 300
Drivers: motorcycling sports	1 in 700
Car drivers (20–24 year olds)	1 in 5,000
Pedestrians, household workers	1 in 10,000
10,000km/year car travellers	1 in 10,000
Hikers in the mountains	1 in 20,000
Flyers: Plane crashes per flight	1 in 100,000
Living in buildings: death in fire	1 in 100,000
Death by lightning strike	1 in 1,000,000
Death by earthquake historically in NZ	1 in 1,000,000
Winning lotto (odds of winning, not fatality)	1 in 4,000,000

**Earthquake
Prone Building**

3.4 Conveying %NBS and seismic risk

In New Zealand the seismic risk associated with buildings is commonly expressed as a percentage of New Building Standard (%NBS) as defined by the New Zealand Society for Earthquake Engineering Assessment and Improvement of the Structural Performance of Buildings in Earthquakes (NZSEE Guidelines, 2006). The process of assessing existing buildings involves making an assessment of performance against the standard required for a new building.

A key message that should be conveyed to clients is the uncertainty that underlies the %NBS result. The authors have seen many examples of spuriously accurate %NBS assessments where the performance is reported to 4 significant figures. Clearly this belies the accuracy with which and assessment can be undertaken, particularly an initial qualitative assessment. It is arguably more appropriate to report in a range or Grade.

It is important to note that this assessment is designed primarily for the purpose of conveying risk in respect of the life safety performance of the structural systems. Risks associated with the performance of non-structural items and impacts on business continuity require separate special study.

We have developed a graphical representation of the NZSEE grading system for earthquake risk as shown in Figure 3.

%NBS	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Seismic Grade	E		D		C			B	A		A+
Relative Risk	> 25 times		10-25 times		5-10 times			2-5 times	1-2 times		< 1 times
Designation as per Building Act 2004	Earthquake Prone Building (%NBS <=33)				Earthquake Risk Building (%NBS <67)			Low Potential Earthquake Risk (%NBS >=67)			

Figure 3. Spectrum of %NBS and relative seismic risk.

The overlapping colour spectrum illustrates that relative risk associated with %NBS transitions more smoothly than the grade changes might imply. The use of this relative risk measure and the complex underlying seismic assessment methodology necessitates careful communication of what is meant by %NBS and the associated seismic risk.

4 HELPING CLIENTS TO UNDERSTAND HOW BUILDINGS BEHAVE IN AN EARTHQUAKE

4.1 Uncertainty of building performance during an earthquake

It is important to convey to our clients that for most buildings it is almost impossible predict the onset of collapse in an earthquake. When we undertake an assessment we are seeking to identify load paths, and test the reliability and resilience of these load paths. Or, conversely we are seeking to identify vulnerabilities in the building that may lead to poor seismic performance. These are important points as they emphasise the need to consider resilience in making a %NBS assessment.

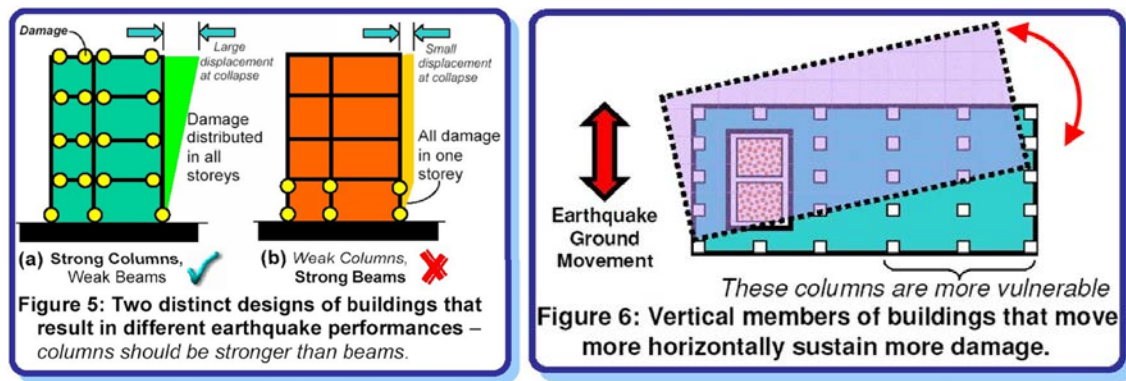


Figure 4. Illustrating building performance and vulnerability.

Figure 4 illustrated an effective means of communicating the concept of desirable and undesirable building performance and the concept of critical structural weakness and vulnerability.

4.2 Communicating uncertainty in the assessment of building performance

It is important our clients understand the overarching philosophy of the New Zealand Code and that buildings should not collapse even if the level of earthquake shaking significantly exceeds the design level of shaking.

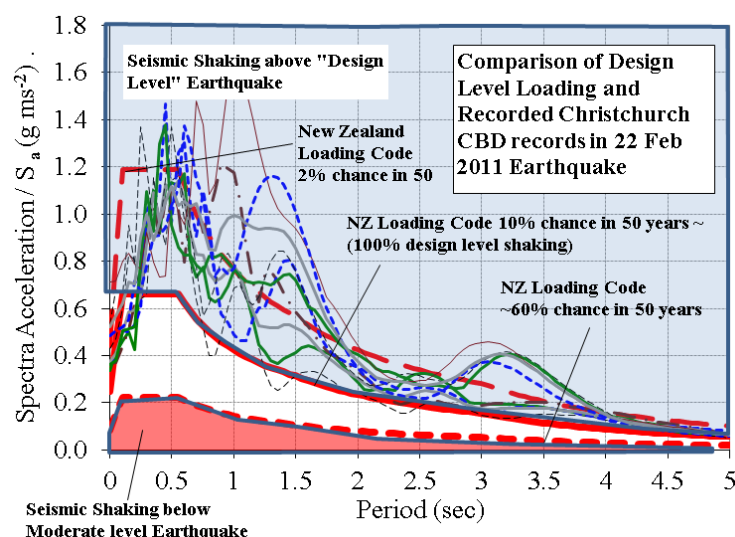


Figure 5. Comparison of “Design Level” and Moderate Level Shaking (33%) with the recorded horizontal acceleration response spectra (5%-damped) in Christchurch CBD from the 22 February 2011 Mw 6.2 earthquake.

Figure 5 reinforces the point that whilst the recorded ground shaking in the 22 February 2011 Christchurch Earthquake greatly exceeded the design level of shaking, with a few notable except it was mainly un-strengthened unreinforced masonry buildings that suffered collapse.

4.3 Explaining seismic load paths and potential failure mechanisms

Visual imagery is a powerful way to convey relatively complex ideas to non-structural engineers.

The following diagrams illustrate how seismic loads flow through a building and its foundation and into the ground.

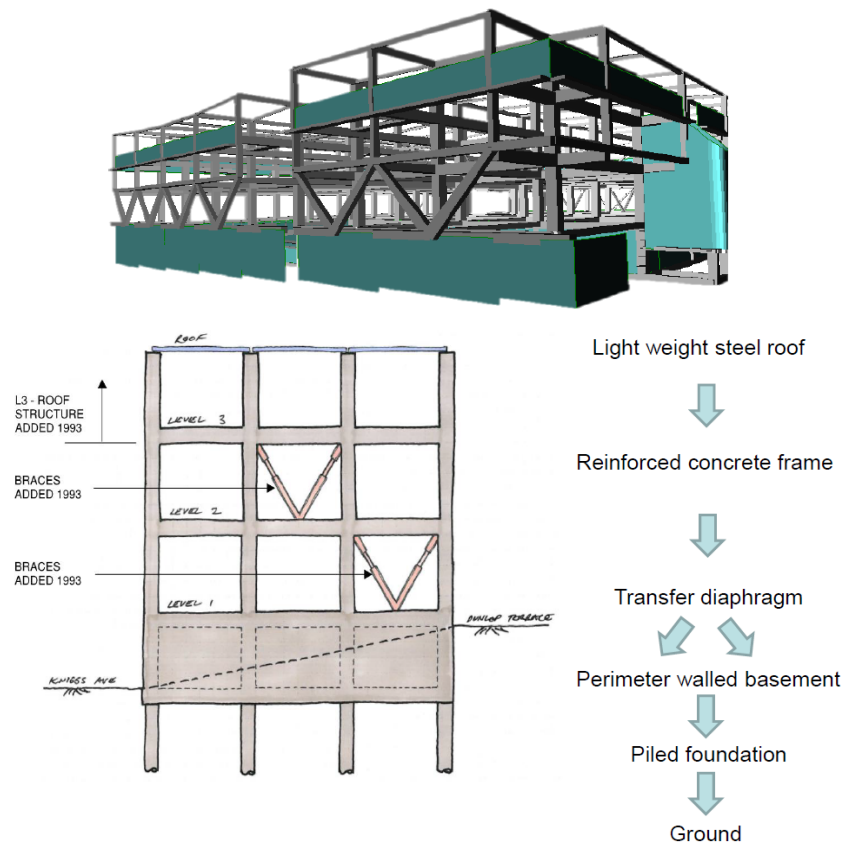


Figure 6. Describing load path.

Figure 7 depicts how hand sketches may be used to good effect to describe potential failure mechanisms. In this case in-plane and out of plane behaviour of masonry infill panels and loads being function of height.

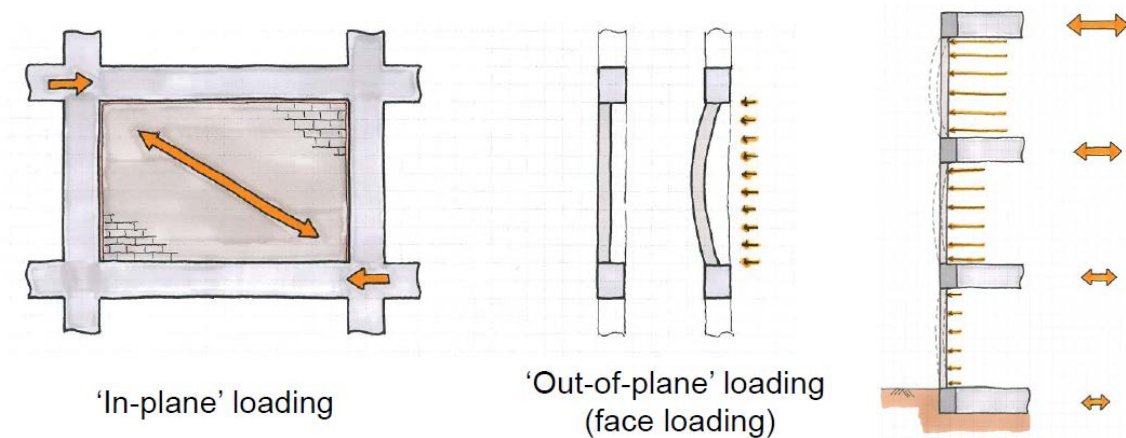


Figure 7. Describing potential failure mechanisms.

Visual manipulation of photographs of existing intact buildings can be used to great effect to illustrate the type of failures that were common in the Christchurch Earthquakes. Figures 8 to 10 illustrate the vulnerability of unreinforced masonry gable wall construction. Presenting these images with actual examples of similar failures that occurred during the Christchurch earthquakes conveys a powerful message about likely behaviour.



Figure 8. Gable wall vulnerability – photo manipulation.



Figure 9. Out-of-plane failure and collapse of unreinforced masonry gable end walls and external walls.



Figure 10. Comparison of similar looking streetscape.

5 COMMUNICATING THE STATUS OF A BUILDING PORTFOLIO

5.1 Explaining the seismic assessment process

Visual communication can be used to good effect to convey the fundamental principles of the seismic assessment process. Figure 11 illustrates how the relative complexity, level of engineering effort, quality of inputs and overall confidence in output increases from provisional assessment and initial assessments through to detailed seismic assessments and implementing strengthening. MBIE (2014) has also produced a useful guidance document for landlord and territorial authorities explaining the seismic assessment process.

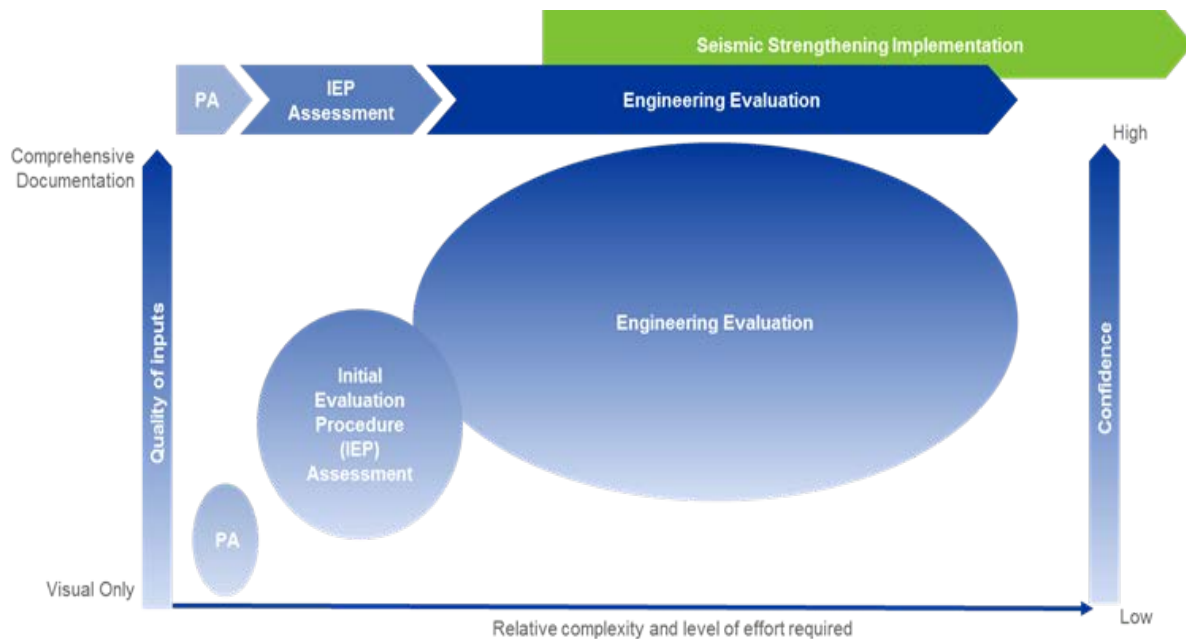


Figure 11. Seismic Risk Mitigation Process.

The consulting process conveyed in this diagram is akin to the way in which a doctor may assess a patient from initial triage, through closer examination, detailed testing, and surgery.

5.2 Presenting the status of a building portfolio

Many of our clients own nationwide portfolios of buildings. These clients want to understand the geographical spread of their seismic risk and the nature of that risk at each location. Figure 12 presents a visual summary of a national portfolio. The size of each circle indicates the scale of the operation at each site, i.e. number of buildings. While the segmented colours indicate the seismic risk status of the buildings at each site.

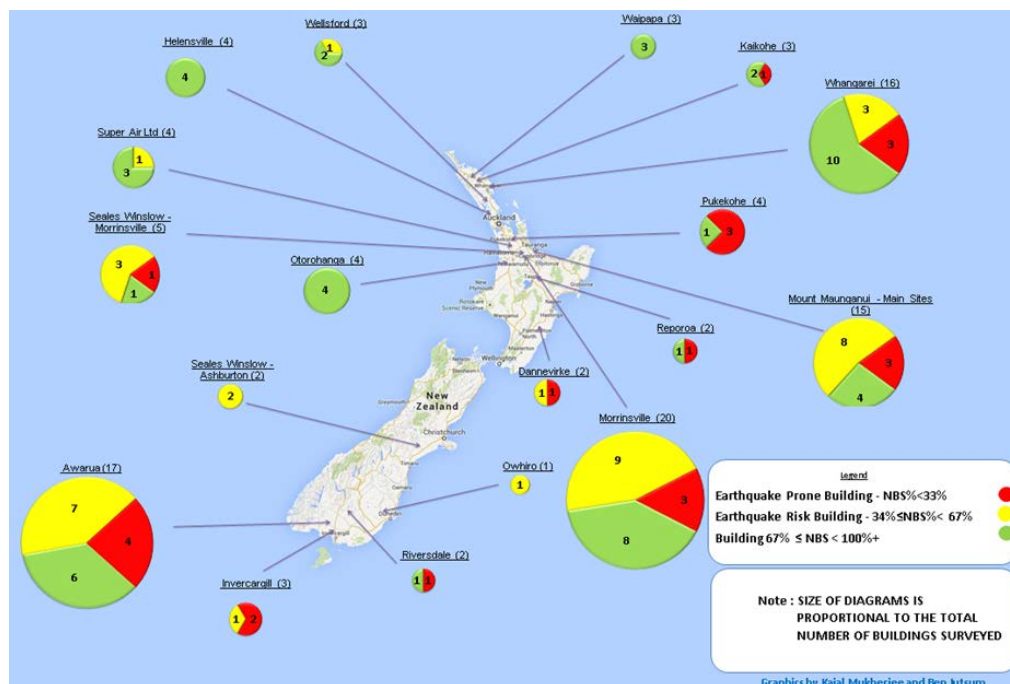


Figure 12. Summary of seismic assessment of a nationwide portfolio of buildings.

6 HELPING CLIENTS TO UNDERSTAND SEISMIC RETROFIT SOLUTIONS

It is not uncommon for owners of buildings commissioning seismic retrofit work to have no technical background and, unsurprisingly, the majority have little knowledge of the fundamental principles of structural engineering. Composite drawings incorporating sketches, photographs and other innovative techniques are an effective means of conveying the structural engineer's design intent.

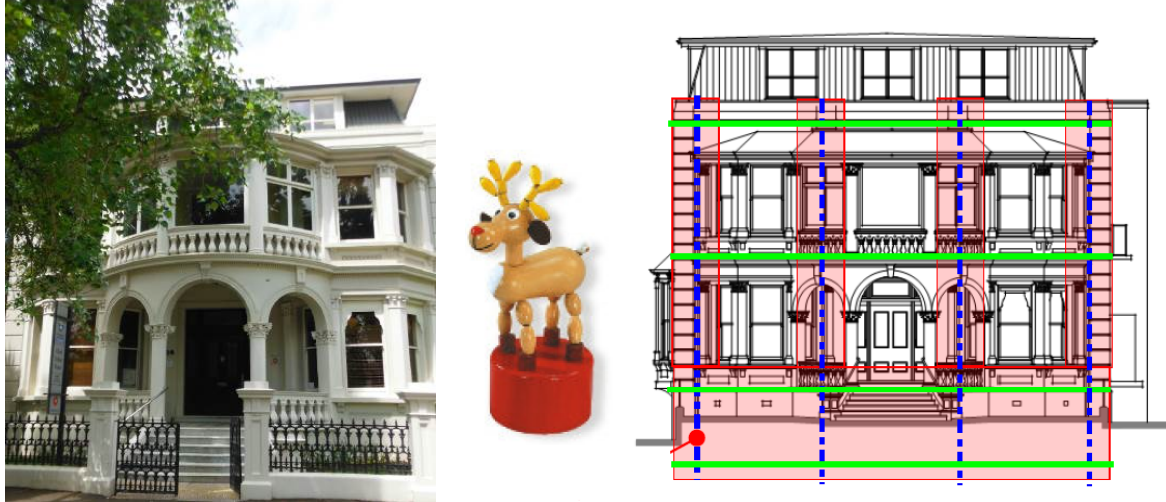


Figure 13. Seismic retrofit of unreinforced masonry building using un-bonded post-tensioning.

Figure 14 shows traditional structural engineering drawings supplemented with annotated sketches and digitally modified photographs to aid clients with visualising proposed retrofit installation.

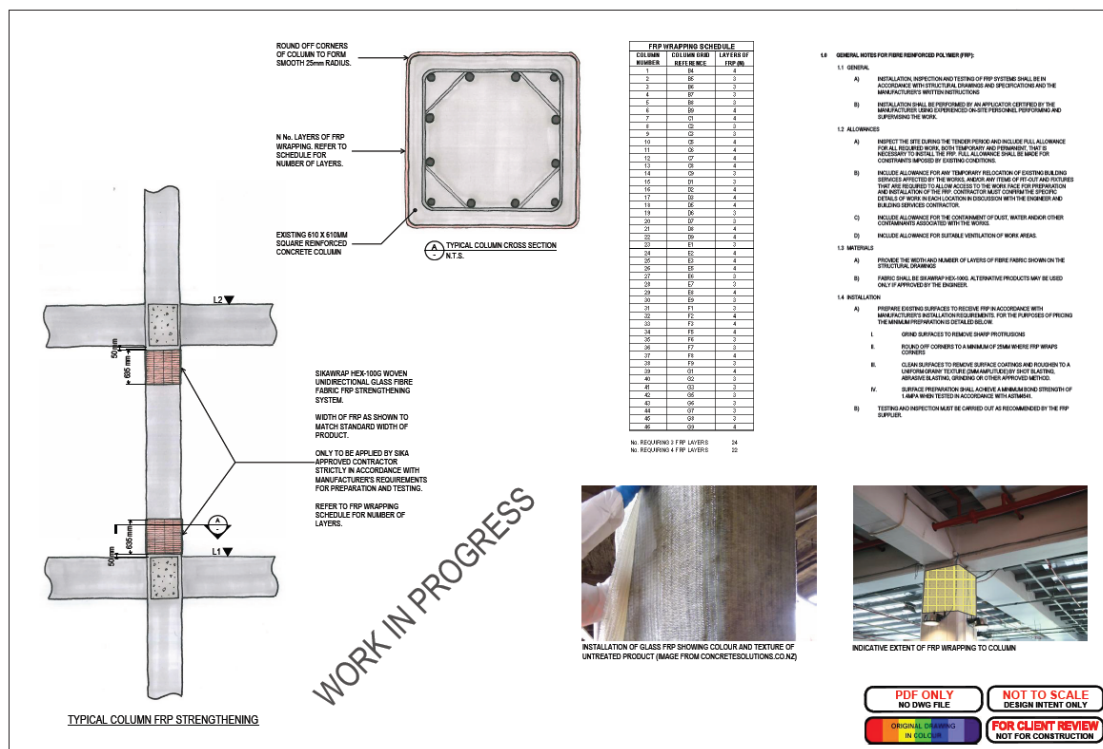


Figure 14. FRP – Fibre reinforced polymer seismic upgrade of reinforced concrete columns.

6.1 Helping clients understand the cost of seismic retrofit

Ferner et al (2014) note that the relationship between seismic performance improvement and the cost of implementing improvement is typically non-linear. This is particularly highlighted in older unreinforced masonry buildings, where modest improvements in performance may be achieved through relatively inexpensive interventions (for example, securing parapets and chimneys), whereas more significant improvements may require the installation of new systems to augment existing structural deficiencies.

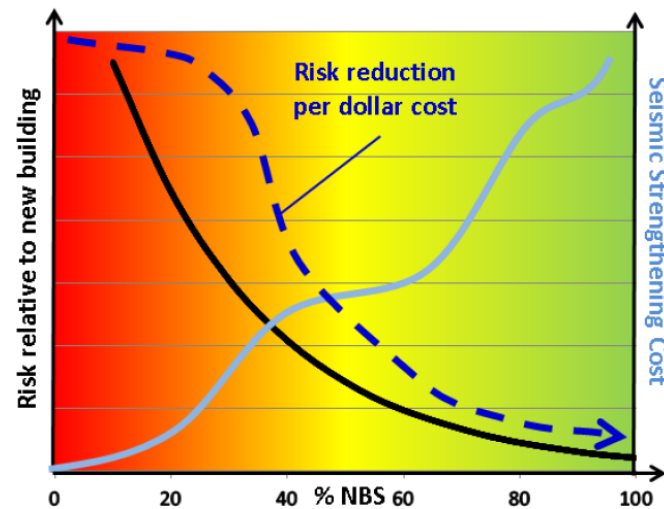


Figure 15. S-curve – comparison of risk reduction, cost of seismic retrofit and achievable %NBS (Ferner et al. 2014).

Figure 15 illustrates how improvements in seismic performance (and hence reduction in seismic risk) are represented by a stepped cost function. The plateaus on the cost curve represent modest increased costs associated with relatively simple interventions, whilst the steeper parts of the curve represent the costs associated with more complex interventions.

7 CONCLUSIONS

Structural engineering is a complex field, littered with jargon and technical principles that can be confusing to those with a non-technical background.

It is incumbent upon structural engineers to convey the technically complex to those not trained in structural engineering. Like all things in our profession this takes practice and experience.

With specific reference to seismic risk in buildings, this paper has presented a selection of examples of visual communication techniques designed to explain relatively complex technical principles in an engaging and easy to understand way.

The authors encourage all structural engineers to continue to develop their consulting skills. It is this commitment to our clients and the general public that will serve to lift standards within our profession and raise the profile and positive perception of structural engineers in our community.

8 REFERENCES

- NZSEE. 2006. *Assessment and improvement of the structural performance of buildings in earthquakes. Incl. Corrigenda 1 & 2* New Zealand Soc. for Earthquake Eng. (NZSEE), Wellington, New Zealand. 343 pp.
- MBIE 2013. *Guidance for Territorial Authorities and Property Owners on Initial Seismic Assessments* Ministry of Business, Innovation and Employment (MBIE), Wellington.
- H. Ferner, Beer, A., Kam, W.Y. & McHattie, S. 2014. A pragmatic approach to seismic risk reduction across a portfolio of high-risk buildings. In *Proc of 2014 ASEC Conf*, Auckland NZ. 9-11 July 2014. Paper No 115