A SEISMIC BUILDING RATING SYSTEM – THE NEW ZEALAND EXPERIENCE

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Abstract

New Zealand engineers developed a seismic building rating system for existing buildings generally known as *%NBS* (% New Building Standard) a few years ago. It came into prominence for defining the assessment of existing buildings for earthquake loads across New Zealand following the recent experience of the Canterbury earthquake sequence. It is now also a key part of the recently passed Building (Earthquake – prone) Buildings Amendment Act 2016 which has the purpose of identifying the most seismically vulnerable buildings throughout New Zealand.

This paper discusses our observed experience with this building rating system to date. This includes from a professional engineering viewpoint of engineers using the system to assess buildings and from the perspective of our experience with various clients who own, tenant or manage the buildings being rated under this system. Various examples are used to illustrate our observed experience.

The paper explores how effective this system is proving to be for the identification and reduction of seismic risk in the New Zealand context including our observations as to the wider effect this is having on building owner, tenant and building manager behavior as well as the wider corporate context. The paper concludes with discussion of possible implications now and into the future and makes recommendations as to aspects that others who may be establishing a rating system may wish to consider.

Introduction

Engineers have long understood the potential damage seismic events can present and have sought ways to reduce the life safety risk of large earthquakes through, for example, design of structures so they behave in predictable ways. Increasingly sophisticated models of earthquake behavior have been developed and have been incorporated into seismic loadings codes. Structural design has become more and more complex with the advent of sophisticated analysis programs and increasingly detailed design codes, all with the aim of reducing the life safety risk from earthquakes. While risk management is inherent to this work it has not often traditionally being presented clearly to clients or the public in this manner.

The recent earthquakes in New Zealand have raised awareness of the risks earthquakes pose to the wider New Zealand community in both monetary and societal terms. As a consequence people are asking questions about the buildings they own and occupy. Increasingly engineers are being expected to explain the risk buildings may pose in the event of an earthquake.

Building rating systems have been developed as tools to assist engineers and the public understand seismic risk. This paper explores the building rating system developed and in use in New Zealand. It describes, from a practitioner viewpoint, our observations of how this system is being used and some of the consequences we are observing, both expected and unexpected.

The *%NBS* Rating system

The seismic rating system being used in New Zealand is referred to as percentage of New Building Standard or *%NBS*. It is defined as:

> *The rating given to a building as a whole expressed as a percent of the new building standard achieved, based on an assessment of the expected seismic performance of an existing building relative to the minimum that would apply under the Building Code (Schedule 1 to the Building Regulations 1992) to a new building on the same site with respect to life safety.* [MBIE, 2017 (1)]

The rating is expressed as a single numeric value; the *%NBS* rating. The New Zealand Society of Earthquake Engineers (NZSEE) developed a grading system (A-E) to complement the *%NBS* earthquake rating. This bands together the assessment results and was developed to reduce the emphasis of the percentage value within an earthquake rating.

Table 1. Building Grading System for Earthquake Risk

Percentage of New Building Standard (%NBS)	*Building Grade*	*Approx. Risk Relative to a New Building*	*Life-Safety Risk Description*
>100	A+	<1 times	Low risk
80 – 100	A	1 – 2 times	Low risk
67 – 79	B	2 – 5 times	Low to Medium risk
34 – 66	C	5 – 10 times	Medium risk
20 – 33	D	10 – 25 times	High risk
<20	E	more than 25 times	Very high risk

The focus is on life safety performance rather than damage to the building or its contents unless this might lead to damage to adjacent property. The earthquake rating assigned is, therefore not reflective of serviceability performance.

The New Zealand rating system requires engineers to consider two forms of life safety hazard; when the ultimate capacity of the building or section of a building is exceeded to such an extent that a significant life safety issue arises and when a falling secondary structural or non-structural building element poses a significant life safety hazard. The aim of the definition is to include elements that present an unavoidable danger to a number of people and preclude from consideration building elements that are of insufficient size to constitute a life safety hazard of reasonable extent.

Defining a building seismic rating relative to a minimum acceptable level avoids the need to quantify the expected performance in absolute terms. Observations following recent earthquakes indicate that prediction of performance of any building in an earthquake is fraught. A building's response is affected by the complex nature of its structure involving the interaction of many elements and the complex nature of the ground on which it sits. There is considerable uncertainty arising from lack of current knowledge and the inability to predict the considerable variability in how earthquake waves propagate from their source to a building and how the building responds to the shaking.

The building rating is intended to reflect its expected relative performance for the full range of earthquake shaking. A building can only be rated as 100*%NBS* if there is confidence that it will perform to the minimum level expected of a new building (life safety only) across all levels of shaking. The *%NBS* rating is required to be reduced until this is the case. For example, a building rated at 34*%NBS* , subjected to shaking at 34*%NBS* of the design level shaking for an equivalent new building (34%ULS shaking), is expected to perform to at least the same minimum level as a new building subjected to the design level of shaking (100%ULS shaking). Similarly when subjected to 67%ULS shaking, this building would be expected to perform to at least the same minimum level as a new building subjected to 200%ULS shaking.

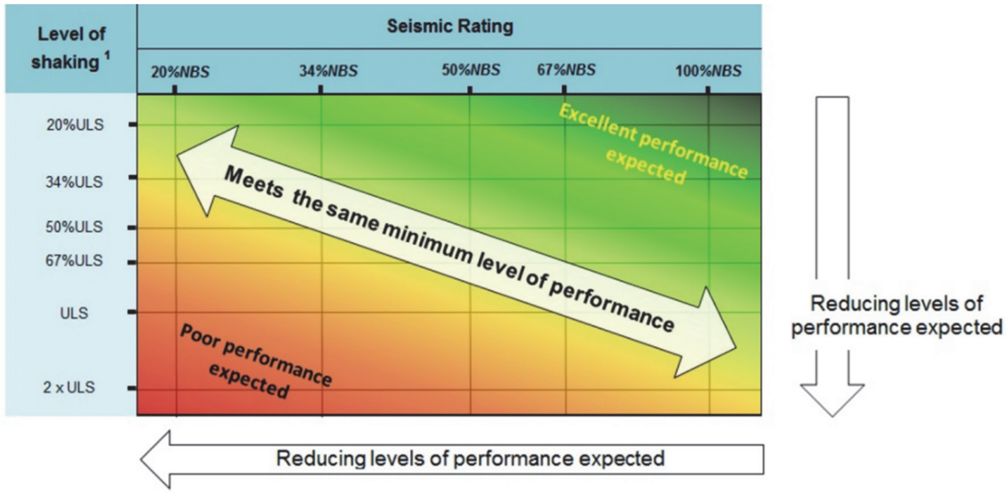

Figure 1. Indicative relationship between seismic performance, earthquake rating and level of shaking [MBIE, 2017 (2)].

Objectives of the Rating System

The *%NBS* rating system was originally developed by the New Zealand Society of Earthquake Engineering (NZSEE) with the objective of providing the property market with a simple, easily understood, and calculable measure of building seismic performance relative to a new building. It was developed with the aim of raising industry awareness and to allow market forces work to reduce earthquake risk.

For a number of years there has been an objective articulated in New Zealand law for the seismic performance of all buildings to be gradually raised to at least a minimum standard. This minimum standard has for the past 15 years been defined using the *%NBS* rating system as > 33*%NBS*. The recently passed Building (Earthquake – prone Buildings) Amendment Act 2016 (EQ prone Buildings Act) did not change this objective or the minimum performance level required. Thus an additional objective of the *%NBS* rating system is to describe the minimum performance standard buildings in New Zealand are required to attain over time in terms of the legislation.

How the *%NBS* rating system is being used

Various terms have entered the New Zealand lexicon following the recent Canterbury earthquake sequence including "munted", "liquefaction" and "*%NBS*". Billboards advising building leases commonly include a statement of a building's seismic rating.

Figure 2. %NBS rating on a billboard advertisement for office space in Wellington June 2013

As part of the EQ Prone Buildings Act which came into force in July 2017 local authorities are currently identifying potentially earthquake prone buildings for further assessment as the first step in improving the seismic performance of these buildings. The building rating *%NBS* is being used to define which buildings are earthquake prone under this regime.

More generally we are observing provision of the *%NBS* rating for a building is now a usual requirement for the pre – purchase due diligence pack for a potential building purchaser. Financial institutions are requiring the *%NBS* rating when making lending decisions for buildings, and are typically not lending for low rated buildings. Similarly insurers are considering a building's rating when deciding whether to insure. Typically, we understand, buildings with low ratings are now uninsurable.

Tenants are using the *%NBS* rating when making decisions as to the buildings they choose to lease and occupy [Steeman, 2018]. We have observed examples where tenants (particularly corporate tenants with large building portfolios such as banks) have moved out of low rated buildings following a building assessment. Our experience is that often tenants are only willing to move into high graded buildings putting pressure on building owners to improve their buildings, an example of market forces at work. Generally we are observing tenants wish to move buildings with a rating >67*%NBS* or even >80*%NBS* i.e. A or B graded buildings. A lack of high rated buildings has put pressure and raised rents in Wellington [Ambler, 2018].

Many corporate entities in New Zealand have developed policies defining the minimum seismic rating in *%NBS* of buildings they are prepared to continue to occupy or lease. Often these policies define a higher rating for new leases than existing ones with the aim of lifting the seismic rating of the portfolio over time.

%NBS is now a term universally used throughout the New Zealand community when describing existing buildings seismic risk and is certainly meeting the objective, as originally envisaged, of raising industry awareness and of driving market forces to reduce seismic risk.

Observations

It is proving very useful to have a way to describe the seismic rating of a building that is consistently used throughout the country and with a term that is familiar to the wider community. Industry and the wider community consistently use the term *%NBS* rating when asking questions about the seismic performance of buildings for which they have an interest.

The *%NBS* rating system is providing clarity for building owners and tenants. It allows seismic risk to be effectively taken into account when financial institutions consider a building for mortgage or insurance purposes, for example. The rating system provides a mechanism, language and comparative context for those difficult conversations with clients about the lowest rated buildings; the earthquake prone buildings.

The *%NBS* rating system provides a single numerical rating. This has been grasped by the community for the clarity it implies. However it suggests an accuracy that is not necessarily real. It is often difficult for building owners to understand there is little difference between a building rated as 69*%NBS* compared with one rated 71*%NBS*. This issue is particularly a problem at the thresholds between building grades i.e. 33*%NBS* – 34*%NBS* and 66*%NBS* - 67*% NBS.* The use of building grades was introduced to assist this understanding and their use is being encouraged by NZSEE. Engineers have not always assisted this understanding by sometimes providing building ratings to multiple decimal points for example 68.73*%NBS,* not reflecting the accuracy of the assessment process used to determine the rating.

The rating system is assisting engineers in communicating with clients about the relative seismic life safety risk pertaining to their building compared with a new building on the same site. We are observing though that the concept of seismic risk is a difficult one for even sophisticated clients to understand. While people assess hazards and consequences as part of our everyday lives, for example driving; our observation is that people struggle to contextualize this explicitly in terms of risk. People do not typically articulate or think of the buildings they own or occupy in terms of risk. This issue is amplified by an environment where society appears to becoming increasingly intolerant of risk. [Schneier, 2013]

Some clients also fail to appreciate that the *%NBS* rating system by its very nature normalizes seismic hazard. The differences in seismic hazard across New Zealand are included in the rating. People generally understand that seismic risk is lower in Auckland than Wellington, for example, but often don't realize that the *%NBS* rating has taken this into account so that two buildings in different cities both rated 50*%NBS* present the same seismic risk profile.

People also struggle with the concept that we are evaluating buildings for life safety risk only not, for example, continued occupancy or level of damage. Our experience is that clients and the wider community have only very limited understanding of the building code objectives and generally expect buildings to be undamaged and immediately re-occupiable following an earthquake.

The rating system is underpinned by The Technical Guidelines for Engineering Assessments [MBIE, 2017 (3)] to guide engineers in the analysis processes. The guidelines were updated and enhanced in 2017 in order to provide additional guidance to engineers to improve accuracy and promote consistency between different engineers completing assessments. Differences in earthquake ratings though can still arise for many reasons including:

- Judgement call differences between assessors, and
- Information available at the time of the assessment.

Issues

Potential Future Code Changes. An obvious implication of the *%NBS* rating system is that if the current loading code changes then all buildings will need to be regraded. This has created a tendency to wish to lock in the existing performance standards in order to provide certainty to building owners and the business community generally. The EQ Prone Buildings Act, for example, has been locked to be the *%NBS* rating in accordance with the loading standard as of 2016 when the legislation passed. The aim is that building owners can have confidence that a building once strengthened to meet the EQ Prone Building legislation will not have to be strengthened again later to a different higher standard.

Balancing ongoing scientific developments and engineering best practice in the assessment of buildings with this need for certainty about building assets is a delicate one. We anticipate this need for certainty by the business community will also make it difficult to change the *%NBS* seismic rating system in the future.

Risk Profile and the Rating System. Seismic risk is a difficult concept for clients to grasp. It is made more difficult because, while the grading system is linear, the risk profile is not linearly related to the *%NBS* rating or grade. Our experience is that many clients struggle with this nonlinear relationship.

%NBS	0% 10% 20%	20% 30%	30% 40% 50% 60% 70%	70% 80%	80% 90% 100%	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. Seismic rating and relative risk.

"Safe". A wider issue is that Engineers are frequently being asked if a building with a particular rating is "safe" [Jury, 2018]. The public have conflated the *%NBS* rating describing levels of seismic risk with the concept of building safety. The concept of seismic risk as it relates to buildings is often confused with a building defined as dangerous under the Building Act. People often assume a building identified as earthquake prone therefore has to be vacated immediately as if it were defined as a dangerous building notwithstanding the definition of dangerous building specifically excludes earthquakes.

This appears to be of particular concern to boards and others with responsibilities under the Health and Safety in Work Act 2015 (H&S Act) "*to eliminate or where elimination is not possible, minimize as far as is reasonably practicable all health and safety risks*". Worksafe New Zealand has issued an advisory [Worksafe, 2018] to reassure people that meeting the timeframes for improving the seismic performance of buildings in accordance with the EQ Prone Buildings Act is sufficient to meet their responsibilities under the H&S Act.

Various boards however continue to express concern noting the extent of their responsibilities as board members. They worry what society's response may be were a damaging earthquake to occur in the period between identification of a low rated earthquake prone building and its remediation. This concern reflects both the difficulty people find in defining risk for rare high consequence events such as earthquakes and what appears to be society's increasing intolerance of risk.

ISA and DSA Assessment Processes. The difference in certainty, reliability and confidence between a seismic rating gained through an initial seismic assessment (ISA) compared with a detailed seismic assessment (DSA) appears to not be well understood by the wider community.
People are naturally attracted to the lowest cost approach to determine the rating of a building they have an interest in; the ISA. Originally conceived as an initial screening tool the ISA is all too often being used to provide a rating upon which significant financial decisions are being made. While excellent as a screening tool it is a qualitative assessment tool providing a comparison of the building in question assuming it was designed to fully meet the codes of the day with a building designed to current codes on the same site.

The ISA is particularly challenging to use for modern buildings where often inspection of the structural system is not easy and where likely significant analytical and design tools will have been used in the design resulting in a structural system that may not be simple with straightforward load paths. This compares with a DSA where the *%NBS* is determined quantitatively thus providing greater reliability in the rating but of course with an associated increased cost for the assessment process.

Reliability and Accuracy of a Rating. Evaluating a *%NBS* rating for a building and conveying what it means to owners, occupiers, and others with an interest in the building is presenting the structural engineering profession with significant challenges. Expressing the precision of the rating so it conveys the reliability and accuracy implied is a particular challenge.

Engineers are also challenged with accuracy and precision in the assessment process itself. Many engineers are more used to designing new buildings than assessing existing buildings. Design of a new building requires meeting certain easily calculable configurational requirements and checking that demands on elements of the structural systems are below a critical limit for a defined level of earthquake shaking. The design codes have plastic curvature limits, combined with detailing requirements, capacity design principles and other criteria such as p-delta stability and global response limits sufficient to meet the code requirements for the ultimate limit state design load while also providing the required resilience for collapse prevention at much greater levels of shaking.

Assessment is subtly different. It requires a holistic review of the building load paths and structural characteristics including crucially the inherent structural resilience of the building. It includes identifying the possible presence of a step change response which may result in a sudden (brittle) and/or progressive complete collapse of the building. Even with the guidance provided by the Technical Guidelines for Engineering Assessments considerable judgement is required based on extensive experience of building performance in earthquakes.

Many analysis techniques can beguile engineers with the seeming precision of the output results where it is easy to forget that the accuracy and reliability of these results depend entirely on the input assumptions (material characteristics, building construction information, etc.) and these input assumptions are often based upon limited information and potentially have a high degree of variability.

Engineering Workforce Requirements. Assessment of a large number of buildings, as is being undertaken in New Zealand, requires a large well skilled workforce. This is a challenge in a small country with a limited group of structural engineering professionals. This issue is being exacerbated by different parties, for example, the various tenants as well as the building owner all wanting an assessment completed for a single building and often each engaging their own engineering advisors. This phenomenon is occurring because commercial/legal advisors sometimes encourage each party to seek their own advice; there is a tendency for parties to keep seeking advice until they get an answer they like; and sometimes because a tenant or owner for a large portfolio of buildings may have engaged a single engineering firm to complete all 'their' assessments in order to achieve a consistency of approach across the portfolio.

Clearly there are greatly increased costs if multiple assessments are completed for the same building. These funds could otherwise presumably be directed to improving the seismic performance of the building. It also ties up engineers who otherwise could be doing other assessments. Multiple assessments of the same building also raises the question of which engineer's assessment to trust. Like the situation of looking at ones watch compared with consulting multiple people to find out the time; in the first instance one knows the time, in the case of the latter - what is the time really?

Lessees' report they depend on their relationships with their landlords. The seismic assessment ratings can get in the way when different engineering firms engaged by the various parties determine different ratings. This can make for a difficult situation particularly for corporate tenants with policies that require them to only lease buildings with ratings above certain levels e.g. grade A or B buildings.

Building Performance. A challenge the recent Kaikoura earthquake highlighted with the *%NBS* rating system is the difficulty engineers have of explaining to building owners and the wider public when buildings do not perform as their rating would suggest in a significant earthquake.

The New Zealand public have been well briefed that URM buildings don't perform well in earthquakes. They always have low *%NBS* ratings. These buildings were observed to have performed poorly in the 2010 – 2011 Christchurch earthquake sequence with extensive coverage in the news media. Yet the URM buildings across Wellington were not significantly damaged in the 2016 Kaikoura earthquake while several modern buildings were immediately identified as having suffered significant damage including Statistics House, Defence House and 161 Molesworth Street.

The subtly that buildings are designed to a risk-based probabilistic earthquake loadings code and that earthquakes may exceed the codes levels we design for or that performance in one event does not guarantee a particular performance in another event is a difficult concept that is not well understood and which the rating system does not well explain.

Incorporating New Learnings into the Rating System. Every significant earthquake provides new learnings for engineers about the ways buildings behave. This is proving a particular challenge for engineers undertaking assessments currently in New Zealand. The 2011 Christchurch earthquake highlighted a number of issues including support of stairs on ledges not previously appreciated for example, while 2016 Kaikoura earthquake highlighted issues with the seismic resilience of some modern building floor systems.

This means that assessments carried out even a few years ago can become quickly out of date. The challenge for engineers is to recognize when an older assessment does not include the most up to date thinking and advise accordingly.

Impact on Different Communities. The rating system is highlighting the seismic vulnerability of many of the smaller towns and communities across New Zealand, including for example, Whanganui and Oamaru as well as the vulnerability of many buildings in the larger centers and including a lot of heritage buildings throughout New Zealand.

Concerns have been raised about the impact on heritage values as well as the economic impact on small rural communities as a result of the implementation of the EQ Prone Buildings Act which uses the *%NBS* rating system to identify the lowest rated buildings. This will likely become a larger issue as buildings are progressively identified and required to be strengthened or otherwise mitigated within the legislated time frames and the impact of the legislation becomes clearer to the community generally. The possibility of a backlash on the rating system and the engineers undertaking the assessments exists as a result, particularly if New Zealand does not suffer any large damaging earthquakes in the next period to remind people of the purpose of the legislation and the impact of damaging earthquakes.

Conclusions

The recent Canterbury Earthquake Sequence and the subsequent Seddon, Cook Strait and Kaikoura earthquakes powerfully reminded New Zealanders the damage large earthquakes can do and their impact on society both financially and more widely. These events have generated significant pressure from those affected by these recent earthquakes; building occupiers, owners, banks, insurance companies as well as boards of large corporations across New Zealand to focus on seismic mitigation measures. Understanding the risk a building presents is a key element and first step.

The *%NBS* rating system, with a single numerical value, is proving to be a valuable tool to describe the seismic rating of a building. It value lies in its simplicity and clarity. The rating system has been defined on a uniform hazard basis describing the expected performance in relative terms to a minimum acceptable standard allowing the expected performance of different buildings across New Zealand to be compared effectively on a uniform risk basis.

Its value is significantly enhanced because of its universal use to the extent that "*%NBS*" is now a part of the New Zealand lexicon. The rating system is encouraging risk based conversations about buildings. It is highlighting though that seismic risk is a difficult concept for people to grasp.

The *%NBS* rating system is however identifying challenges:

The subtly that buildings are designed to a risk-based probabilistic earthquake loadings code and that earthquakes may exceed the codes levels we design for or that performance in one event does not guarantee a particular performance in another event are difficult concepts that are not well understood and which the rating system does not well explain.

Also not well understood is that buildings are assessed with a life safety focus not a damage limitation or continued occupancy focus. The rating system is starting to highlight a potentially growing difference in expectations between the public and the approach structural engineers and the design codes take in designing buildings. This points to an increased focus in the future on damage susceptibility in the assessment of existing buildings as well an increased focus on low damage design for new buildings.

The New Zealand experience with *%NBS* suggests that any rating system developed to describe seismic risk must be clear, focused and simple. Significant decisions are made on the future of existing buildings on the basis of the seismic rating. Assessments need to be thorough and robust and the ensuing rating as reliable and as clear as possible.

Crucially the challenge for engineers is to communicate seismic risk clearly and in a manner that a non-technical audience can understand. A widely used rating system such as *%NBS* certainly assists in these conversations.

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