

Strengthening Buildings for Earthquake Implementing New Zealand Legislation

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ABSTRACT:

In 2004 new provisions for dealing with earthquake risk buildings were introduced into the Building Act in New Zealand. All buildings except small residential buildings are now covered. The legislation required 73 territorial authorities to develop policies on earthquake-prone buildings, consult publicly on the policies, and submit them to the Department of Building and Housing. An earthquake-prone building is defined as one that would have its ultimate capacity exceeded in an earthquake one-third as strong as that used to design a new building at the same site. The new requirements led to considerable debate in the various communities on earthquake strengthening. Economic, social and heritage aspects were of main concern, as territorial authorities determined policies to match their widely varying seismic, economic and social circumstances. The Department of Building and Housing provided guidance to territorial authorities for developing suitable policies. This included supporting the NZSEE in developing its recently released recommendations, *Assessment and Improvement of the Structural Performance of Buildings in Earthquake*. Territorial authority policies have been in place for almost two years and vary widely in their approach and the required times for strengthening. Implementation of the legislation is helping to reduce earthquake risk of existing buildings in New Zealand. The issues raised by the legislation, the challenges faced and the approaches taken provide valuable insights for those contemplating similar legislation or mitigation programmes.

KEYWORDS:

Legislation, seismic strengthening, retrofit, earthquake-prone, buildings

1. INTRODUCTION

The New Zealand Building Act 2004 introduced the requirement for territorial authorities (TAs) to develop policies on earthquake-prone buildings in their area by 30 May 2006. This is a long-term strategy that focuses on the most vulnerable buildings in an earthquake. The changes reflect lessons learnt from the effects of earthquakes internationally and in New Zealand, and growing recognition of the inadequacies of past earthquake design practices when reviewed in terms of current knowledge.

The new legislation covers existing buildings (other than small residential buildings) that are less than one-third of the strength required for a new building. Bridges and other structures that could collapse and would be likely to cause injury, death or damage are also covered. The changes were developed in close consultation with the engineering profession. They were designed to allow consultation between territorial authorities and building owners in developing their policies.

The Napier earthquake in 1931 triggered the development of earthquake design standards in New Zealand. From 1935 until 1965 all buildings throughout New Zealand were designed for a lateral load of 10% of gravity. In 1965 a new standard was introduced. This split the country into three seismic zones, A, B and C. Design lateral forces were to be distributed in an inverted triangular shape. Design coefficient depended on building period, importance and zone. Basic coefficients for normal buildings were 12%g in Zone A, 10%g in Zone B and 8%g in Zone C, reflecting peak ground accelerations of around 30%g for Zone A.

In 1976 zonation became continuous according to assessed seismicity on an equal probability basis. The concept of ductility was introduced and detailing for ductility was required in material standards. The concept of capacity design was introduced and changes in the design spectra were introduced.

In 1984, 1992 and 2005 new standards were issued, but philosophies were not substantially changed. The seismic risk maps were altered to reflect the substantial new knowledge and interpretation of New Zealand's seismic risk.

2. REQUIREMENTS FOR EXISTING BUILDINGS

2.1 From 1968 to 2004

In 1968, legislation was introduced to deal with buildings of high earthquake risk. These were defined as being those of unreinforced concrete or unreinforced masonry, having an assessed capacity less than half of the 1965 standard. Each TA, usually a city or district council, could apply to the government to take up powers to classify earthquake-prone buildings and require owners to reduce or remove the danger. Most major cities and towns took up the legislation, some much earlier than others and substantial progress was made over the 36 years the legislation was in force. There was criticism at the loss of many older buildings or the introduction of intrusive strengthening measures that detracted from heritage characteristics. For many buildings, though, the requirements provided an opportunity to replace them with new buildings of greater size and efficiency.

As an indication of the effect of this legislation, Wellington City Council achieved strengthening or demolition of 500 out of 700 buildings identified as earthquake-prone. This was achieved between 1968 and 2003.

2.2 The 2004 provisions

2.1.1 Background

A major drawback of the 1968 legislation, which continued in effect till 2004, was that the strength level defining earthquake-proneness referred to an increasingly outdated standard. In applying the provisions of the legislation, most TAs called for strengthening to one-half or two-thirds of the 1965 standard. Many buildings strengthened to these requirements, particularly non-ductile buildings of unreinforced masonry, are well short of what is now required for a building not to be earthquake-prone.

Failures of relatively recent buildings in Northridge and Kobe heightened the concern amongst earthquake professionals in New Zealand that legislation was needed to require seismic strengthening of the most vulnerable buildings and to extend the range of buildings covered.

2.1.2 New legislation

The New Zealand Society for Earthquake Engineering (NZSEE) pushed for this legislation and in 2004 a new Building Act was passed, bringing about substantial changes in the building controls regime for new buildings in New Zealand. These included new rules governing the licensing of building practitioners (including designers) and the introduction of minimum levels of capability for organisations (usually TAs) responsible for issuing building consents.

Included in the new Building Act were revised provisions governing earthquake-prone buildings. The scope of buildings covered by the legislation was extended to include all buildings except some residential buildings. The provisions do not apply to residential buildings unless they are two or more storeys *and* contain three or more household units.

The legislation defines an *earthquake-prone building* as one that would have its ultimate capacity exceeded in a *moderate earthquake and* would be likely to collapse causing injury, death or damage to other property. A *moderate earthquake* is defined in regulations as *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 in the design of a new building at that site.*

The legislation allows any TA that is satisfied that a building is earthquake-prone to require the owner to take action to reduce or remove the danger. The strength required to reduce or remove the danger is not specified in the Building Act or regulations.

The Act requires each territorial authority to have a policy on earthquake-prone buildings. This was a deliberate move to allow each community to achieve a balance between the need to address earthquake risk over time and other demands on the funds and resources of the community. TA policies were required to state the approach,

priorities and timetable to be followed. Specific provisions for heritage buildings were required. TAs were required to consult locally in developing their policies, and to provide a copy of their policy to the Department of Building and Housing. To keep policies up to date with any advances, the Building Act requires TAs to review their policies every 5 years.

The Department of Building and Housing, which administers the Building Act, is given no powers to call for changes to the details of earthquake-prone building policies. Review of the policies by the Department was confined to being satisfied that they described the approach to be taken, indicated priorities, showed how heritage buildings would be dealt with, and were adopted following proper public consultation.

The new provisions are directed only at the worst of existing buildings. It was assessed that buildings with less than one-third of the strength of a new building have at least 10 times the risk of serious damage or collapse when compared to a new building. In Wellington, the capital city, and in an area of high seismicity, it was estimated that about 10% of buildings would be earthquake-prone. The danger being addressed is the performance of buildings in a major earthquake, comparable with that used for design of new buildings. The moderate earthquake definition is a device for identifying the most vulnerable of existing buildings to be covered by legislation. It was considered that, over time, market forces would bring about improvements to buildings that were above the one-third level and thus outside the legislative requirements.

2.2.3 NZSEE guidance document

In order to help designers assess existing buildings in line with the provisions of the Building Act, the New Zealand Society for Earthquake Engineering (NZSEE) produced a document *Assessment and Improvement of the Structural Performance of Buildings in Earthquakes* [NZSEE (2006)]. This was developed with the support of the Department of Building and Housing over a period of ten years and was published in June 2006. Most TAs have referred to this document in their policies. It is available on the NZSEE website, www.nzsee.org.nz.

The NZSEE guidelines contain an Initial Evaluation Procedure (IEP) for a quick and preliminary evaluation of existing buildings. The method takes account of building form, natural period of vibration, critical structural weaknesses (vertical irregularity, horizontal irregularity, short columns and potential for building-to-building impact) and the design era of the building.

2.2.4 Benefit-cost studies

In the lead-up to the legislation, benefit-cost studies were done to assess benefits and costs of improving the structural performance of the different types and ages of existing buildings. These studies [DHCL (2002)] looked at the relative merits of setting the definition of earthquake-proneness at the status quo, one-third of new building standard, two-thirds of new building standard and full new building standard. Allowances were made for the increasing proportion of buildings captured as the threshold is raised. The choice of the one-third level in the Act reflects the results of these studies as well as recognition of the need for legislation to target only the most vulnerable buildings.

3. DEVELOPMENT OF EPB POLICIES

In June 2005 the Department issued a guidance document to assist TAs in developing their policies [DBH(2005)]. This document outlines the range of issues to be considered in developing the policy, such as the seismic hazards in the area, the age and range of existing building stock, and likely effects on the local economy. To indicate the nature and size of document expected a “model” policy was included for a fictitious place, Quaketown.

3.1 Approaches

It was suggested that TAs adopt either an active or passive approach to dealing with earthquake-prone buildings.

3.1.1 Active approach

Under an active approach, a TA would carry out an initial evaluation of buildings in its district to identify those likely to be at high risk. Results would be used to establish priorities for further, more detailed evaluations, set timetables for action and determine required performance levels for upgrading. For buildings falling below the

one-third criterion on initial assessment, a TA would then advise owners that their buildings are potentially earthquake-prone. Owners would then have the chance to provide further information and carry out a detailed assessment of the building. The policy would state which party is to bear the cost of the assessment. Adopting an active approach would allow the worst risks to be dealt with first.

3.1.2 Passive approach

Under this approach, the TA would wait for a building consent application for significant work on the building, before assessing its earthquake-proneness. Once assessment is done, the procedures would be similar to the active approach. Under the passive approach, the order in which risks are dealt with depends entirely on the timing of building consent applications.

3.1.3 Mixed approaches

The guidance document suggested that TAs consider using different approaches for different categories of buildings. For example, important buildings such as hospitals and schools might warrant an active approach, while for some other categories, such as industrial buildings, a passive approach may be justified.

3.2 Priorities

The guidance document encouraged TAs to consider the relative importance of buildings in setting priorities and timetables for initial assessment, advising owners, issuing notices, and for this strengthening or demolition work to be done. The model policy for “Quaketown” showed timetables for review of 2 to 5 years and for strengthening / removal of 15 to 35 years, depending on building importance.

3.3 Heritage buildings

Heritage buildings, historic locations and culturally significant sites are given protection on a national basis by the Historic Places Act 1993 and TAs may protect locally significant locations under the Resource Management Act 1991. Many heritage buildings in New Zealand are of unreinforced masonry and had been subject to the earlier earthquake-prone building requirements. This past experience highlighted special issues regarding these buildings. There is a desire to retain them as part of New Zealand’s heritage. Their vulnerability in earthquake is recognised but there is a reluctance to spoil their original form with obtrusive structural strengthening. Frequently there are difficulties in funding strengthening measures. Against this background, TA policies were required to include procedures recognising the heritage value of these buildings and the need for dialogue between the TAs and the owners and the benefits of a flexible approach.

4. ANALYSIS OF POLICIES SUBMITTED

4.1 Territorial authorities in New Zealand

Local government in New Zealand is the responsibility of territorial authorities (TAs) that are governed by elected city or district councils. There are 73 territorial authorities ranging in population from 611 to 400,000 with a median of 31,500. Population density varies from 0.5 to 1600 people per square kilometre, with a median of 11.

Most TAs are accredited Building Consent Authorities (BCAs) with responsibilities for local implementation of the Building Act. In this role, BCAs deal with building consent applications for all buildings and are responsible for satisfying themselves, on reasonable grounds, that the proposed buildings will meet the requirements of the Building Code, and for certifying that the completed building has been built according to the approved plans and specifications. All buildings must comply with the national, performance-based Building Code. TAs are not at liberty to set their own building standards and there is very limited scope for TAs to grant waivers on a case-by-case basis.

In general, the philosophy of the Building Act and the Building Code is to promote uniform application of building controls over the whole country. The setting of earthquake-prone building policies by TAs is one of the very few aspects of the building control regime where local differences can exist.

4.2 Time to prepare policies

As intended by the legislation, there is a wide variety of approaches by TAs as each took its own view of the risks and their community's willingness to participate in improving the robustness of the building stock. The TAs had 21 months from the passing of the legislation in which to respond by adopting a policy. The earliest was received by the Department 6 months before the due date and the last was received nearly 16 months late. Half of the TAs submitted their policies on time. The time taken is considered to be a reflection of the effort needed to complete community consultations and possibly an underestimation of the development work required. Figure 1 graphs the adoption of policies against time. In view of the long-term objectives of the legislation and policies, the lateness of receipt of some policies was not seen as critical.

4.3 Approaches adopted

Each TA could decide whether it wanted to adopt an active or passive approach or a mix of the two. Figure 2, shows the distribution of choices according to relative seismic hazard. It can be seen that passive approaches were favoured more by TAs in the low seismic risk category.

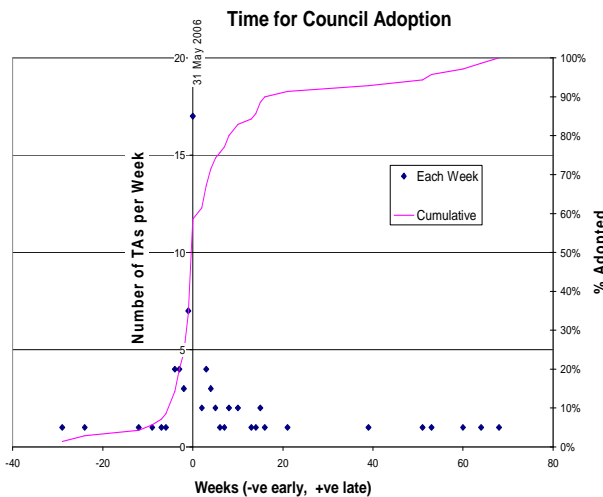


Figure 1 – Time for adoption of EPB policies

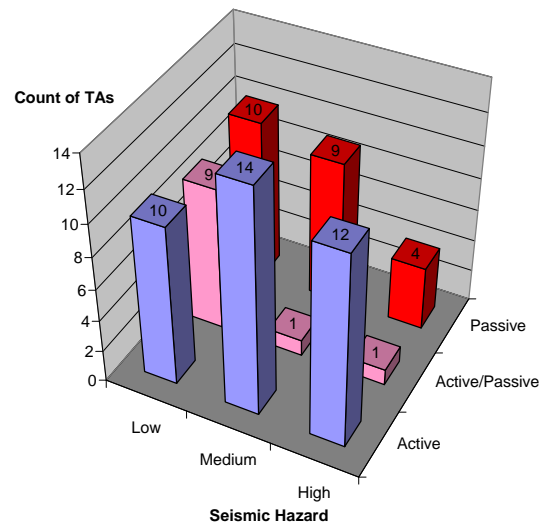


Figure 2 – Approach based on seismicity

4.4 Timetables for identification and retrofit

Timetables for identifying earthquake-prone buildings and notifying owners varied from 1 to 25 years with an average of 5 years. Timetables for requiring action to strengthen or demolish varied from 1 years to 50 years although some did not specify a final date. The low value reflects the shortest time for the most important category of building while the high value is the longest time for the least important category.

4.5 Required strengthening levels

A level just above the one-third threshold was adopted by 31 of the TAs with most encouraging a level much higher. Nineteen TAs specify a strengthening level of two-thirds or more of new building standard for at least one category of building. The guidance document model policy suggested a requirement to achieve a level *as nearly as is reasonably practicable to that of a new building*. This expression is used in other parts of the Building Act and encourages significant reduction of risk while allowing particular circumstances to be taken into account. This approach was adopted, at least in part, by nine TAs. Only two TAs included specific reference to a post-earthquake situation.

4.6 Heritage building provisions

Most TAs recognised the need for special treatment and dialogue with owners when heritage buildings were affected. Some allowed the timetables for strengthening to be amended if circumstances warranted, and provided more time and opportunities for dialogue to resolve the special challenges involved. A few TAs included specific budgets to assist those with heritage buildings to have their buildings strengthened or at least to have them examined.

5. IMPLEMENTATION ISSUES

During the development of policies, the public consultations, and the initial implementation over the last two years a number of issues emerged:

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”. This is a Building Act process whereby the Department examines the circumstances and “determines” if the Building Act and Code have been complied with. 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.

5.2 Minimum content of policies

The public consultation process is a vital part of the requirements in the Act giving the affected community to comment on the detailed provisions. The process carries some obligation on the TA to examine their seismic hazard, risks to buildings and infrastructure, and likely impacts of any proposed policy on the social and economic well-being of the community. Some smaller TAs requested to submit the model “Quaketown” policy with their name substituted. Technically this would have been possible, provided that the TA had publicly consulted on the content of the policy. In fact, most TAs found it necessary to consider specific local issues and use the Quaketown model policy as a guide.

The question was asked if a TA could have a policy to do nothing about earthquake-prone buildings. The Department’s response to the question was that each Councillor needed to consider the defensibility of a policy to do nothing when considered in hindsight after a damaging earthquake in their area.

The Act gave notice of the government’s intention to reduce earthquake risk over time and set the basic parameters such as the type of buildings covered and the strength level defining an earthquake-prone building. But it did not *require* TAs to take action. The extent, nature and timetable for action were entirely up to each TA. Having to develop their own policy was difficult for many TAs, but their “ownership” of the policies does allow them to change the policies if they are not working. The Building Act does not give the Department the power to change the technical provisions of the policies.

5.3 Timetables for identification and strengthening

It was generally accepted by all TAs that legislation was warranted to deal with the earthquake risk of existing buildings over time. The indicative timetables given in the Department's guidance document were generally followed. Some TAs elected to shorten them, others chose to extend them. Some TAs have already found that the timetables for strengthening are shorter than can reasonably be achieved. Wellington City is currently seeking to extend its original timetables as a result of experience in implementing its policy over the first two years. They are also introducing special provisions to make it easier for owners of adjoining buildings to work together to improve the structural performance of their buildings.

By requiring a policy from each TA, the Act has ensured that reducing earthquake risk is on the agenda, but the timetable for this is in the hands of local community and its leaders.

5.4 Required strengthening level

Neither the Act nor the Regulations specify the required strengthening level for a building that is determined to be earthquake-prone under the Act. This has given rise to uncertainty and differing interpretations. Some argue that strengthening to a level just above the one-third threshold is sufficient because, by definition, such a strengthened building would not be earthquake-prone under the Act. Others point out that a TA is within its rights to decide what is meant by *reduce or remove the danger*. Some TAs have called for a strengthening level of two-thirds of new building standard, being their interpretation of an NZSEE recommendation to achieve at least two-thirds. The Department favours an approach, adopted by some TAs, that requires strengthening to a level *as nearly as is reasonably practicable* to that of a new building. This lifts the standard as high as possible without insisting on an arbitrary minimum. A potential drawback of this definition is that it leaves more to the discretion and judgement of the building officials.

In the first two years since adoption of the policies, there have been no referrals for a determination on this issue, but it seems likely that some will be made.

5.5 Buildings strengthened under previous legislation

It is unfortunate that the previous legislation defined earthquake-prone buildings according to a 1965 standard that became increasingly removed from subsequent changes in the New Zealand structural loading standards in 1976, 1984, 1992 and 2005. For unreinforced masonry buildings, this has meant that many of those strengthened to the previous requirements will again be classed as earthquake-prone and subject to requirements to strengthen further. Naturally, owners of such buildings are not happy with this situation, but it does not alter the actual risks their building represents, except to the extent that even the most simple of strengthening measures can result in large improvements in structural performance – beyond what can be proven by engineering assessment. The Department has suggested that TAs consider giving such buildings a lower priority for action.

5.6 Buildings affected by a recent earthquake

On 20 December 2007 a magnitude 6.8 earthquake struck the town of Gisborne on the east coast of the North Island. It caused significant, but not extensive damage to a range of buildings, but particularly to unreinforced masonry buildings. The repair of damaged buildings has raised interesting questions that may lead to changes to the Act.

Buildings damaged by the earthquake but which have a residual strength above the one-third threshold, do not need to be brought back to the strength level prior to the earthquake – though owners who are insured would wish to do this. The Act gives TA powers to require action on buildings that are earthquake-prone or are dangerous. Only one of the earthquake-prone building policies provides for the post-earthquake situation, and so the timetables in the policies do not match the need for urgent action. However, the Building Act allows TAs to issue a notice for the danger to be reduced or removed within “not less than ten days”.

If a building is damaged so that it falls below the one-third threshold to become earthquake-prone, can it be designated earthquake-prone? If so, shouldn't the earthquake-prone building policy contain specific provisions for this situation, for example, requiring immediate action?

These questions will be examined by the Department. Changes to the Act may be recommended.

6. CONCLUSIONS

Recent legislation in New Zealand seeks to address earthquake risk of existing buildings over time by targeting the most vulnerable buildings – defined as those with one-third or less of the capacity of a new building. This applies to all buildings except small residential buildings. Territorial authorities are required to have policies on earthquake-prone buildings. These must address the approach, priorities and provisions for heritage buildings. TAs must consult the public on the details of their policy, but the content of the policy is up to each TA.

Each of the 73 TAs in New Zealand has adopted a policy and is in the process of implementing it. There have been considerable challenges in developing the policies and the impacts on the community and building owners in particular is not yet fully known. There is general acceptance of the need to reduce the earthquake risk represented by existing, particularly older, buildings.

Each local community has the ability to change its policy at any time to adjust for changing circumstances or to respond to unforeseen impacts of its policy.

The legislation has required each local community to put earthquake risk reduction on its agenda, and has left the local community to develop appropriate policies that reflect local conditions and perceptions of earthquake risk. Improvement timetables in the policies range from 1 to 50 years, depending on building importance and location.

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