**Section 6:**

**Assessing and improving the seismic performance of existing buildings**

**6.1 Introduction**

Assessing and strengthening existing buildings is a complex task that requires specialist skills and experience. Buildings of different types and ages must be considered, which adds to the complexity. This section will discuss the assessment process and also address techniques for strengthening, and the costs involved, drawing on understanding developed both in New Zealand and overseas.

Except in passing, we do not cover here the post- earthquake inspection of buildings, which will be dealt with in Volume 7 of the Report. The present focus is on assessments carried out in anticipation of possible future earthquakes. Such inspections are designed to ensure that the likely performance of buildings is understood, and strengthening works appropriate to enhance a building’s performance are able to be carried out.

**6.2 Assessing the potential seismic performance of buildings**

6.2.1 New Zealand Society of Earthquake Engineering Guidelines

It is important to have agreed procedures for evaluating the seismic resistance of existing buildings. Their purpose is to determine the susceptibility of buildings to damage from earthquakes, and to devise and implement structural improvements that will bring the buildings up to or above a predetermined minimum level. Evaluation of an existing structure requires not only knowledge of the current design standards but also an understanding of the potential limitations that older buildings have. These include material properties, methods of construction, and potential weakness in structural form. It is also necessary to consider the different levels of design strength and ductility associated with previous design standards.

For present purposes, it is possible to divide structural assessments into two broad types: those that are carried out to assess the strength of buildings in the event of a future earthquake and those that are carried out after an earthquake. However, there are many similarities and some overlap between these types of assessments. The terminology currently in use is shown below.

**Table 1: Broad types of structural assessments of buildings**

|  |
| --- |
| **Building assessments for future earthquakes Building assessments post-earthquake** |
| Initial Evaluation Procedure (IEP) Overall Damage Survey or Initial Assessment |
| Desktop Study Rapid Assessments (Levels 1 and 2) |
| Detailed Assessment Detailed Engineering Evaluation (DEE) |

**6.2.1.1 Building assessments post-earthquake**

In the immediate aftermath of a major earthquake, Initial and Rapid Assessments are used as a basic sifting method for identifying the worst of the immediate hazards. The New Zealand Society for Earthquake Engineering (NZSEE) has prepared guidelines for territorial authorities in the document *Building Safety Evaluation During a State of Emergency: Guidelines for Territorial Authorities*1 published in August 2009, which sets out a process of structural safety evaluations of damaged buildings. For a Rapid Assessment, inspectors do a quick visual evaluation of the type and extent of a building’s structural damage, and on that basis are able to post a green (inspected), yellow (restricted use) or red (unsafe) placard. Rapid Assessments are initially Level 1 (external only) followed by Level 2 (where appropriate), which involves both external and internal visual inspection. The percentage of New Building Standard (% NBS) is not calculated in this process.

In the disaster recovery phase a Detailed Engineering Evaluation (DEE) may be required. In draft guidance from the former Department of Building and Housing, a DEE is defined as:

A review of the building design, construction, and how the building has performed in recent earthquakes to understand its potential performance in future earthquakes and to determine what repair or strengthening is required to bring it into a satisfactory level of compliance or to simply improve its future performance.

The DEE is a similar assessment to a Detailed Assessment (discussed below) with the difference being that there is an assessment of the effects of the damage caused by one or more earthquakes. A percentage of NBS may be calculated in this process.

**6.2.1.2 Building assessments for future earthquakes**

The assessment of a building’s performance in possible future earthquakes can be carried out by various methods. The recommendations of a NZSEE Study Group on earthquake risk buildings are embodied in *Assessment and Improvement of the Structural Performance of Buildings in Earthquakes*3, dated June 2006, which we will refer to as the NZSEE Recommendations. This document contains the most recent methodology being used by the engineering profession in New Zealand.

The NZSEE Recommendations were developed to assist engineers because the processes used to assess the structural performance of a building in an earthquake are different from the processes used when designing buildings. The Recommendations suggest that the assessments should only be carried out by a chartered professional engineer with experience in earthquake engineering. We note that the Recommendations have no regulatory standing and there is no formal monitoring of practices in assessing existing buildings.

The NZSEE Recommendations describe two levels of assessment. The first is an Initial Evaluation Process (IEP) and the second a Detailed Assessment.

**6.2.1.2.1 Initial Evaluation Process (IEP)**

The IEP provides an approximate assessment of likely performance of a building in an earthquake. It is intended to be a coarse screening involving as few resources as reasonably possible to identify potentially high risk (or earthquake-prone) buildings. The objective of the IEP is to identify, with an acceptable level of confidence, all high risk buildings. At the same time the process must not catch an unacceptable number of buildings that would, on detailed evaluation, be outside the high risk category. It is expected that those carrying out the IEP would be New Zealand Chartered Professional Engineers with a background of experience in the design of buildings for earthquakes or in possession of some specific training. The IEP is designed as a largely qualitative process involving considerable knowledge of the earthquake behaviour of buildings and judgement as to key attributes and their effect on performance.

The procedure to be followed in an IEP is described in detail in the NZSEE Recommendations. Broadly, it comprises the following steps:

**Step 1:** Gathering general information on the building, for example photos, a rough sketch of the building plan, a list of any particular features that would be relevant to the building’s seismic performance and a list of information sources used to complete the assessment.

**Step 2:** Calculating the baseline percentage new building standard (% NBS)b. This involves, first, calculating the nominal % NBS. The (% NBS)nom is a general measure of the performance (with respect to requirements for a new building, NZS 1170.5:20044) of a particular building in a given location, assuming it is well-designed, of regular form, with no critical structural weaknesses and complying with the relevant code provisions at the time it was built.

The (% NBS)b modifies this nominal value to account for assessed ductility, location (hazard factor and near fault factor) and occupancy category (i.e. the appropriate return period factor) but again assumes a good structure complying with the code current at the time when it was built.

**Step 3:** Calculating the Performance Achievement Ratio (PAR), which may be regarded as the ratio of the performance of the particular building, as inspected, in relation to “a well-designed and constructed regular building of its type and vintage on the site in question”. This step takes into account structural weaknesses such as irregularities, short columns, poor site characteristics, potential for pounding by neighbouring structures and other factors.

**Step 4:** Calculating the percentage of new building standard (% NBS) by multiplying the assessed baseline by the PAR. This is done for the longitudinal and transverse directions of the building and the lower of the two values is used.

**Steps 5, 6 and 7:** These steps involve marking the percentage of NBS buildings as “Potentially Earthquake-Prone” if the percentage of NBS is less than 33 or as “Potentially an Earthquake Risk” if less than 67. The final step is assigning a provisional Seismic Grade for seismic risk.

For unreinforced masonry buildings (generally built prior to 1935) an attributed scoring process is suggested as an alternative to Steps 2 and 3 above, given that these buildings are generally not designed to resist earthquakes. The percentage of NBS is then determined directly from the total attributed score.

**6.2.1.2.2 Detailed assessment**

The IEP described above provides only an approximate assessment of a building’s likely performance in an earthquake. Detailed assessment procedures are intended to provide a more accurate assessment of the performance and validate the status of a high risk, potentially earthquake-prone building. The NZSEE Recommendations state that:

They allow the engineer to look in more detail at the characteristics of the building, its response to earthquake shaking, the demands it places on structural elements, and the capacity of such elements to meet those demands by maintaining structural integrity under imposed actions and displacements.

The focus is the determination of demand on structural elements, resulting from the response of the building, and assessment of the capacity of such elements to meet the demand without causing loss of structural integrity.

Engineers might use a variety of models, approaches, and analytical tools to assess this performance and

are advised to carry out a full inspection of the building as part of their Detailed Assessment. The NZSEE Recommendations detail what should be included in this inspection. Given that an existing building’s unique demands and capacities must both be calculated, the assessment inevitably takes more effort and time to determine the level at which Ultimate Limit State (ULS) will be reached, compared to an IEP.

Both the IEP and detailed assessment procedures result in a percentage of NBS being assigned to a building.

6.2.2 Grading systems

**6.2.2.1 NZSEE grading system**

The NZSEE Recommendations recorded the NZSEE’s proposal that a grading system be introduced for buildings to reflect their assessed structural performance. The grading system proposed was set out in the Recommendations. It envisaged buildings being graded in bands from A+ to E. It was linked to the percentage of NBS value, and the Standards current at the time the building was built. Indications were given of the relative risk of the strength and/or deformation capacities of the building being exceeded over the life of the building. Grades D and E were for buildings classified as high risk: buildings with critical structural weaknesses would commonly fall within these two grades.

The Royal Commission understands that the uptake of this grading system has been low. It is not clear why this is the case. Such a system would avoid the misleading degree of accuracy implied when a percentage of NBS is stated (see section 6.2.4 below).

**6.2.2.2 The Structural Engineers Association of Northern California Earthquake Performance Rating System (EPRS)**

The Structural Engineers Association of Northern California5 (SEAONC) has been developing an Earthquake Performance Rating System (EPRS) since 2006, which utilises existing evaluation methodologies and translates results into a format that may be more easily understood. In SEAONC’s view, the objective of a methodology for rating the earthquake performance of buildings is to communicate seismic risk to non-engineers. We agree with that observation. The ultimate goal is for the rating system to spur action that will reduce seismic risk in the overall building inventory.

The SEAONC EPRS uses a scale of 1 to 5 stars and separately considers three dimensions: Safety (death, injuries and entrapment), Repair Cost (dollars), and Time to Regain Function (downtime). Descriptions of each star rating value are provided in Table 2. The EPRS has the aim of assessing both new and existing buildings in consistent terms to help address questions of interested non-engineers, who typically seek to contrast one building with another. The SEAONC EPRS does not predict precise numerical values; rather, it assigns a rating category based on definitions and expectations

|  |
| --- |
| **Rating Repair cost** |
| Building performance would lead to conditions requiring earthquake-related repairs commonly costing less than 5% of the building replacement value. |
| Building performance would lead to conditions requiring earthquake-related repairs commonly costing less than 10% of the building replacement value. |
| Building performance would lead to conditions requiring earthquake-related repairs commonly costing less than 20% of the building replacement value. |
| Building performance would lead to conditions requiring earthquake-related repairs commonly costing less than 50% of the building replacement value. |
| Building performance would lead to conditions requiring earthquake-related repairs costing more than 50% of the building replacement value. |

stated by the underlying evaluation methodology.

|  |
| --- |
| **Rating Safety** |
| Building performance would not lead to conditions commonly associated with earthquake-related *entrapment*. |
| Building performance would not lead to conditions commonly associated with earthquake-related *injuries*. |
| Building performance would not lead to conditions commonly associated with earthquake-related *death*.   |  | | --- | | **Rating Time to regain function** | | Building performance would support the building’s basic intended functions within *hours* following the earthquake. | | Building performance would support the building’s basic intended functions within *days* following the earthquake. | | Building performance would support the building’s basic intended functions within *weeks* following the earthquake. | | Building performance would support the building’s basic intended functions within *months* following the earthquake. | | Building performance would support the building’s basic intended functions within *years* following the earthquake. | |
| Building performance in select locations within or adjacent to the building leads to conditions known to be associated with earthquake-related *death*. |
| Performance of the building as a whole leads to conditions known to be associated with earthquake-related *death*. |
|  |

**Table 2: SEAONC definitions for star rating values for each of the three dimensions (source: SEAONC, 2011)**

SEAONC acknowledges that a successful risk reduction programme is multidisciplinary, and states that the biggest challenges to earthquake risk reduction are not in engineering, but in finance, policy and regulation.

The most effective rating system would be one that:

• fills existing knowledge gaps;

• leverages the interests of motivated stakeholders;

• does not mandate implementation without the needed resources; and

• involves minimal logistical costs to implement and regulate.

One challenge identified by SEAONC is that many owners of existing buildings do not want them to be given a seismic rating, and definitely do not want to pay for it. Market forces have been identified as a way to drive demand. It was envisaged that from the outset, the rating system would first be adopted by building owners, or “sellers”, who would benefit from it (for example, developers who have just incurred significant expenditure to meet current seismic standards and are competing for tenants against older buildings that do not measure up, as well as major tenants who want information on downtime and risk to life and contents), and only later by “buyers” who request ratings in order to make comparisons between buildings. The system described above is specific to American practices and would need to be developed further to align with current evaluation procedures before being applied in New Zealand.

**6.2.2.3 Discussion**

We consider that providing a form of grading system that is more easily understood by territorial authorities, building owners, tenants and the general public would be highly beneficial. We consider that an appropriate grading system should be developed by the Ministry of Business, Innovation and Employment in consultation with territorial authorities, building owners, NZSEE, and other interested parties. Such a grading system could be based on or similar to that already set out in the NZSEE Recommendations, using letter grades A to E. The advantage of this form of grading system is that the general public are familiar with such grades and could more easily understand that a D or E grade would indicate a building that poses a clear earthquake risk. Conversely, buildings receiving higher grades may be able to attract higher rental returns and/or lower insurance premiums.

We note that, unlike the SEAONC rating system, the NZSEE grading system focuses on issues of life safety, and does not extend to considerations of repair cost and time to regain function. Concentration on life safety would make the grading system simpler to apply, and we expect that such a grading system would respond to the main emphasis of public concern about the seismic performance of buildings.

6.2.3 Practice in assessing the potential seismic performance of buildings

Knowing how buildings behave in earthquakes, how to identify the key elements of buildings, how to judge the way these elements are likely to perform in an earthquake and the threat that the failure of these elements poses to life requires considerable engineering judgement. Firms use a range of analysis software and modelling techniques, including hand calculations.

The Royal Commission sought information from engineering firms about the practice of assessing likely structural performance of buildings in an earthquake. Responses were received from OPUS International Consultants, Beca Carter Hollings & Ferner Ltd (Beca), and Sinclair Knight Merz. These responses indicate that although firms’ methodologies and analytical tools are likely to be based on the NZSEE Recommendations3 discussed above, and may be consistent within individual firms, there may be less consistency between different firms, resulting in potentially varying levels of assessment of individual buildings across New Zealand’s building stock.

There are several reasons why assessments could vary within the industry. The NZSEE Recommendations have no regulatory standing, meaning there is no compulsion for them to be followed. There is no monitoring of the practice of assessing buildings to identify inconsistencies and address these, or to ascertain whether the NZSEE Recommendations are being followed. Assessing existing buildings, across a range of building types, requires knowledge and experience of each building type, and the standards or practices followed when the building was designed and constructed. Engineers are dependent on the quality of the plans and documentation they receive when judging the likely performance of a building. If the plans are inaccurate or incomplete, then the assessment will be inaccurate; for example, plans may not necessarily reflect how the building was actually constructed or altered. Given the age of some buildings, especially unreinforced masonry (URM) buildings, plans are also likely to only be available in paper form in council files (if at all). In carrying out assessments, engineers are therefore hampered by both the lack of ease of access to records and the inadequacy of many records when available.

Difficulties are experienced in judging how well

an element will perform when it does not fully satisfy current design criteria. Guidance is required on details that are frequently encountered.

For example: the inelastic deformation capacity of plastic hinges in reinforced concrete beams where reinforcement is not fully constrained against buckling; beam column joints that do not contain the specified amount of joint zone reinforcement; or columns that are not confined to the level specified in current Standards. We recommend that research be undertaken so that guidelines can be produced on how such details can be assessed in a consistent manner.

The evidence given to the Royal Commission showed that there are inconsistencies in building assessment practice. It is clearly important that a degree of consistency occurs, given:

a) the result of an assessment may lead to a building being classified as earthquake-prone under the Building Act 2004 and therefore placing a requirement on the owner to undertake certain actions, at their cost; and

b) such assessments may be an important factor in decisions about a building’s viability or tenancy.

Consistency and quality in building assessments could be achieved through the NZSEE Recommendations being given regulatory standing, and some monitoring being undertaken of their implementation. We note however that we propose that the NZSEE Recommendations be reviewed (Recommendation 72).

6.2.4 Issues with the term “new building standard” (NBS)

**6.2.4.1 Introduction**

Under the Building Act 2004 buildings are classified as earthquake-prone if they are unable to withstand a moderate earthquake. As discussed in section 2 of this Volume, the term “moderate earthquake” is defined in the Building (Specified Systems, Change the Use, and Earthquake-prone Buildings) Regulations 2005 as an earthquake that would generate shaking at the site of the building that is of the same duration, but 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 on that site. We note that the emphasis is on the level of shaking and its duration. Neither the Act nor the Regulation draws a comparison with the performance of a new building.

Both territorial authorities and the structural engineering profession have adopted the acronym NBS when assessing the potential seismic performance of an existing building. Expressions such as 100% NBS, 67% NBS and 33% NBS are increasingly used to describe the comparison between the seismic resistance of an existing building with that of a new building at its ULS.

We think it is likely that most non-engineers would assume that an existing building (be it of unreinforced masonry or built in accordance with Standards previously in force) assessed as 100% NBS, in accordance with the methodologies set out in the NZSEE Recommendations, would have a seismic performance equal to that of a new building built to current design standards. However, this is misleading, because in an earthquake that exceeded the design earthquake for the ULS, the existing building would be likely to collapse before a new building. We explain this further in the following sections, dealing respectively with reinforced concrete and unreinforced masonry buildings.

**6.2.4.2 Reinforced concrete buildings**

The NZSEE Recommendations state that “in determining the strength and deformation capabilities of an existing component, calculations shall be based on the probable values of strengths of materials in the buildings”. This is different from the design of a new building where factors of safety are built into the design criteria to ensure that the specified performance can be met with a very low probability of failure. Using probable strengths and focusing on satisfying just the ultimate limit state requirements eliminates the conservative assumptions in both strength and deformation capacities.

In the design of a new structure, design strengths are used, and materials Standards specify material strain limits. The intention behind the use of conservatively assessed design strengths and material strain limits is to ensure, given material variability, that:

• an earthquake with an intensity equal to that considered for the design ultimate limit state can be sustained with a very high level of certainty (a very low probability of failure); and

• there is a margin of safety against collapse for an earthquake with a magnitude of shaking 1.5 times that of the design level earthquake.

In NZS 3101:20066 it has been assumed that the ratio of displacement ductility required for a 2500-year return period earthquake is 1.5 times that corresponding to a 500-year return period earthquake.

In NZS 1170.5:20044 the corresponding ratio (which

is based on analyses in which elastic perfectly plastic hysteretic response was assumed) is given as 1.8. However, the elastic perfectly plastic assumption is not realistic for reinforced concrete. Using a more realistic hysteretic rule, in which strain hardening is accounted for and energy dissipation in small displacement cycles is induced, reduces the ductility demand. Allowance for these factors led to the 1.5 factor being used in NZS 3101:20066.

The difference in likely seismic performance of a building that is assessed on the basis of probable (average) strengths when compared to a new building, which is designed using design strengths, can be gauged from the average ratio of probable to design strengths.

The design strength of a section is taken as strength reduction factor times a theoretical strength, which is based on the assumption that the reinforcement and concrete both have their lower characteristic strengths. The average (probable) strength of reinforcement specified for use in potential plastic regions is 1.08 times the lower characteristic strength and the probable strength of concrete is generally taken as 1.5 times its specified strength. The use of these two strength ratios results in the probable strength of a section typically being 1.1 times the theoretical strength. Allowing for

the strength reduction factor, which is taken as 0.85 for flexure, with or without axial load, gives a ratio

of probable to design strength of 1.1/0.85 that is

approximately equal to 1.3.

For a building with an importance level of 2 the factors of safety inherent in the design of a new reinforced concrete building are intended to give the building probable strength and deformation capacities to enable the structure to survive a 2500-year return period earthquake without collapse. Assessment of a building given a classification of 100% NBS implies that it has probable strength and deformation capacities for the ultimate limit state earthquake with a return period of

500 years. On this basis the building with 100% NBS in which deformation is the limiting factor is five times as likely to reach its critical limiting deformation condition

considered as a measure of the relative risk. Two ratios are given, one based on deformation and one based on strength. These values have been assessed from the ratios of earthquake return factor, R, to return periods given in NZS 1170.5:20044. It is emphasised that these values are approximate and they are intended only to indicate the order of magnitude of relative risk.

|  |  |
| --- | --- |
| **% NBS Deformation critical** | **Strength critical** |
| 100 5 | 2 |
| 67 12 | 5 |
| 33 50 | 21 |
| 20 125 | 50 |

**Table 3: Ratio of number of times a critical condition is reached in an existing building with a given % NBS to a new building designed to current standards (relative risk)**

**6.2.4.3 Unreinforced masonry**

The NZSEE Recommendations3 propose that unreinforced masonry is assessed assuming that the masonry has 15% damping. Modifying the response spectrum for this level of damping reduces design accelerations and displacements to 65% of the corresponding values assumed in standard force-based design where 5% damping is assumed.

A more recent publication based on research at The University of Auckland7 recommends that a displacement ductility of 2, together with a Sp factor of 0.7, should be used for unreinforced masonry elements. Where the period is not known, it was recommended that the *ku* factor is taken as 1.2. Using these values the design response spectra are reduced to 58% of the standard 5% damped elastic response spectra. The justification given for this reduction is that URM structures behave in a non-linear mode, and they dissipate energy by rocking and sliding of bricks. We note that NZS 4230:2004, *Design of Reinforced Concrete Masonry Structures*8, specifies that concrete masonry structure walls with minimum reinforcement would be designed as elastically responding with a structural

as a building designed to current design standards.

ductility factor of 1 and an Sp

factor of 1. In this case

If strength is critical rather than deflection, a building

with 100% NBS is twice as likely to sustain the limiting conditions as a new building.

Table 3 below indicates the ratio of the number of times a critical condition may be reached in a building with a given percentage of NBS when it is compared to new building built to current design standards. This may be

there would be no reduction in the standard 5%

damped elastic spectra. The two sets of values

for URM and concrete masonry structures are in sharp contrast with the lower strength and deformation demands being assumed in the assessment of unreinforced masonry structures, which have poorer and less defined material properties. This seems questionable. We consider that further study is required to justify this difference.

The reduction in design actions in URM structures is based on the results of tests on walls subjected to in-plane pseudo-static (see C4.3.2A in The University of Auckland’s recent research publication7). Given the requirement for slip and rocking of masonry units within the walls, which is required to provide the damping, the question arises as to the effect of this disruption in the wall on the structural performance for out-of-plane actions, which will always be present in earthquakes. Furthermore, URM walls depend on gravity loading for their strength and for energy dissipation by sliding. Clearly the resistance associated with gravity loading could be appreciably modified by vertical ground motion, especially for masonry units near the top of a structure.

We consider that the recommendations for either the use of 15% damping, or the assumption of a structural ductility factor of 2 and an Sp factor of 0.7 for use with unreinforced masonry elements, should be treated with caution in assessing the percentage of NBS for an URM building. We expect that the relative risk of an URM building assessed as 100% NBS would be considerably greater than 5 when compared to a new building designed to current standards. We consider this is an area that requires more research, particularly for masonry members subjected simultaneously to in-plane and out-of-plane actions.

**6.2.4.4 Conclusion**

The Royal Commission considers that the present use of “33% NBS” conveys an incorrect expectation that the performance of a building in an earthquake is at 33% (or other nominated figure) of the capacity of a new building. This confusion was reported in and apparent from the evidence given at the Royal Commission’s hearing into earthquake-prone buildings in November 2011. We consider the use of the undefined term “NBS” should be avoided. For reasons we address in section 6.2.4.1, the proper comparison is in fact with that of a new building at its ultimate limit state (ULS) and use of “% ULS” instead of “% NBS” would avoid the implication that the existing building’s performance would match that of a new building. In the balance of this Volume, we use the term “% ULS” accordingly.

We consider that the Ministry of Business, Innovation and Employment should clearly describe to territorial authorities and the public the difference between the expected behaviour of an existing building built under previous standards or codes prior to collapse and the behaviour of a building which complies with the current Building Code.

6.2.5 Practical assessment considerations

In section 2 of this Volume we discussed the evolution of seismic design standards that has taken place in New Zealand since 1935. Against that background, we now note some matters that we consider should be taken into account in an assessment of the potential seismic performance of buildings designed to standards in force earlier than those which currently apply.

An initial step is to consider the differences in design strength and the ductility provisions that have been introduced between the time the building was designed and the current design standards were written. Fenwick and MacRae9, and MacRae et al.10 record these changes. Knowledge of the changes in design practice gives a guide to aspects of the structure that need to be studied closely.

**6.2.5.1. Allowing for flexural cracking**

The reduction in section properties that is made to allow for flexural cracking in reinforced concrete structures can make a significant difference to the calculated periods of vibration of buildings as well as the inter-storey drift levels. In assessing the seismic performance of buildings it is important that allowance is made for this effect. Table 4 below gives typical values assessed from the different recommendations for moment resisting frames and structural walls. The values given for the frames are weighted average values based on recommended stiffness values for beams and columns.

|  |
| --- |
| **Year Code Moment Structural**  **Standard resisting walls frames** |
| 1965 NZSS 1900 1.0 1.0 |
| 1976 NZS 4203 0.75 0.75 |
| 1982 NZS 3101 0.67 0.5 |
| 1995 NZS 3101 0.43 0.3 |
| 2006 NZS 3101 0.43 0.3 |

**Table 4: Recommended section properties for seismic analyses given as a proportion of gross section properties (source: Fenwick and MacRae, 2009,**

**and MacRae et al., 2011)**

**6.2.5.2 Allowing for accidental torsion**

In NZS 4203:197611 allowance was made for accidental torsion introduced into buildings due to torsional ground motion and the possible non-uniform distribution of live-load in the building. This effect was allowed for by requiring the calculated distance between the centre of mass and the calculated centre

of lateral stiffness to be increased by a distance of one- tenth of the width of the building. This allowance has been maintained in all subsequent loading Standards.

**6.2.5.3 Calculating inter-storey drifts**

When assessing the inter-storey drift capability of an existing building in terms of current design standards it is essential to allow for a number of major changes that have occurred in the last two decades. These changes are briefly outlined below and further details are given

in Fenwick and MacRae, and MacRae et al.

In NZS 4203:197611 and 198412 the design seismic forces were determined from the design response

of a building it was essential that allowance was made for the peak inter-storey drifts and for these elements the design inter-storey drifts were doubled.

In NZS 4203:199213 and NZS 1170.5:20044 the design inter-storey drift was taken as the structural performance factor, Sp, times the peak displacement based on the equal displacement concept. To this displacement an allowance was added to allow for the additional inter- storey drift associated with P-delta actions. The Sp factor for ductile structures was taken as 0.67 in NZS 4203:199213 and 0.7 in NZS 1170.5:20044. Where peak values are required for the design of stairs or ramps the design displacement should be divided by Sp though this correction is not given in the design Standards. (We have previously recommended that the design displacement for stairs is further increased so that there is a safe means of egress in the event of an earthquake with an unusually high intensity of shaking.)

In buildings where the lateral resistance is provided by structural walls, multiplying the elastic drift by the

spectrum that was divided by the factor 4

/

*SM*

to allow

structural ductility factor can appreciably under-

for the reduction in design forces associated with

ductile behaviour. This reduction was equivalent to assuming the structure had a displacement ductility,

estimate the inter-storey drifts in the lower levels of a

building. This arises as the inelastic deformation is associated with the formation of a plastic hinge near

µ = 4

/

*SM*

. The equal displacement concept implies

the base of the wall. This discrepancy is illustrated in

the resultant deflection is equal to µ times the elastic

deflection induced by the design forces. However, in the design Standards the design displacement scaled to allow for inelastic deformation was defined as the

elastic deflection times 2/*SM* for the equivalent static

method and 2.2/*SM* (in NZS 4201:1984) for the modal

response spectrum method. In effect the design displacement was being taken as 50% and 55% of the predicted peak displacement for the equivalent static and modal response spectrum methods respectively. Where stairs or ramps are connected at different levels

Figure 87 and it arises as the inelastic deformation is

not spread over the height of the building, as is the case in a ductile moment resisting frame structure. In NZS 4203:199213 and NZS 1170.5:20044 this discrepancy was removed by requiring the critical inter-storey drifts to be based on the greater of the drifts found, by multiplying the elastic inter-storey drift by the structural ductility factor, or by the value found from the equivalent of a pushover analysis. In interpreting inter-storey drifts in structural wall buildings designed to Standards prior to 1992, it is important to make allowance for this discrepancy.

Push over

Elastic

Scaled elastic

(a) Structural wall (b) Deflected shape profile

**Figure 87 : Difference between push over and scaled elastic deflected shapes**

Peak inter-storey drifts predicted by inelastic time history analyses are found to be appreciably higher than the corresponding values predicted from equivalent static and modal response spectrum methods. Figure 88 illustrates the difference that has been observed. To allow for this discrepancy a drift modification factor was introduced into NZS 1170.5:20044. When assessing the performance of an existing building against current design criteria it is important to allow for the drift modification factor.

Modal

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

Scaled modal

Non linear time history profile

(a) Building (b) Deflected shape envelope

**Figure 88: Drift modification factor**

**6.2.5.4 Allowing for P-delta actions**

Allowance for P-delta actions was introduced into NZS

4203:199213. For buildings where the seismic resistance is provided by ductile moment resisting frames the requirement to consider P-delta actions typically increases the lateral strength and inter-storey drifts by 30%. For structural walls the effect is smaller.

**6.2.5.5 Confinement of columns**

Prior to 1995 not all columns were required to be confined. The lack of confinement means that it is likely that some columns in existing buildings designed prior to 1995 will not be sufficiently ductile to sustain the inelastic deformation required by current design methods.

**6.2.5.6 Load tracking and detailing of connections**

In an assessment of an existing building the first step is to identify the load paths to ensure that inertial induced seismic forces have a logical load path so that the forces can be transmitted to the foundation soils. Each load path must satisfy the requirements of equilibrium and compatibility. Of particular concern are the parts of the load path that pass through the connections of different structural elements, such as occurs in beam-column joints. It is essential to ensure that there is a valid load path through the detail.

An example of load tracking though a structural steel junction is given in section 8.3 of Volume 2.

Figure 89 illustrates a case of a beam-column joint where there is no valid load path through the detail. The bottom reinforcement in the beam is anchored in the mid-region of the beam-column joint. To satisfy equilibrium, the flexural tension force in the beam reinforcement must be anchored at the location where the diagonal compression force through the joint meets the vertical compression force in the lower column. As drawn this requires the beam tension force to be resisted by tension in the concrete at the location marked by b. Once this concrete cracks in tension, equilibrium cannot be maintained and the cracks b-c and b-d will form and collapse will occur. If the beam reinforcement had been anchored on the far side of the joint zone from where it entered the column, the beam- column joint may have sustained a few load cycles before failure occurred. The addition of joint zone ties, preferably also with the addition of intermediate column bars, would have enabled a number of different load paths to be sustained through the detail, giving a more robust beam-column joint zone. The capacity of the joint zone to sustain inelastic load cycles is increased with the addition of joint zone ties and intermediate column bars.

**N**

**T C**

**M** = bending moment

**C** = compression force

**T** = tension force **C N** = axial load

c

**M**

b

d a **T**

**C T**

**Figure 89: Inadequately detailed beam-column connection**

**6.2.5.7 Other factors**

The Royal Commission’s study of the representative sample of buildings highlighted a number of aspects of buildings that need to be considered in making an assessment of their potential seismic performance. The more important of these aspects are briefly described below, with greater detail given in Volume 2 of the Report.

In lightly reinforced structural elements such as walls and some beams it was found that only one crack formed and opened up creating high strains in the reinforcement. This was due to insufficient tension force being transmitted across the crack to induce secondary cracks in the wall. There were two main consequences. First, very high localised strains were induced in the reinforcement, which in some cases caused the reinforcement to fail. Secondly, the lack of flexural cracks meant that the wall was stiffer than assumed in the design, where allowance would have been made for the reduction in stiffness associated with flexural cracking. The consequence of this is that the building attracted higher seismic forces than indicated by the design calculations.

NZS 3101:199514 and NZS 3101:200615 do not have appropriate design criteria for moderately and heavily

/

loaded walls, *N A f* ʼ 0.1 and the assessment of these

*g c*

elements needs to be carried out with caution.

The formation of plastic hinges in reinforced concrete elements causes elongation to occur. This can have a number of adverse effects, which include:

• the formation of wide cracks in floor slabs that contain precast pretension units; and

• plastic hinges in coupling beams can push coupled walls apart. Where there are floors tied into the walls the restraint provided by the walls can increase the shear capacity of the coupling beams. In extreme cases this may cause the coupled wall to act as a single unit reducing its ability to dissipate seismic energy.

The formation of wide cracks in floors can result in the failure of non-ductile mesh. Where mesh is used to tie critical elements together, such as floors to structural walls, retrofit should be undertaken to provide a ductile connection.

Incompatible deformations of adjacent structural walls were found to cause local failures in adjacent elements, such as floors or beams that were tied into the walls.

Some structural elements such as L and/or T-shaped walls have a greater lateral strength in the forward direction of displacement than in the reverse direction. Under seismic actions this difference in strength can cause the element to ratchet in the weaker direction, thereby increasing the lateral displacement of the building.

Irregularities in plan and/or elevation can lead to concentrations of strain and displacement at certain locations in the building, which generally reduce the seismic performance of the building.

In a number of buildings built prior to the mid-1970s

the perimeter columns were confined by deep spandrel beams or what was intended to be non-structural infill. However, this infill creates short columns that have frequently failed in shear.

Flexural torsional interaction in reinforced concrete members is not covered in the current Concrete Structures Standard, NZS 3101:200615. It is postulated that this interaction may have reduced the seismic performance of a shear core that was subjected simultaneously to high flexural and torsional actions.

Particular care needs to be taken to identify

irregularities in structural elements which sustain gravity loads and/or seismic actions. Such irregularities may take the form of offsets in structural walls or columns. Beams that are required to act as transfer elements also require careful consideration. Where these occur particular care is required to assess the limitations that these details impose on the seismic performance.

**6.3 Techniques for and costs of retrofitting unreinforced masonry buildings**

6.3.1 New Zealand experience

The Royal Commission obtained examples of seismically retrofitted buildings and costs from Beca Carter Hollings and Ferner Limited (Beca), and Opus International Consultants Limited (Opus). These are summarised in Appendix 1 to this Volume. These examples provided a description of the strengthening work undertaken, the associated costs and, for Christchurch buildings, how they performed in the Canterbury earthquakes.

The information showed that the techniques for retrofitting a building vary significantly depending on the size and complexity of the task. The main strengthening techniques used were:

• tie-back of gable walls and facades;

• façade retention;

• steel bracing;

• adding a layer of reinforced concrete to brick walls; and

• plywood diaphragms added.

The costs of the retrofits also varied significantly ranging from $430/m2 for a relatively small, less complex project (such as façade retention) to $3600/m2 for a complex project. Opus provided examples of buildings that had been strengthened and had performed well in the Canterbury earthquakes. These buildings were strengthened to 67% of the loadings Standards requirements for new buildings at the time of strengthening, at a cost ranging between 100% and 120% of a new replacement structure.

Holmes Consulting Group16 conducted two studies

in 2005 and in 2009 for the Christchurch City Council on the costs to upgrade heritage buildings. The Royal Commission requested an update of this information. The update17 addressed the cost of upgrading all earthquake-prone buildings to 33% and 67% of Full Code Loading18 (FCL). The update found that a reasonable average cost allowance for seismic strengthening is as follows:

• $500/m2, (±30%) for 33% FCL; and

• $1250/m2 (±30%) for 67% FCL.

In addition to these costs, allowance needs to be made for other costs such as repair, reinstatement and other required upgrades. The Royal Commission notes that the examples of buildings provided are for structures of note or community importance. They may not be representative of a more general pool of buildings and the costs may be greater than typical buildings would require.

6.3.2 USA experience

Rutherford and Chekene19, consulting engineers in California, provided the Royal Commission with two reports detailing techniques for seismic retrofitting and costs. These reports detail various seismic strengthening techniques including:

• strong-backs installed either internally or externally;

• steel or concrete moment frames and steel brace frames;

• addition of cross-walls;

• post-tensioning; and

• Shotcrete, Fibre Reinforced Polymer (FRP) and other similar methods.

New Zealand practice is generally consistent with the approaches detailed in these reports.

For additional information on seismic retrofitting and the performance of buildings after the 22 February 2011 earthquake, see Ingham and Griffith20, and the

discussion in it.

6.3.3 Guidelines for strengthening URM

buildings

Engineers at The University of Auckland7 have prepared and made publicly available draft guidelines *(Assessment and Improvement of Unreinforced Masonry Buildings for Earthquake Resistance* and related commentary7*)* for assessing and improving the seismic strength of URM buildings. When complete they will be a major update, giving examples of the application of current URM analysis methodologies referred to in Chapter 10 of the NZSEE Recommendations3.

They provide guidance and design examples for

the calculation of design actions using Section 8 of NZS 1170.5:20044, described above. It is noted that out-of-plane design actions on a part, such as a parapet, are based on a rocking period of this element, which reduces the part spectral shape coefficient and hence the design actions. By strengthening these elements, the part’s period will be reduced as the rocking motion of the part is inhibited, leading to a higher part design action coefficient, which must be accounted for.

In addition to these guidelines7, the Royal Commission has been made aware21 that an internationally representative group of seismic design engineers (including New Zealand experts) is working on an update to the American Society of Civil Engineers (ASCE) – Structural Engineering Institute (SEI)22 *(Seismic Rehabilitation of Existing Buildings)* standard of practice for the design of retrofit. This document and its companion document, ASCE/S61 31-0323 *(Seismic Evaluation of Existing Buildings)*, will be combined and the update is currently expected to cover both seismic evaluation and retrofit. A subgroup of the update committee is working specifically to improve procedures for URM buildings. They are also including a section “System – Specific Performance Procedures”. This, which is also now in draft form, will describe parameters that may be assumed in assessments of simple URM structures.

6.3.4 Improving URM buildings

Ingham and Griffith24 recommended a four-stage improvement process for URM buildings. These stages are:

**1st stage**: ensure public safety by eliminating falling hazards. This is done by securing/strengthening URM building elements that are located at height (e.g. chimneys, parapets, ornaments and gable ends).

**2nd stage**: strengthen masonry walls to prevent out-of-plane failures. This can be done by adding reinforcing materials to the walls and by installing connections between the walls and the roof and floor systems at every level of the building so that walls no longer respond as vertical cantilevers secured only at their base.

**3rd stage**: ensure adequate connection between all structural elements of the building so that it responds as a cohesive unit rather than individual, isolated building components. In some situations it may be necessary to stiffen the roof and floor diaphragms, flexurally strengthen the masonry walls, and provide strengthening at the intersection between perpendicular walls.

**4th stage:** if further capacity is required to survive earthquake loading, then in-plane shear strength of masonry walls can be increased or high-level interventions can be introduced, such as the insertion of steel and/or reinforced concrete frames to supplement or take over the seismic resisting role from the original unreinforced masonry structure.

In our Interim Report, we recommended that the first

of the stages be implemented throughout New Zealand and that the second stage be implemented in areas of moderate and high seismicity. We also undertook to give consideration to stages 3 and 4. Since publishing the Interim Report, we have received a further report from Ingham and Griffith20 recording the consequences of the 22 February 2011 earthquake, and conducted hearings in which there was extensive evidence about the performance of URM buildings.

On the basis of the further studies and information conveyed at the hearings we now confirm the views expressed in the Interim Report that, for safety considerations, falling hazards such as chimneys, parapets and ornaments should be given a higher level of protection. In addition, however, we consider that the external walls of all URM buildings should be supported by retrofit, even in areas of low seismicity.

We have recorded in section 4 of this Volume the many instances where external walls failed in the February earthquake, causing loss of life. We summarised the evidence in section 5.3.1, where we noted that 19 of the buildings that failed had weak walls, 11 were cases where the façades rotated and fell out into the street and seven were instances where side walls failed collapsing inwards, or onto adjacent buildings. We consider that there is a demonstrated need in the interests of public safety for these elements of URM buildings to be strengthened throughout New Zealand.

We also consider that the design actions for the elements and connections to be strengthened should be based on the provisions in NZS 1170.5: 2004: *Section 8 – Requirements for Parts and Components*4. A part is described in the commentary to the Standard as follows:

A part is an item within, or attached to, or supported by the structure. Parts are not generally included in the design of the primary seismic load resisting system.

It may also be an element of the main structural system which can be loaded by earthquake action in a direction not usually considered in the design of that element, such as face loading on a masonry shear wall, or upwards loading on a cantilever.

Thus “part” may include ornamentation, canopies, parapets, chimneys, gable ends and external walls. These provisions will determine that the factors used in determining the design actions on these parts and their connections will be greater than factors applied to the mass of the building as a whole. The site horizontal ground acceleration is modified to allow for the amplification of response up the height of the structure, as well as other modifications for the part spectral shape coefficient, part response factor and part risk factor.

For buildings less than 12m in height and with a fundamental period less than 0.5 seconds, the lateral force coefficient for the part is generally of the order of 2.25 times the base shear coefficient for an elastically responding structure.

The potential need to implement the third and fourth stages of retrofit recommended by Ingham and Griffith24 should be taken into account in the detailed assessment of buildings that are earthquake-prone and strengthened in accordance with the findings of that detailed assessment.

**6.4 Improving non-URM buildings** Determining what changes need to be made to an existing building to bring its seismic performance up to an acceptable level requires a high level of skill. An initial step would be to identify which structural features are likely to limit the seismic performance from a close examination of the structural drawings. Where to look for such critical features might be gained from knowledge of the changes that have occurred in design and construction practice between the time when the building was designed and the current time. Fenwick and MacRae, and MacRae et al. could help with this task.

In carrying out an assessment it should be noted that the detailing that is used is generally more important in terms of identifying the level of earthquake resistance against collapse than the design strength that was provided. Consequently the detailing that was used in the construction as described on the structural drawings and in the specification should be studied closely.

Caution is required in planning structural retrofit to ensure that one element, such as a column, does not adversely affect other structural elements. For example, retrofitting a column to increase its lateral deformation capacity by adding confinement may have the effect of increasing the seismic actions induced in the beam-column joints, which generally cannot be easily retrofitted. A consequence of this could be that the joint zone may fail in a brittle mode. Alternative strategies that could be considered include:

• stiffening the structure so that the seismic forces have an alternative load path, which reduces the deformation imposed on the column, or other structural element;

• weakening structural elements, such as beams where they frame into beam-column joints, by cutting some of the flexural reinforcement in the beams adjacent to the column faces. This action may reduce the seismic actions induced on the joint zone and on the columns to a safe level but at the expense of additional deformation that needs to be sustained in the beam.

• providing an alternative means of support for gravity loads in the event that either the columns or beam-column joints fail;

• reducing the seismic actions by reducing the seismic mass; and

• providing additional damping capacity (energy dissipation) to the structure by base isolation or other means as described in Volume 3.

**6.5 Conclusions and recommendations – assessing and improving buildings**

6.5.1 Assessing existing buildings

Assessing the likely strength of a building structure is a specialised task requiring not only analytical technique but experience that has led to the development of sound professional judgement. The Royal Commission considers these assessments should be undertaken by engineers with relevant experience. The training and organisation of the engineering profession is discussed in a later Volume of this Report.

The Royal Commission considers that improving New Zealanders’ understanding of the nature of a building they may be purchasing, using or passing by is important. The NZSEE and SEAONC grading systems were discussed in section 6.2 of this Volume. We consider that developing such a grading system would be beneficial and should be developed by the Ministry of Business, Innovation and Employment in consultation with territorial authorities, building owners, NZSEE, and other interested parties. Such a grading system could be based on or similar to that already set out in the NZSEE Recommendations, using letter grades A to E.

**Recommendation**

We recommend that:

72. The Ministry of Business, Innovation and Employment should work with territorial authorities, building owners, the New Zealand Society for Earthquake Engineering and other interested parties to develop a grading system for existing buildings that is able to be understood by the general public and adequately describes the seismic performance of a building.

The Royal Commission considers that the NZSEE Recommendations3 are generally sound. However, the IEP and Detailed Assessment processes should be reviewed to take into account the risk that plans may not accurately record actual construction decisions and materials, especially for older buildings. In addition, the review should consider substantive issues; for example, inadequate restraint of bars in beams and columns against buckling. The resulting new practice standards or methods for evaluating existing buildings should also

be given regulatory standing and monitored, to ensure consistency in application and use, given the potential resulting classification as an “earthquake-prone building” under the Building Act 2004.

**Recommendations**

We recommend that:

73. The Ministry of Business, Innovation and Employment should review the NZSEE Recommendations3 and, in conjunction with engineering practitioners, establish appropriate practice standards or methods for evaluating existing buildings.

These practice standards or methods should have regulatory standing, and be monitored by the Ministry of Business, Innovation and Employment for consistency of application.

74. Structural engineers assessing non-URM buildings should be familiar with the practical assessment considerations discussed in section 6.2.5 of this Volume. Those considerations should also be referred to in the practice standards or methods developed in accordance with Recommendation 73.

We consider that the use of 15% damping, or the assumption of a structural ductility factor of 2 and an Sp factor of 0.7, should be used with caution in assessing the percentage ULS for an URM building. We expect that the relative risk of an URM building assessed as 100% ULS would be considerably greater than 5 when compared to a new building designed to current standards. We consider this is an area that requires more research.

As discussed in section 6.2.4 of this Volume, the Royal Commission considers that allocating a percentage of NBS to existing building performance in an earthquake conveys an incorrect expectation of the building’s performance when compared to buildings designed to the current standards. We consider that the use of the undefined term “new building standard” (NBS) should therefore be avoided and the Ministry of Business, Innovation and Employment should clearly describe to territorial authorities and the public the difference between the expected behaviour of an existing building prior to collapse and the behaviour of a building that complies with the current Building Code.

**Recommendations**

We recommend that:

75. Further research should be carried out into the suitability of assuming 15 per cent damping, and a structural ductility factor

**Recommendations**

We recommend that:

77. For unreinforced masonry buildings, falling hazards such as chimneys, parapets and ornaments should be made secure or removed.

of 2 and an S

p

factor of 0.7, in assessing

78. The design actions for the elements and

unreinforced masonry elements.

76. The Ministry of Business, Innovation and Employment should clearly describe to territorial authorities and the public the difference between the expected behaviour of an existing building prior to collapse, and the behaviour of a building that complies with the current Building Code.

6.5.2 Improving existing buildings

We consider that there is a demonstrated need in the interests of public safety for the hazardous elements of unreinforced masonry buildings to be strengthened throughout New Zealand. For the reasons we have addressed in this Volume, we consider that falling hazards such as chimneys, parapets and ornaments should be given a higher level of protection. In addition, we consider that the external walls of all URM buildings should be supported by retrofit, even in areas of low seismicity. We are also of the view that the design actions for the elements and connections to be strengthened should be based on the provisions in NZS 1170.5:2004: *Section 8 – Requirements for Parts and Components*4.

The potential need to implement the third and fourth stages of retrofit recommended by Ingham and Griffith should be taken into account in the detailed assessment of URM buildings which are earthquake-prone and such buildings strengthened in accordance with the findings of that detailed assessment.

connections to be strengthened should be based on the provisions in NZS 1170.5:2004: *Section 8 – Requirements for Parts and Components*4.

79. The external walls of all unreinforced masonry buildings should be supported by retrofit, including in areas of low seismicity.

80. The detailed assessment of unreinforced masonry buildings that are earthquake-prone should take into account the potential need to:

a ensure adequate connection between all structural elements of the building so that it responds as a cohesive unit;

b increase the in-plane shear strength of masonry walls; or

c introduce high-level interventions (such as the insertion of steel and/or reinforced concrete frames) to supplement or take over the seismic resisting role from the original unreinforced masonry structure.

Such buildings should be strengthened in accordance with the findings of that detailed assessment.

81. Recommendations 75 to 80 should be undertaken within the same timeframes as recommended in Recommendations 82 to 86 for unreinforced masonry buildings.

We discuss the level at which a building should be considered earthquake-prone under the Building Act

2004 in section 7 of this Volume.

**References**

1. New Zealand Society for Earthquake Engineering. (2009). *Building Safety Evaluation During a State of Emergency: Guidelines for Territorial Authorities*. Wellington, New Zealand: Author.

2. Various authors. (Revision 7 as at June 2012). *Guidance on Detailed Engineering Evaluation of Earthquake Affected*

*Non-residential Buildings in Canterbury, Part 2, Evaluation Procedure*. Draft prepared for the Department of

Building and Housing. Retrieved from <http://sesoc.org.nz/images/Detailed-Engineering-Evaluation-Procedure.pdf>

3. New Zealand Society for Earthquake Engineering. (June 2006). *Assessment and Improvement of the Structural*

*Performance of Buildings in Earthquakes; including Correngendum No 1*. Wellington, New Zealand: Author.

4. NZS 1170.5:2004. *Structural Design Actions, Part 5: Earthquake Actions – New Zealand*, Standards New Zealand.

5. SEAONC Existing Buildings Committee Building Rating Subcommittee. (2011). *SEAONC Rating System for the Expected Earthquake Performance of Buildings*. Paper presented at the Structural Engineers Association of California (SEAOC) Conference. Retrieved from <http://www.seaonc.org/pdfs/2011_07_11_EPRS_SEAOC_2011.pdf>

6. NZS 3101:2006. *Concrete Structures Standard,* Standards New Zealand.

7. Ingham, J. (Ed.). (2011). *Assessment and Improvement of Unreinforced Masonry Buildings for Earthquake Resistance: Supplement to “Assessment and Improvement of the Structural Performance of Buildings in Earthquakes”* and *Commentary*. Draft dated February 2011. Based on recommendations from research by the Faculty of Engineering, The University of Auckland. Wellington, New Zealand: New Zealand Society for Earthquake Engineering. Retrieved from [http://www.retrofitsolutions.org.nz/retrofit-manuals/unreinforced-masonry-buildings/.](http://www.retrofitsolutions.org.nz/retrofit-manuals/unreinforced-masonry-buildings/)

8. NZS 4230:2004. *Design of Reinforced Concrete Masonry Structures*, Standards New Zealand.

9. Fenwick, R.C. and MacRae, G. (2009). Comparisons of New Zealand Standards used for Seismic Design of Concrete Buildings. *Bulletin of the NZ Society for Earthquake Engineering*, 42(3), 107-203.

10. MacRae, G., Clifton, C. and Megget, L. (2011). *Review of NZ Building Codes of Practice: Report to the Royal Commission of Inquiry into the Building Failure Caused by the Canterbury Earthquakes*. Christchurch, New Zealand: Canterbury Earthquakes Royal Commission.

11. NZS 4203:1976. *Code of Practice for General Structural Design and Design Loadings for Buildings*, Standards New Zealand.

12. NZS 4203:1984. *Code of Practice for General Structural Design and Design Loadings for Buildings*, Standards New Zealand.

13. NZS 4203:1992. *Code of Practice for General Structural Design and Design Loadings for Buildings*, Standards New Zealand.

14. NZS 3101:1995. *The Design of Concrete Structures*, Standards New Zealand.

15. NZS 3101:2006. *Concrete Structures Standard*, Standards New Zealand.

16. Holmes Consulting Group Limited. (2009). *Heritage Earthquake Prone Building Strengthening Cost Study*.

Report prepared for the Christchurch City Council. Christchurch New Zealand: Canterbury Earthquakes

Royal Commission.

17. Holmes Consulting Group Limited. (2012). *Report: Royal Commission Reports: 107494*. Christchurch, New Zealand: Canterbury Earthquakes Royal Commission.

18. We infer that “FCL” is used to denote the design earthquake for the ultimate limit state.

19. Rutherford and Chekene. (2006). *Techniques for the Seismic Rehabilitation of Existing Buildings* (FEMA 547/2006

Edition). Washington D.C., United States of America: Federal Emergency Management Agency.

20. Ingham, J.M. and Griffith, M.C. (October 2011). *The Performance of Earthquake Strengthened URM Buildings in the Christchurch CBD in the 22 February 2011 Earthquake: Addendum Report to the Royal Commission of Inquiry*. Christchurch, New Zealand: Canterbury Earthquakes Royal Commission.

21. Working drafts of this document were attached to personal communications between F. Turner and the

Royal Commission.

22. American Society of Civil Engineering. (2007). *Seismic Rehabilitation of Existing Buildings* (ASCE Standard

ASCE/SEI 41-06). Reston, Virginia, United States of America: Author.

23. American Society of Civil Engineering. (2003). *Seismic Evaluation of Existing Buildings* (ASCE Standard

ASCE/SEI 31-03). Reston, Virginia, United States of America: Author.

24. Ingham, J.M., and Griffith, M.C. (August 2011). *The Performance of Unreinforced Masonry Buildings in the*

*2010/2011 Canterbury Earthquake Swarm: Report to the Royal Commission of Inquiry*. Christchurch, New Zealand: Canterbury Earthquakes Royal Commission.

Note that Standards New Zealand was previously known as the Standards Institute of New Zealand.

**Section 7:**

**Earthquake-prone buildings policy and legislation**

**7.1 Introduction**

We have addressed in a summary way the existing statutory provisions for earthquake-prone buildings in section 2 of this Volume. In this section we now discuss in more detail the subject of policies for earthquake- prone buildings that territorial authorities are required to adopt and review under the Building Act 2004.

We also discuss related provisions of the Building Act that present questions of interpretation or act as impediments to addressing earthquake-prone buildings. Other issues covered include the interaction between the Building Act and the Resource Management Act 1991, and whether people such as building owners are appropriately informed when making decisions on earthquake-prone buildings.

**7.2 Policies about earthquake-prone buildings**

For ease of reference, we again set out section 131 of the Building Act 2004:

**131 Territorial authority must adopt policy on dangerous, earthquake-prone, and insanitary buildings**

(1) A territorial authority must, within 18 months after the commencement of this section, adopt a policy on dangerous, earthquake-prone, and insanitary buildings within its district.

(2) The policy must state –

(a) the approach that the territorial authority will take in performing its functions under this Part; and

(b) the territorial authority’s priorities in performing those functions; and

(c) how the policy will apply to heritage buildings.

As we noted in section 2 of this Volume, section 132 of the Building Act requires territorial authorities to review a policy adopted under section 131 at least every five years. In adopting and reviewing the policy, the territorial authorities must follow the special consultative procedure set out in section 83 of the Local Government Act 2002.

This involves the giving of public notice of the proposed policy, enabling persons interested in it to make submissions, which must be considered by the council. When the Building Act 2004 came into force, territorial authorities were required to finalise their policies and submit them to the former Department of Building and Housing by May 2006.

As can be seen from section 131 of the Act, the policies adopted must state what approach the council intends to take in performing its functions “under this Part”, the priorities that will be set, and how the policy will apply to heritage buildings. The Part of the Building Act in which section 131 appears deals generally with building, and we assume that the intended reference is in fact to “Subpart 6–Special provisions for certain categories of buildings”. This means that a policy adopted under section 131 will relate only to dangerous, earthquake- prone and insanitary buildings, as the heading of the section implies. Our focus is on earthquake- prone buildings.

7.2.1 Active and passive earthquake-prone policies

Following the introduction of the 2004 Act, the

former Department of Building and Housing prepared guidelines1 intended to assist territorial authorities in the development of their policies on earthquake-prone buildings under the new statutory provisions. This document was entitled *Earthquake-Prone Building Provisions of the Building Act 2004: Policy Guidance for Territorial Authorities*, which we will refer to as the DBH Guidelines. The foreword to the DBH Guidelines noted that it was not “prescriptive”, and that it was expected that territorial authorities, in consultation with their communities, would develop policies that struck a balance between the need to address earthquake risk and other priorities, taking account of the “social and economic implications of implementing the policy”.

In the introduction section of the DBH Guidelines, it was observed that:

The definition of an earthquake-prone building is set out in section 122 of the Act and in the related regulations that define ‘moderate earthquake’. This definition is significantly more extensive and requires a higher level of structural performance for buildings than that provided by the Building Act 1991. It encompasses all buildings, not simply those constructed of unreinforced masonry or unreinforced concrete. Small residential buildings are exempt from these provisions.

It was also observed that while the legislation required all territorial authorities to address the issue of earthquake-prone buildings, the nature of individual responses could vary. It is also worth noting the statement setting out the Departmental view of the intent of the legislation. This was described as follows:

**Intent of the Legislation**

New Zealand is subject to earthquakes of varying severity and some parts of it are seismically more active than others. In these seismically more active locations, the population’s life and health, its buildings and other built infrastructure are at considerable risk.

The Building Act 2004 is the legislative expression of the government’s policy objective for New Zealand buildings. The legislation relating to EPBs seeks to reduce the level of earthquake risk to the public over the time and target the most vulnerable buildings. Strengthening buildings to improve their ability to withstand earthquake shaking will involve costs to TAs, building owners and the community generally.

For this reason, the government has not imposed a “one size fits all” approach to the management of problems associated with earthquake-prone buildings. The measures of the legislation recognise that local economic, social and other factors have an impact on the implementation of these provisions of the Act. The measures in the legislation also recognise the need for a consistent, transparent and accountable approach to the implementation of the provisions in order to protect both building owners and users.

Against the background of that view of the intent of the legislation, the balance of the DBH Guidelines emphasised that it was for each individual territorial authority to decide on the content of its policy. In an appendix to the document, a distinction was made between “active” and “passive” approaches.

Under an active approach, high risk buildings would be identified, and priorities and timeframes for action and guidelines for performance levels for upgrading set. The territorial authority would serve notice on the owners requiring them, at their cost, to carry out a

detailed assessment and/or performance improvement as appropriate. This approach would provide a territorial authority with information about the earthquake-prone buildings in its district and enable it to make decisions about how they should be managed. It was noted that setting up and managing this approach would involve significant costs to the territorial authority and there would be a greater impact on building owners.

In outlining the alternative passive approach, the DBH Guidelines said:

**A passive approach**

If a TA were to adopt a more reactive approach, the IEP and detailed assessment and any improvement of structural performance would be triggered by an application under the Building Act for building alteration, change of use, extension of life or subdivision.

With this arrangement, on receipt of an application relating to a building that the desktop research indicated could be earthquake-prone, a TA would undertake an IEP on the building. If this process indicated that the building was likely to be earthquake-prone, the TA would seek a detailed assessment of the building’s structural performance before issuing a building consent. If the detailed assessment indicated that a building was earthquake-prone, a TA would issue a notice to reduce or remove the danger to the level set out in its EPB policy. This work could be undertaken as part of the building work for which an owner seeks consent. However, once an application activates the EPB policy, a TA should require any necessary upgrading to be undertaken even if a building owner decides not to undertake the building work set out in the application.

This second approach has the significant disadvantage that it relies on a somewhat haphazard order

of remediation based essentially on an owner’s intention for a building. This could leave some significant high-risk buildings untouched for a long period of time.

On the other hand, the cost of administering such a programme would be significantly less than an active programme.

In a passive approach, assessment is carried out to identify high risk buildings but improvement of structural performance is only required after an application for consent for alteration of an existing building (section 112 of the Building Act) or a change of use (section 115). Assessment of the structural performance of the building would be at the owner’s cost. This approach imposes less time pressure on territorial authorities and is less costly to administer. However, the disadvantage is that it relies on a somewhat ad-hoc approach based on owners’ intentions and this could leave some high- risk buildings untouched for a long period.

In practice, the provisions of the Act have resulted

in territorial authorities allowing decades to carry out the strengthening of buildings, even when they have adopted an active policy that nominally requires the strengthening of all earthquake-prone buildings within the district. If an authority adopts a passive policy, the requirement to strengthen the building is triggered only when an application for a building consent for alterations is lodged with the territorial authority, or the Building Act provisions relating to change of use, extension of life or subdivision (sections 115 to 116A) are engaged. Consequently, many buildings have been left without strengthening, even when they are known to be earthquake-prone.

7.2.2 Territorial authorities’ current earthquake-prone buildings policies

All 67 territorial authorities have adopted an earthquake-prone buildings policy. Analysis of these policies as at May 2012 showed that 43 had active policies (as characterised by the DBH Guidelines); 12 had passive policies and 12 had policies with some active elements and some passive elements. There has been an increase in the number of active policies since 2007 when 33 territorial authorities had active policies. Several territorial authorities are currently reviewing their policies.

Timeframes specified in the policies for (a) identifying potentially earthquake-prone buildings; (b) completing initial evaluations of those buildings; and (c) undertaking strengthening are summarised in the following table:

**Table 1: Timeframes specified in territorial authority earthquake-prone policies (source: Department of Building and Housing, May 2012)**

**Policy element Timeframe range (shortest maximum timeframe to complete to longest**

**maximum timeframe to complete)**

**Average of timeframe ranges set in policies**

Identify potentially earthquake-prone buildings

Within one year to within 30 years

NB: only one policy sets the period at 30 years; the next longest period is within 20 years

2.6 years

Complete initial evaluations of those buildings

Within one year to within 25 years

NB: only one policy sets the period at 25 years; the next longest period is within 10 years

2.5 years

Complete strengthening of earthquake- prone buildings

Within one year to within 70 years

NB: only one policy sets the period at 70 years; the next longest period is within 55 years

17 years

**Notes:**

• Not all policies specify timeframes in which to identify potentially earthquake-prone buildings or in which to complete initial evaluations of those buildings.

• Territorial authorities that do specify timetables for action generally have active policies.

7.2.3 Issues arising under the current legislation and options to address these

It is clear from submissions and evidence to the Royal Commission, and the discussion above, that territorial authorities have widely varying policies to address earthquake-prone buildings. This variation is often, but not solely, related to the concepts of active or passive policies outlined in the DBH Guidelines. In practice, the ability for territorial authorities both to choose a level of passivity or activity, and the time- frames in which to take any specified action, have resulted in little or no action in many areas of New Zealand. Territorial authorities must take into account the social and economic nature of their city or district but the risk to life of hazardous older buildings should also be taken into account and the right balance struck. We do not consider the right balance has been achieved. We set out below the advantages and disadvantages of allowing passive or active policies, or removing the ability to have a passive policy. We also discuss the question of specifying timeframes in which action should be taken.

**7.2.3.1 Active or passive policies**

**Option 1: Status quo – territorial authorities can elect to have an active or a passive policy**

|  |
| --- |
| **Advantages Disadvantages** |
| No change to current legislative provisions and Inconsistent approach across country associated departmental guidance |
| Councils are familiar with the current approach Passive approach can mean that buildings are never strengthened until they change use or are altered |
| Communities can decide if they wish to address the issue actively or not |

**Option 2: Require territorial authorities to take an active approach**

|  |
| --- |
| **Advantages Disadvantages** |
| Councils will be aware of the earthquake-prone buildings Smaller councils or councils in low seismic risk areas  in their districts and required to actively enforce the may not have the capability to enforce an active policy retrofit of these buildings until they are no longer  considered earthquake-prone. |
| Consistent approach across the country More resource intensive for territorial authorities |
| Greater impact on building owners (will be required to address the seismic resistance of their building) |

We have taken these advantages and disadvantages into account in the subsequent discussion and in formulating the recommendations in section 7.4 below.

**7.2.3.2 Timeframes**

The Royal Commission heard submissions from territorial authority representatives urging that the maximum timeframe for strengthening earthquake- prone buildings should be set in legislation with provision made for territorial authorities, in consultation with their communities, to be able to reduce those timeframes but not extend them. Advantages and disadvantages of that approach, and the alternative of leaving the timeframe to the discretion of the individual territorial authorities, are set out in the following tables.

**Option 1: Set timeframes for addressing earthquake-prone buildings nationally, with ability for territorial authority to reduce timeframes but not extend**

|  |
| --- |
| **Advantages Disadvantages** |
| More consistent approach across the country Economic viability for some small or low risk areas |
| Certainty of action, increasing public safety May remove possibility of independent judgement for special cases (i.e. significant buildings) |
| Enforceable approach |
| Addresses issue of adjoining buildings  (See discussion below) |

**Option 2: Territorial authorities able to specify timeframes**

**Advantages Disadvantages**

Local communities can determine timeframes based on likely impacts and outcomes for their city or district

Inconsistency across the country

Possibly lengthy timeframes adopted, resulting in inaction

Once again, we have taken the advantages and disadvantages of these options into account in formulating the recommendations in section 7.4 below.

**7.3 The earthquake-prone threshold** As has been discussed in section 2 of this Volume, section 122(1) of the Building Act 2004 defines an earthquake-prone building as one that will 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 the Building (Specified Systems, Change the Use, and Earthquake- prone Buildings) Regulations 2005. Regulation 7 of the Regulations defines a “moderate earthquake” as one 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…that would be used to design a new building at the same site”.

It is this provision that is relied on for the proposition that, in order to avoid being categorised as earthquake- prone, an existing building must not be below 34% of new building standard (NBS). (We have addressed in section 6 of this Volume misleading aspects of the NBS concept and noted our preference for the term ultimate limit state (ULS), which we adopt in the following discussion.)

The Royal Commission has considered whether the definition of “moderate earthquake” should be amended to refer to a higher proportion of shaking than one-third of that used for the design of new buildings. If buildings were considered earthquake-prone when they could not withstand a higher level of shaking, territorial authorities would be empowered to require strengthening works for a wider pool of buildings.

The key issues in relation to whether such a change would be desirable are life safety, economic considerations and cultural (including heritage) values. We set out below seven options (including as the first option maintenance of the status quo) with a summary of what we consider the principal advantages and disadvantages of each would be. The discussion of the options below treats 34% ULS as the effective threshold under the existing law; the implied precision in translating one-third to 33.3% would not be sensible. (We also note that there are recommendations in section 6 of this Volume for specific strengthening works for unreinforced masonry buildings, which we consider should be carried out in any event.)

**Option 1: Status quo – retain 34% ULS as the level below which a building is considered earthquake-prone**

|  |
| --- |
| **Advantages Disadvantages** |
| Engineers generally understand the current practice Does not achieve the same decrease in risk of building  (albeit with some differences of implementation) collapsing as would a higher percentage of ULS;  for example, 67% ULS |
| Lower cost – see section 7.3.1 below Benefit from building performance reduces over time  (i.e. 34% in five years’ time may not be equivalent to  34% now), potentially requiring further upgrade |
| Evidence of performance of buildings in Canterbury Because % ULS is assessed taking into account the earthquakes does not show that 34% ULS is inadequate seismicity levels for different regions, 34% in a low as a national standard seismicity region is a very low level of performance |

**Option 2: Raise the level below which a building is considered to be earthquake-prone to 67% ULS**

|  |
| --- |
| **Advantages Disadvantages** |
| Reduces the likelihood of a building collapsing Significant cost to building owners |
| Safer building stock in New Zealand, and for a longer Economic impact due to building owners abandoning period of time than for strengthening to 34% ULS or demolishing buildings and no replacement building  stock being developed, leading to businesses (especially smaller businesses in lower growth areas) closing due  to lack of available, suitably priced premises |
| Increased workload on territorial authorities to conduct building assessments and enforce requirements |
| May result in increased demolition of older buildings May result in increased demolition of older buildings where cost of retrofit outweighs benefit, reducing hazard where cost of retrofit outweighs benefit, resulting in loss to the public of unreinforced masonry buildings, including heritage  buildings, and the contribution they make to amenities |
| Would require further expenditure and work on buildings already strengthened to 34% ULS |

**Option 3: Raise level at which a building is considered to no longer be earthquake-prone to as near as is reasonably practicable to 100% ULS**

|  |
| --- |
| **Advantages Disadvantages** |
| Safer building stock in New Zealand Large cost to building owners |
| Economic impact due to building owners abandoning or demolishing buildings and no replacement building stock being developed, leading to businesses (especially smaller businesses in lower growth areas) closing due to lack of available, suitably priced premises |
| Increased workload on territorial authorities to conduct building assessments and enforce requirements |
| Likely to result in increased demolition of older buildings Likely to result in increased demolition of older buildings where cost of retrofit outweighs benefit, reducing hazard where cost of retrofit outweighs benefit, resulting in loss to the public of unreinforced masonry buildings, including heritage  buildings, and the contribution they make to amenities |
| Would require further expenditure and work on buildings already strengthened to 34% ULS |

**Option 4: Keep the level at or below which a building is considered to be earthquake-prone at 34% ULS but allow territorial authorities to adopt a policy to achieve and enforce 67% ULS following public consultation**

|  |
| --- |
| **Advantages Disadvantages** |
| Engineers generally understand the current practice Does not achieve the same decrease in risk of building  (albeit with some differences of implementation) collapsing as a nationally-required higher percentage of ULS; for example, 67% ULS |
| Inconsistent approach across country may cause confusion |
| Communities may focus on investing in the upgrade of Communities may focus on investing in the upgrade  key historic buildings for their district, with remaining of key historic buildings for their district, with remaining buildings being demolished over time, reducing cost and buildings being demolished over time, thereby reducing increasing public safety overall stock of older buildings (including some  heritage buildings) |

**Option 5: Allow different levels at or below which a building is considered earthquake-prone, set nationally, for areas based on seismic risk and population density**

|  |
| --- |
| **Advantages Disadvantages** |
| Economic impact reduced on small/low socio-economic Inconsistent approach across country may cause areas confusion |
| Public safety increased Building owners may move out of CBD areas due to increased building strengthening requirements |
| Territorial authorities may not have the capability to enforce |

**Option 6: Keep level below which a building is considered to be earthquake-prone at 34% ULS and ensure potentially dangerous aspects of building are mitigated (i.e. secure or remove falling hazards, strengthen walls to prevent out-of- plane failures)**

|  |
| --- |
| **Advantages Disadvantages** |
| Economic impact reduced on small/low socio-economic Initial economic impact on building owners areas |
| Quick fix to at-risk buildings Buildings that cannot remove the danger will have to be demolished |
| Cheaper than ensuring entire building is at 67% ULS Communities will not have the ability to consider the particular nature of their city or district and building stock, and determine a higher level of safety if they consider it justified |

**Option 7: Keep level below which a building is considered to be earthquake-prone at 34% ULS, ensure dangerous aspects of a building are mitigated (i.e. secure or remove falling hazards, strengthen walls to prevent out-of-plane failures), and allow territorial authorities to adopt a policy to achieve and enforce a higher percentage of ULS following public consultation**

|  |
| --- |
| **Advantages Disadvantages** |
| Economic impact reduced on small/low socio-economic Initial economic impact on building owners areas |
| Quick fix to at-risk buildings Buildings that cannot remove the danger will have to be demolished |
| Communities with higher seismicity or large component of older building stock can decide to reduce risk for their area |

Having considered these various options, we are in no doubt that it is desirable that there be a clear national policy, that is actively pursued, understood by the relevant parties, and implemented. In particular, the need to address known key hazards presented by unreinforced masonry buildings, as discussed in section 5 of this Volume, is clear. However, we consider that the potential impact of setting the level at which a building is considered earthquake-prone much above 34% ULS is significant and is unlikely to be outweighed by the advantages.

The question of when the benefit in raising that level may outweigh the cost of doing so is discussed directly in section 7.3.1 below. The advantages and disadvantages of the options can also usefully be addressed under the headings of life safety, economic impact and cultural impact. These are discussed further in section 7.3.2, where we also make some observations about the perception of earthquake risk.

7.3.1 Earthquake-prone policy costs

The Ministry of Business, Innovation and Employment

(MBIE) has engaged consultants Martin, Jenkins and Associates (MJA) to develop a model for the purposes of quantifying the costs and benefits to the New Zealand economy arising from various policy options for addressing earthquake-prone buildings.

Development of the model is largely complete, with its key inputs being:

• probability weighted range of large to very large earthquakes1 based on the different seismicity of New Zealand regions, in accordance with GNS Science advice;

• benefits of forgone deaths (calculated using

the New Zealand Transport Agency estimate of

$3.67 million per life), injury costs and damage repair costs);

• costs of strengthening buildings; and

• discount rate of 6.5% used to convert future cashflows to current values for the net present value (NPV) analysis. This reflects the opportunity cost of capital, prescribed by the Treasury as appropriate for general purpose office and accommodation buildings.

The model has been formally reviewed by the economic research firm Infometrics. The Royal Commission has been provided with the model and understands its methodology and purpose. We note that there is significant uncertainty in the cost data sourced by MJA regarding the need for, and costs of, strengthening buildings across New Zealand. MJA comment that the data held by New Zealand authorities is “scarce and not particularly reliable”. This probably reflects the generally cautious approach to earthquake-prone policy implementation taken by territorial authorities to date.

The Royal Commission notes that MJA have explored a number of avenues in an endeavour to gather and generate robust data about the building stock. This has included making use of Quotable Value Limited data, seeking information from all territorial authorities and contacting the largest councils for updated numbers on earthquake-prone buildings in their areas. As a result of this exercise, MJA advised that it is evident that “less than 10% of all pre-1976 buildings in New Zealand have had any sort of assessment”.

In view of the shortcomings of the cost data, the focus of the NPV analysis has been to use the most conservative data reasonable, and determine whether any feasible policy options would generate a net benefit. MJA concludes that even under the most conservative of cost assumptions, there is no policy option that would generate a net benefit, due largely to a combination of the low probability of a large or very large earthquake occurring and the timing in which costs and benefits are incurred (costs of strengthening buildings are incurred in initial years; benefits associated with deaths, injuries and building repairs avoided accrue following an earthquake).

In order to determine the potential magnitude by which costs exceed benefits, the analysis was informed by a closer investigation of the potential costs of strengthening buildings across New Zealand (the key cost driver). As noted above, updated information was sought from the largest councils, which led to a tentative estimate of 15,000–25,000 buildings in need of strengthening2. With the repair costs estimated at $300/m2 to strengthen to above 33% ULS and

$640/m2 to strengthen to 67% ULS, the following NPVs (compared to doing nothing) give some indication of the magnitude of the net total cost of the policy options, in 2012 dollars:

• status quo: above 33% ULS over an average

28 years – approximately $1 billion

• above 33% ULS within 15 years – approximately

$1.7 billion; and

• 67% ULS within 15 years – approximately $7.6 billion.

It should be noted that social and economic costs associated with a major earthquake are excluded due to difficulty in isolating impacts of earthquake- prone building policy changes compared to impacts of damage to infrastructure, non earthquake-prone buildings and residential housing.

The merits of a policy change for the strengthening of earthquake-prone buildings should not be based on economic analysis alone. There are a number of non-quantifiable benefits that are relevant to the overall policy decision, as discussed at various points in this Volume. It should also be noted that strengthening will lead to an increased level of confidence, which has an intrinsic but unquantifiable benefit.

7.3.2 Other considerations

**7.3.2.1 Life safety**

Some guidance on setting standards for life safety can be gained by considering the lives lost and the injuries sustained in the Canterbury earthquakes.

The Royal Commission has examined all fatalities caused by building failure in the February 2011 earthquake. These fatalities are described in this Volume of the Report or in Volumes 2 (PGC building) or 6 (CTV building). Excluding the PGC and CTV buildings, and the death of an infant caused by an internal exposed brick chimney breast collapsing, the majority of other fatalities (39 out of 41) were caused by URM buildings failing in some way. Of the 41 deaths, 29 (70%) were caused by URM façades (or parts of façades) collapsing onto people exiting from or passing by the buildings. In 10 cases (24%) people died inside buildings, and of those six involved cases where a neighbouring building fell onto the building where the deceased were. The other two deaths were caused by a free-standing concrete block wall collapsing onto the victim (90 Coleridge Street) and a concrete spandrel falling onto a vehicle in which the deceased person was seated (43 Lichfield Street).

Care is needed in drawing conclusions applicable nationally from the evidence available in Christchurch. The ground motion characteristics resulting from earthquakes vary from earthquake to earthquake. In addition, the soil conditions in Christchurch are not representative of New Zealand as a whole. For these reasons, it is appropriate to consider the Christchurch experience as indicative only. It is also relevant to note that the commercial area of the CBD was largely unoccupied at 4:35am on 4 September 2010 and that several of the CBD buildings damaged in the September earthquake remained unoccupied, with barricades protecting public space (at least to some extent) when the 22 February 2011 earthquake occurred.

However, the extent of the loss of life in the February earthquake was largely unanticipated by the New Zealand community.

**7.3.2.2 Economic impact**

Although the economic consequences of a major earthquake are profound at the national level, the optimum decisions on strengthening based on economic impact will vary considerably from city or district to city or district. Decisions which are optimal in one part of the country may be less appropriate in another.

It is apparent from submissions by territorial authorities that the factors affecting decisions at the local level include:

• the proportion of earthquake-prone buildings in the portfolio of existing buildings;

• the intensity, volume and concentration of earthquake-prone buildings and hence the scale of economic risk to the local community as well as New Zealand as a whole;

• the level of economic activity: whether there is high, medium or low growth in the city or district;

• market considerations: availability and demand, robustness of the rental market, expectations of risk; and

• funding: availability of loan or grant funding to accelerate the reduction of earthquake risk.

**7.3.2.3 Cultural impact**

An important matter that must be taken into account in considering the future of existing buildings is the value communities place on the contributions historic buildings make to cultural values. These values may also have a significant economic worth. Napier and Oamaru are examples in which the local economy is closely aligned to the character of the heritage building stock.

Many structures have heritage value and some form a vital part of the built environment. Many heritage buildings are also earthquake-prone. In a report provided to the Royal Commission, the New Zealand Historic Places Trust2 (NZHPT) noted:

Heritage values are aspects or qualities of a place that are valued by communities. These values are identified and treasured to ensure survival for present and future generations. Ensuring that all

the relevant threats and risks are identified is a core part of heritage planning. Heritage places and areas are often diverse and include buildings (including structures), historic gardens, historic sites having

no physical buildings or structures, archaeological sites, and places and areas of significance to Ma-ori.

Further, the NZHPT notes the responsibility at present assigned to territorial authorities:

With regard to earthquake prone policies, the term

‘heritage buildings’ is used under section 131 of the Building Act 2004. Territorial authorities must state how their policy will apply to heritage buildings. This term is also used in section 125 of the Building Act 2004 with regard to provision for copies of requirement notices to be provided to the NZHPT.

**7.3.2.4 Understanding earthquake risk**

How government, society, communities and individuals think about and plan for the risk of an earthquake underlies the discussions about how to identify and deal with New Zealand’s earthquake-prone buildings. The DBH Guidelines1 suggested that some communities may take the view that all of the earthquake-prone buildings in their area should be strengthened, but others may consider a lower level of strengthening sufficient. This implies that communities decide the level of risk they find acceptable. However, the idea that people accept a certain level of risk when they enter, live and work in earthquake-prone or earthquake- risk buildings is something that is rarely articulated explicitly. In fact, it is difficult for communities and individuals to recognise and understand events like damaging earthquakes, which rarely occur but often have a very large impact when they do. This means that people may not make informed, accurate and well-balanced choices about the risks associated with earthquake-prone buildings, or even think about these risks at all.

Civil defence literature recognises how people’s perceptions of risk affect the way they plan for a disaster. McClure et al.3 discuss how people judge the probability of disasters according to a range of factors, including optimistic biases in people’s judgements and whether or not they have personally experienced the event. Many people have an optimistic bias, which means that they see themselves as less likely than others to be harmed by an earthquake in the future, even if they live in a location prone to earthquakes. In 2010, J.S. Becker discussed in McClure et al.,3 highlighted how optimistic bias may be compounded by people’s beliefs about the different levels of risk particular hazards pose in different regions: people estimated the chance of being in an earthquake in Canterbury as less than for Wellington. Experiencing the event reduces optimistic bias. Hudson-Doyle4 discusses how the civil defence literature explores various models scientists can use to communicate with the wider public about the probability of an event happening, particularly when the science is uncertain.

McClure et al. consider that New Zealanders should not use what has happened in Canterbury as a basis for their risk judgements. Instead, they should base their actions on the actual level of risk in their own region, regardless of how that compares to the rest of New Zealand.

We encourage the Ministry of Business, Innovation and Employment and other agencies such as GNS Science and the Ministry of Civil Defence and Emergency Management, and professional engineering bodies such as IPENZ and NZSEE, to assist the public to understand the levels of risk for their community and region.

**7.4 Conclusions and recommendations**

7.4.1 The earthquake-prone threshold

As noted in section 5.2.1, the September earthquake created ground motions approximately at the design level for the ULS under the current design standard, NZS 1170.5:2004. This was a level of shaking which was therefore well beyond the one-third level used for establishing that a building is earthquake-prone under the current legislation. The shaking in the February earthquake was 1.5–2 times the design level. Although Ingham and Griffith present data that suggest that the performance of URM buildings in the February earthquake that had been strengthened to 33% NBS was not significantly better than those that had not been strengthened, the test to which those buildings were subjected by the earthquake was well beyond that of a moderate earthquake as currently defined.

It must also be borne in mind that such strengthening as had taken place in the Christchurch CBD was based on a hazard factor, Z, of 0.22. It is clear now that the hazard factor did not accurately represent the actual level of seismic risk. If buildings had been retrofitted on the basis of the Z factor of 0.3 that was subsequently applied, the performance of buildings might have been better.

Overall, we do not consider that the experience

of the Canterbury earthquakes should lead to the abandonment of the current one-third rule, which we have concluded should remain as the appropriate Standard. We have also noted, however, in various sections of this Volume that the majority of deaths due to the collapse of URM buildings in the February earthquake occurred in public places outside the buildings that failed, due to the out-of-plane collapse of façades, gable ends and parapets. Other deaths were the result of the collapse of walls from neighbouring buildings.

To counter what has been proven to be a particular source of danger, we consider that a higher level of protection should be given, to prevent this form of collapse, than is justified for the building as a whole. Apart from this one exception, there appears to be no evidence that to protect life safety the shaking level to be resisted for earthquake-prone buildings should be set higher than one-third of the requirement for new buildings.

The Royal Commission has therefore concluded that the present threshold for characterising a building as “earthquake-prone,” based on the definition of “moderate earthquake” in the Building (Specified Systems, Change the Use, and Earthquake-prone Buildings) Regulations 2005 is appropriate and should be maintained.

However, we also consider that territorial authorities should also be empowered to adopt earthquake-prone building policies that are stricter than the statutory minimum where they consider that is appropriate, taking into account particular economic considerations, building characteristics, and/or seismic circumstances that are relevant to their districts. We see no reason to prevent that approach, which appears to have been successfully adopted and achieved community acceptance in Gisborne District.

We also consider that territorial authorities should be able to adopt a policy that would require a greater level of strengthening than the statutory minimum for buildings of high importance or high occupancy, where public funding is to be contributed to the strengthening or where the hazard to public safety justifies it.

Adoption of a policy that exceeded the statutory minimum would require the territorial authority to follow the special consultative procedures of the Local Government Act 2002. These policies would be able to take into account matters such as the affordability of strengthening, perceptions of reduced risk, local economic considerations, market influences such as rentals, rates, insurance, and other costs implicit in seismic risk.

7.4.2 Upgrade timeframe

We are of the opinion that the maximum time permitted to complete the evaluation and strengthening of existing buildings should be set nationally. The Royal Commission has heard evidence that the catalogue of existing buildings held by local authorities is incomplete. However, based on information provided by Quotable Value Limited to the former Department of Building and Housing, the number of existing

commercial, industrial, high-rise residential and other non-residential buildings/unit titles across New Zealand is approximately 194,000. These properties represent a total area of over 170 million square metres of space.

The opportunity to extend time to rectify deficiencies has resulted in passive policy implementation, in turn resulting in divergent standards of safety from district to district. This approach has allowed structurally unsound buildings to remain a threat to the occupants and the public for a significant period, when measured against the estimated return period for an earthquake of damaging effect.

The size of the task required of territorial authorities and owners to address earthquake-prone buildings is such that, if the timeframes are set too tightly, there may be insufficient resources (whether in terms of engineering design or physically carrying out the necessary work) to comply with the obligations imposed. There might also be unintended impacts, such as the abandonment of buildings. There is nevertheless considerable merit in completing the work expeditiously as there is obvious benefit in society being better prepared before a destructive earthquake.

Having regard to these considerations and the cost of strengthening buildings, we consider that a period of two years should be set as the maximum time allowed for territorial authorities to complete initial evaluations of all URM buildings. A further five years should be allowed for all URM buildings to be strengthened to the required level. In the case of URM buildings we note that the requirement of strengthening to 34% ULS that we recommend in this section is in addition to the specific strengthening works that we have discussed in section 6 for the building as a whole and the obligation to apply a 50% ULS standard in respect of parapets, gable ends or façades. It might be that carrying out those works would result in the 34% ULS strength being achieved in any event.

For all other buildings, territorial authorities should identify those that are likely to be earthquake-prone through an initial evaluation process to be completed within five years. Owners would be allowed a further 10 years to undertake strengthening to above the earthquake-prone level or demolish buildings judged to be unsafe in a moderate earthquake.

From the end of this 15-year period, we consider that the state of the building stock should be monitored, having regard to the deterioration of buildings with the passage of time. The Ministry of Business, Innovation and Employment should give consideration to the best means of ensuring that this monitoring is carried out.

There should be legislative authority for territorial authorities to adopt a policy providing for shorter timeframes, after following the special consultative procedures of the Local Government Act.

Implementation of these changes to the existing legislation would mean that territorial authorities would not need to adopt earthquake-prone building policies after following the special consultative procedure, unless seeking to impose stricter obligations (whether as to the level of strengthening, or the time by which it is to be achieved): the rules would be set nationally in the legislation.

Implementation of these changes would also require each territorial authority to develop a database listing all earthquake-prone buildings in its district.

7.4.4 Exemptions

There are some buildings that are very seldom used and are so located that their failure in an earthquake is most unlikely to cause loss of life, or serious injury to passers-by. An example is rural churches (we note that Gisborne District Council treats these churches as a special case).

We consider that there is a good case for such buildings to be exempt from the general legislative requirements for earthquake-prone buildings. If that policy position is adopted, we consider it should be set out in legislation so that one rule applies nationally.

7.4.5 Recommendations

**Recommendations**

We recommend that:

82. The Building Act 2004 should be amended to require and authorise territorial authorities to ensure completed assessments of all unreinforced masonry buildings within their districts within two years from enactment of the Amendment, and of all other potentially earthquake-prone buildings within five years from enactment.

83. The legislation should be further amended to require unreinforced masonry buildings to be strengthened to 34% ULS within seven years from enactment of the Amendment and, in the case of all other buildings that are earthquake- prone, within 15 years of enactment.

84. The legislation should be further amended to require that in the case of unreinforced masonry buildings, the out-of-plane resistance of chimneys, parapets, ornaments, and external walls to lateral forces shall be strengthened to be equal to or greater than 50% ULS within seven years of enactment.

85. The legislation should provide for the enforcement of the upgrading requirements by territorial authorities, with demolition (at owner’s cost) being the consequence of failure to comply.

86. The legislation should allow territorial authorities to adopt and enforce a policy that requires a shortened timeframe for some or all buildings in the district to achieve the minimum standard required by the legislation, after following the special consultative procedures in the Local Government Act 2002.

87. The legislation should allow territorial authorities to adopt and enforce a policy that requires a higher standard than the minimum ULS required by the legislation for some or all buildings in the district, after following the special consultative procedures in the Local Government Act 2002.

88. The legislation should allow territorial authorities to adopt and enforce a policy that requires a higher standard of strengthening for buildings of high importance or high occupancy, where public funding is to be contributed to the strengthening of the building or where the hazard to public safety is such that a higher standard is justified, after following the

special consultative procedures in the Local

Government Act 2002.

89. Guidance should be provided by the Ministry of Business, Innovation and Employment

to territorial authorities on the factors to be considered in setting discretionary policies under the amended legislation. These factors should include the nature of a community’s building stock, economic impact, numbers

of passers-by for some buildings, levels of occupancy, and potential impact on key infrastructure in a time of disaster (e.g. fallen masonry blocking key access roads).

90. The legislation should exempt buildings that are very seldom used and are so located that their failure in an earthquake is most unlikely to cause loss of life, or serious injury to passers-by.

**7.5 Drafting issues with the current legislation**

The Royal Commission notes there are issues with or questions about the interpretation of sections of the Building Act 2004 and/or with how the current provisions for earthquake-prone buildings interact with other sections in the Building Act.

7.5.1 Section 124 of the Building Act 2004

It is clear from the evidence presented to the Royal Commission by representatives of territorial authorities that there is uncertainty about whether the councils may lawfully require that earthquake-prone buildings be strengthened to a level beyond the one-third level set out in the Regulations, and rival views have been advanced, based on differing legal advice. The issue arises directly when the territorial authority is exercising its powers under section 124(1) of the Building Act, which provides:

**124 Powers of territorial authorities in respect of dangerous, earthquake-prone, or insanitary buildings**

(1) If a territorial authority is satisfied that a building is dangerous, earthquake prone, or insanitary, the territorial authority may – (a) put up a hoarding or fence to prevent

people from approaching the building nearer than is safe:

(b) attach in a prominent place on, or adjacent to, the building a notice that warns people not to approach the building:

(c) give written notice requiring work to be carried out on the building, within a time stated in the notice (which must not be less than 10 days after the notice is given under section 125), to –

(i) reduce or remove the danger; or

(ii) prevent the building from remaining insanitary.

The question is whether, in a notice issued under section 124(1)(c), a council can require work to be carried out that would require a building to be brought up to a state that exceeds the one-third threshold for earthquake-prone status. A legal opinion obtained by Christchurch City Council concluded that a council could not lawfully require strengthening beyond the one-third level. The majority of councils who presented evidence and submissions to the Royal Commission supported the view held by Christchurch City Council. An alternative approach has been advanced by the Gisborne District Council. That Council has adopted a policy that earthquake-prone buildings should be

strengthened to a two-thirds level acting on the advice of the Council’s solicitors that the minimum one-third requirement is applicable only to what constitutes an earthquake-prone building and not to the standard of upgrading that may be required once the building has been classified as earthquake-prone.

The issue turns on the meaning that should be given to the words “reduce or remove the danger”, in section 124(1)(c)(i). Given that section 124(1) deals with dangerous, earthquake-prone and insanitary buildings, and that insanitary buildings are separately dealt with in sub-paragraph (1)(c)(ii), the phrase “reduce or remove the danger” is clearly used to apply to both dangerous buildings and those that might not be dangerous, but are nevertheless earthquake-prone. There is plainly still a distinction between the two kinds of building, as section 121(1) provides:

**121 Meaning of dangerous building**

(1) A building is dangerous for the purposes of this Act if, -

(a) in the ordinary course of events (excluding the occurrence of an earthquake), the building is likely to clause –

(i) injury or death (whether by collapse or otherwise) to any persons in it

or to persons on other property; or

(ii) damage to other property; or

(b) in the event of fire, injury or death to any persons on other property is likely because of fire hazard or the occupancy of the building.

This provision is consistent with the legislative history which, as we have explained in section 2 of this Volume, has consistently provided separately for dangerous buildings and earthquake-prone buildings since the Municipal Corporations Act 1968.

We doubt that it was intended that section 124(1)(c)(i) should have the effect of authorising a notice that required an earthquake-prone building to be strengthened beyond the level at which it would have ceased to be earthquake-prone. The Council’s only relevant powers are in relation to earthquake-prone buildings as defined. The better view is that once an earthquake-prone building has been strengthened so that it would satisfy the one-third rule, it would cease to be subject to the council’s powers to require improvement. Equally, a territorial authority’s earthquake-prone buildings policy could not require strengthening of buildings that had satisfied the

one-third rule and were therefore not earthquake-prone (or were no longer earthquake-prone). This is the conclusion that generally seems to have been reached

by territorial authorities, and while the issue cannot be authoritatively resolved by the Royal Commission (that is a matter for the Courts), it is appropriate that we note our view that the powers in section 124(1)(c) of the Building Act do not authorise a requirement for seismic strengthening beyond that necessary to withstand a moderate earthquake as defined in the Regulations.

Ms Townsend, the Deputy Chief Executive of Sector Policy at the former Department of Building and Housing, who gave evidence to the Royal Commission, conceded that the Department had been of the view that the law did not authorise requirements for strengthening beyond the one-third threshold since 2005. We consider it is time this issue was addressed by Parliament.

However, as earlier discussed, we do consider it is appropriate to authorise territorial authorities to require a greater level of strengthening than the law currently appears to allow if they wish to do so as a matter of policy. The legislation should be amended to confer that power clearly. It is undesirable for there to be any uncertainty on such an important matter.

7.5.2 Sections 121–124 and section 129 of the Building Act 2004 – Dangerous buildings or parts of buildings

**7.5.2.1 Parts of buildings**

Evidence provided to the Royal Commission showed that there was uncertainty about the extent of the application of sections 122 and 124 of the Building Act 2004. The key issues are:

• whether building elements such as balconies, parapets, chimneys etc. that are likely to collapse and cause death in a moderate earthquake but where the remainder of the building is not earthquake-prone, fall within the meaning of section 122 of the Building Act 2004; and

• if a building with such weakness is an earthquake- prone building, does a territorial authority therefore have legal power to require retrofitting of these elements under section 124?

The legislation as currently drafted gives scope for argument on this issue. For example, section 122(1) refers to a building being earthquake-prone if, amongst other things, the building would be likely to collapse. Similarly, in the immediately preceding section, a building is said to be dangerous if the building is likely to cause injury or death. Then, by section 124(1), a council is empowered to put up a hoarding to prevent

people from approaching the building. Arguably, these words are not apt to include only a particular part of the building being considered. The definition of “building” in section 8 of the Act does not assist.

The former Department of Building and Housing stated that, in its view, it was the intention that section 124 of the Building Act 2004 apply to parts of a building that are earthquake-prone. A Determination under the Building Act 2004 clarifying this intention was issued on behalf of the Chief Executive of the former Department of Building and Housing in June 2012. Notwithstanding that Determination we consider that legislative amendment to make it clear that parts of a building are included within sections 122 and 124 would be desirable to put the matter beyond doubt.

**7.5.2.2 Immediate action required to repair or demolish a dangerous building that is not earthquake-prone**

Territorial authorities also expressed concerns to the Royal Commission about their ability to require the repair or immediate demolition of buildings which, although not earthquake-prone, have been damaged in an earthquake and pose a danger.

For instance, if a building is damaged in a moderate earthquake and parts of the building appear dangerous such that immediate action to fix should be taken:

• section 121 would not apply as it did not happen “in the ordinary course of events (excluding the occurrence of an earthquake)”; and

• section 122 might not apply as the building may not be deemed earthquake-prone, or the statutory processes involved may result in timeframes that are too long to ensure the danger is addressed at an appropriate time.

This means that the general power conferred on territorial authorities by section 129 of the Building Act to take action to avoid immediate danger arising from the state of a building after an earthquake may not be available. That is so because section 129 applies only where there is immediate danger to the safety of people “in terms of section 121 or section 122”. We note that in our discussion of the collapse of 605–613 Colombo Street (see section 4.9.4.3) we suggested that the CCC should have considered exercising its power to demolish under section 129. The Council was clearly reluctant to do so, despite the fact that under the Canterbury Earthquake (Resource Management Act) Order 2010 the power could have been exercised without a resource consent.

Appropriate powers to deal with buildings in a dangerous state in the aftermath of the Canterbury earthquakes were conferred by the Canterbury Earthquake Recovery Act 2011, in force from 19 April 2011. Section 38 of that Act authorised the Chief Executive of the Canterbury Earthquake Recovery Authority to carry out or commission certain works. These included the demolition of all or part of a building. That Act also provided, in section 39(2), for notice to be given to the owner or occupier, but under section 39(5) no notice was needed where the work was necessary because of sudden emergency causing or likely to cause loss of life or injury, damage to property (including any adjoining property) or damage to the environment. While section 38(6) of that Act also provided that the section did not override any requirements for resource consents or building consents that might apply to the works, such requirements could be varied by Orders in Council made under the Act.

Conferral of a power in these terms or similar terms would meet the perceived gap in territorial authority powers that was addressed in the submissions to the Royal Commission. We consider that it is important that territorial authorities are able to address buildings that pose a danger due to damage caused by an event such as an earthquake. That should include the ability to take immediate action in respect of a building in a dangerous condition as a result of an earthquake.

**Recommendations**

We recommend that:

91. The Building Act 2004 should be amended to make it clear that sections 122 and 124 of the Act apply to parts of a building.

92. The Building Act 2004 should be amended to empower territorial authorities to take action where a building is not deemed dangerous under section 121 or earthquake-prone under section 122 but requires immediate repair or demolition due to damage caused by an event such as an earthquake.

7.5.3 Adjacent and adjoining buildings

The Canterbury earthquakes showed there can be a significant risk to buildings that are next to damaged or dangerous buildings. Territorial authorities submitted that they should have the power to enforce a tighter timeframe for repair or other action if a building is affected by the risk of collapse of an adjoining building.

The Building Amendment Bill (No. 4), which is currently before Parliament, would go some way towards addressing this issue, if enacted in the form in which it was introduced. The Amendment would alter sections 124 and 125 of the Building Act 2004 to give councils the ability to restrict entry to affected buildings (defined as buildings which are “adjacent to, adjoining, or nearby a dangerous building as defined in section 121”) for particular purposes, or to particular persons. We do not think that it is necessary to go further, in the context of our recommendation that there be set statutory timeframes for the strengthening of earthquake-prone buildings generally.

In addition, many agencies are required to consider different aspects of the consequences of earthquakes. Instances were reported at the Royal Commission’s hearings in which communication of knowledge about the state of buildings, which might have been significant, did not take place. As examples, tenants were not advised of risk; neighbours did not appreciate the possibility of an adjacent collapse; and Earthquake Commission (EQC) assessors felt constrained by privacy obligations. This lack of communication is evident in the Royal Commission’s findings on the buildings that collapsed causing death discussed in section 4 of this Volume (for examples, see section 4.8: 382 Colombo St, section 4.9: 593 Colombo St, section 4.14: 738 Colombo St, and section 4.25: 391 and 391A Worcester Street). Sharing of knowledge and information can reduce the level of risk that dangerous structures create. We have noted that the privacy provisions of the Earthquake Commission Act 1993 inhibit the sharing of information and we recommend an amendment to these provisions (see section 4.25.4.3 of this Volume). In our opinion statutory bodies, engineers and other professional persons should have a duty to disclose to the relevant territorial authority and any affected neighbour, information of which they have become aware that a building in a dangerous or potentially dangerous condition. Building owners should have a similar obligation in respect of their own tenants, and neighbouring occupiers. Legislation should provide for this duty, and also for the protection of those carrying it out from civil or other liability, or allegations of professional misconduct.

**Recommendations**

We recommend that:

93. The proposed amendments to sections

124 and 125 of the Building Act 2004 in the

Building Amendment Bill (No. 4) should be enacted.

94. Section 32(4) of the Earthquake Commission Act 1993 should be amended to allow for disclosure of information that may affect personal safety. A suggested wording is set out in section 4.25.4.3 of this Volume.

95. Legislation should provide for:

a a duty to disclose information that a building is in a dangerous or potentially dangerous condition to the relevant territorial authority and any affected neighbouring occupier;

b the above duty to be applied to statutory bodies, engineers and other professional persons who have become aware of the information;

c a similar duty on building owners

in respect of their own tenants and neighbouring occupiers; and

d the protection of those carrying out these duties in good faith from civil or other liability or allegations of professional misconduct.

7.5.4 Buildings divided into separately owned parts.

Mr Joe Arts (owner of a heritage building in the Christchurch CBD) presented evidence to the Royal Commission on the issue of separately owned titles in a building and “party walls”. The building that he owned through a family company was built in 1905. He illustrated the weak state of the party wall that separated his part of the building from an adjoining tenancy and indicated that he had to meet the cost of strengthening because of difficulties in securing a contribution from the neighbouring owner without resorting to expensive litigation. He stated that his part of the building could be fully strengthened to meet the current design standard, a process that was underway when the September earthquake struck. However, in order for those works to be effective, it was necessary for the party wall to be strengthened. Mr Arts submitted that there should be a requirement on all owners of parts of a building that will behave in an earthquake as a single structure to strengthen their part of the building at the same time.

A policy for party-wall notification is included in the Dunedin City Council’s earthquake-prone buildings policy. Under this policy, if a building is being strengthened, the Council will notify all owners of neighbouring parts of buildings that share party walls and recommend that they should also strengthen their building and work cooperatively with the other building- part owners.

There is a similar issue that needs to be addressed which arises when walls become end walls as a result of the removal of walls on a neighbouring property which have previously provided support to the adjoining building (see the discussion of the building at 246 High Street in section 4.19 of this Volume for an illustration of this issue).

There are three possible options to address the matter of separately owned parts of a building, as discussed below.

**Option 1: Do nothing**

**Advantages Disadvantages**

Maintains property rights of individual owners Potential inconsistency in the strengthening levels of the entire building

**Option 2: Include a policy in the territorial authority’s earthquake-prone encouraging concurrent action by building- part owners**

|  |
| --- |
| **Advantages Disadvantages** |
| Maintains property rights of individual owners Has persuasive value only as territorial authorities can only recommend strengthening |
| Market forces will impact on owners’ decision to Territorial authorities can take different approaches on strengthen building whether to include in an earthquake-prone policy |
| Potentially increased resistance to earthquakes Possible adverse reaction from building owners |
| Costs to strengthen fall equally on all owners |

**Option 3 – Ensure by legislation that separately owned parts of a building are strengthened contemporaneously as part of the requirement to strengthen to 34% ULS (or a higher percentage where that is the territorial authority’s policy)**

|  |
| --- |
| **Advantages Disadvantages** |
| Consistency Would remove owners’ property rights |
| Increased safety for building occupiers Adverse reaction from building owners not intending to strengthen their part of the building on the same timeframe |
| Overall strengthening required by law means whole building to be addressed in any case |
| Potentially increased resistance to earthquakes |
| Costs to strengthen fall equally on all owners |

If this matter is not addressed, owners of different parts of a building may not take collective action at the same

time, which would be more efficient, provident and

**Recommendations**

effective. The objective of earthquake strengthening to

a nationally set standard within definite timeframes is

unlikely to be achieved if owners of individual titles in what is effectively one building cannot be compelled to strengthen at a similar time. While it would be possible for the issues to be resolved in litigation before the Courts, resources would be better allocated to carrying out the strengthening works for the whole building at one time. Providing through legislation an appropriate process by which the relevant issues could be resolved between owners is likely to result in more efficient, effective and timely implementation of the strengthening objectives.

We recommend that:

96. Legislation should ensure that all portions of a structure are included in the requirement to strengthen buildings to achieve the minimum level required by the legislation by the due date. In drafting the legislation, consideration should be given to providing for a fair process in which all owners of a building divided into separate titles may be required to strengthen the building at the same time

97. Territorial authorities should be authorised and required to ensure the acceptable strength of remaining walls, particularly end walls, when issuing building consents for the removal of adjoining walls.

7.5.5 Altering an existing building

Section 112 of the Building Act 2004 deals with alterations to existing buildings. Section 112(1) prevents building consent authorities from issuing building consents for alterations unless satisfied that, after the alteration, the building will comply as nearly as is reasonably practicable with the provisions of the Building Code that relate to means of escape from fire and access and facilities for persons with disabilities. The subsection provides:

A building consent authority must not grant a building consent for the alteration of an existing building, or part of an existing building, unless the building consent authority is satisfied that, after the alteration, the building will-

(a) comply, as nearly as is reasonably practicable… with the provisions of the building code that relate to-

(i) means of escape from fire; and

(ii) access and facilities for persons with disabilities (if this is a requirement under section 118); and

(b) continue to comply with the other provisions

of the building code to at least the same extent as before the change of use.

The Royal Commission heard evidence that section

112(1)(a)(ii) can operate as an impediment to building owners strengthening their buildings. This is because many old or historic buildings are difficult to alter to allow for disabled access, and in some cases there can be heritage and resource consent issues that need to be pursued. The need to comply with this provision has added a cost consideration that has been influential in the decision whether or not to proceed with the strengthening work.

Representatives of the former Department of Building and Housing informed the Royal Commission that this provision was included at Select Committee stage when the Building Act 2004 was being considered by Parliament, and it was not then envisaged that it would be an impediment to earthquake strengthening being undertaken.

While it is important that egress from a building at a time of fire or earthquake (section 112(a)(i)) remains subject to this rule, we consider it would be preferable if building consents could be issued for strengthening works without the need to comply with the disabled access rule. We say that having regard to the need

to strike an acceptable balance between cost and strengthening work, and the desirability of the latter actually being carried out. This objective could be achieved by simply adding words of exemption to the provision, limited to building consents for works to strengthen the building.

**Recommendation**

We recommend that:

98. Section 112(1) of the Building Act 2004 should be amended to enable building consent authorities to issue building consents for strengthening works without requiring compliance with section 112(1)(a)(ii). The existing provision would continue to apply to building consents for other purposes.

7.5.6 Inclusion of residential buildings

As has been seen, section 122(1) of the Building Act 2004 defines buildings as earthquake-prone by reference to the ability of buildings to survive a moderate earthquake. However, the subsection does not apply to all kinds of buildings, because section 122(2) excludes buildings that are used wholly or mainly for residential purposes unless they are of two or more storeys, or contain three or more household units. In the result the vast majority of dwellings are not covered by the legislation.

Several territorial authorities submitted to the Royal Commission that residential buildings should be included in the definition of earthquake-prone buildings. Wellington City Council, for example, submitted that, although mandatory strengthening requirements should not apply to residential buildings, territorial authorities should be able to take action in respect of particular elements, e.g. unreinforced masonry chimneys, concrete tile roofs, and substandard foundations. Wellington City advised us that it has endeavoured to take a proactive approach to this by encouraging homeowners to secure or fix these parts of their homes.

Advantages and disadvantages of considering residential buildings as earthquake-prone buildings are set out in the following table.

|  |
| --- |
| **Advantages Disadvantages** |
| Safer residential building stock Cost impact for building owners |
| Owners/potential owners and tenants will have more Increased workload for territorial authorities due to the information about the status of the house they are potential assessment of buildings  living in |
| Buildings or parts of buildings that are hazards in significant earthquakes are able to be made safer |

There are clearly some elements of residential buildings that pose hazards in earthquakes, for example, unreinforced masonry chimneys, and it is desirable that these should be made more resilient. We also consider that the significance of this issue is one that will vary across New Zealand, depending on the seismic risk of the region and the nature of the housing stock. We therefore consider that this should be addressed by territorial authorities in consultation with their communities.

**Recommendation**

We recommend that:

99. The Building Act 2004 should be amended to authorise territorial authorities to adopt and enforce policies to address hazardous elements in or on residential buildings (such as URM chimneys), within a specified completion timeframe consistent with that applied to non-URM earthquake-prone buildings in their district.

**7.6 Addressing the cost of strengthening existing buildings**

As discussed in section 7.3.1 above, the cost of strengthening existing buildings across New Zealand to 34% ULS, and addressing the main hazard elements of unreinforced masonry buildings, is very significant. The Royal Commission has heard from several parties that the costs of upgrade can be a significant barrier to, for example, the retention of historic buildings, leading to inaction due to competing claims on resources. The Property Council submitted that there should be changes in the taxation regime to allow for the deductibility of earthquake strengthening expenditure. It was noted that, historically, the treatment has been that such costs must be capitalised, meaning that effectively there is no ability to deduct because of the removal of tax depreciation on buildings.

The Property Council urged the Royal Commission to recommend that the Government change the tax regime to allow for the deductibility of strengthening costs.

We do not consider that this is a matter on which

we can properly make a recommendation under our Terms of Reference. Indeed, funding for, or other assistance mechanisms to support, the strengthening of earthquake-prone buildings (including heritage buildings) are not matters our Terms of Reference require us to address. However, we record our view that it is important that barriers to addressing the risk posed by earthquake-prone buildings are considered, and removed or mitigated as and where possible.

**7.7 Impediments to the rebuild, repair, or demolition of dangerous buildings – the Resource Management Act 1991 and the Historic Places Act 1993**

District plans made under the Resource Management Act 1991 contain provisions that require resource consent applications to be made where buildings are scheduled for protection. Buildings are typically scheduled for protection where they are considered by territorial authorities to be of special merit in terms of architectural, historical or other qualities, such as impact on the streetscape or significance as part of a group of buildings. It is also common for district plans to rank protected buildings in accordance with the assessed importance of particular buildings, and to provide for different kinds of resource consent accordingly. Depending on the nature of the alteration proposed (e.g. the action proposed might be minor or significant, or it might be proposed to demolish the building altogether), applications for resource consent may or may not be publicly notified. District plans are made following a public process in which affected persons and members of the public have the right to make submissions, and to pursue arguments about the provisions at hearings before the councils, and in the Environment Court. Notionally, at least, when the various statutory procedures have been completed and the district plan becomes operative, its provisions reflect the community’s collective view as to the rules that should govern the use of land and buildings in the district.

There is a quite separate process under the Historic Places Act 1993, which also seeks to recognise buildings that are of historical or cultural significance. That Act seeks to promote the identification, protection, preservation and conservation of the historical and cultural heritage of New Zealand (see section 4). The New Zealand Historic Places Trust maintains a register of historic places, historic areas, wahi tapu and wahi tapu areas. While inclusion in the register provides recognition of the importance of a building, it does not provide statutory protection. However, territorial authorities must have regard to the register in preparing their district plans. In addition, the New Zealand Historic Places Trust will usually be treated as an affected party in the case of applications for consent to alter a registered building that is also scheduled in a district plan.

Further, there are provisions in the Historic Places

Act that relate to archaeological sites. Under section 2 of that Act, an archaeological site is defined so as to include, among other things, any place in New Zealand that was associated with human activity that occurred before 1900, or any place that is or may be able (after investigation by archaeological methods) to provide evidence relating to the history of New Zealand. It is unlawful to destroy, damage or modify any archaeological site without the authority of the New Zealand Historic Places Trust. Buildings erected prior to 1900 might be within this definition, and if so, their demolition would require the Trust’s authority.

We heard evidence of cases where it is clear that the need to obtain a resource consent delayed demolition of buildings in Christchurch after the September earthquake, and the building subsequently collapsed in February causing loss of life. We refer in particular to the building at 605–613 Colombo Street discussed in section 4.12.2.4 of this Volume.

The Royal Commission considers that the immediate securing of dangerous buildings should not be impeded by the consent process and that life safety should be a paramount consideration for all buildings, regardless of heritage status. We consider that it would be appropriate for legislation to make it plain that, where a building is in a state that makes demolition or the carrying out of other works necessary to protect persons from injury or death, no consent for those works is required, regardless of whether the building is protected by a district plan or registered under the Historic Places Act.

**Recommendation**

We recommend that:

100. Legislation should provide that, where a building is in a state that makes demolition or protective works necessary to protect persons from injury or death, no consent is required, regardless of whether the building is protected by a district plan, or registered or otherwise protected under the Historic Places Act 1993.

**7.8 Knowledge**

7.8.1 Public Information and education

The Royal Commission considers there is considerable confusion and misunderstanding among building owners, tenants and territorial authorities about the risk buildings pose in earthquakes, what an assessment of building strength means, the likelihood of an earthquake, and the legal obligations under the Building Act 2004 for earthquake-prone buildings. This contributes to inaction and delay in addressing earthquake-prone buildings. It is desirable in particular that building owners have a better understanding of their rights and obligations. The Royal Commission believes that raising awareness about these matters would be of significant assistance in addressing earthquake-prone buildings.

We also consider that territorial authorities should be required to maintain and publish a schedule of earthquake-prone buildings. We have noted in section 7.4.2 that implementation of the changes in our Recommendation 80 above would result in territorial authorities having databases of the earthquake-prone buildings in their district. We consider that the creation of public knowledge about the status of a building as earthquake-prone would be an effective means of encouraging the strengthening of existing buildings.

**Recommendations**

We recommend that:

101. Territorial authorities should be required to maintain and publish a schedule of earthquake-prone buildings in their districts.

102. The Ministry of Business, Innovation and

Employment should review the best ways

to make information about the risk buildings pose in earthquakes available to the public and should undertake appropriate educational activities to develop public understanding about such buildings.

103. The engineering and scientific communities should do more to communicate to the public the risk buildings pose in earthquakes, what an assessment of building strength means, and the likelihood of an earthquake.

7.8.2 Roles of other parties

The Royal Commission heard evidence from which we conclude that there is a lack of knowledge amongst industry participants, such as insurers, valuers and property managers, about the risks involved with earthquake-prone buildings and the legal obligations under the Building Act 2004. These parties play an influencing role in the market, through pricing, purchasing and leasing advice. This lack of knowledge has potentially prevented building owners and tenants making informed decisions about the risk from, and requirements for, earthquake-prone buildings. Parties who are in an advisory position to building owners and tenants need to ensure that they understand, to an appropriate level, the issues relating to earthquake-prone buildings, and that this information is communicated to those they are advising in an understandable way.

**Recommendations**

We recommend that:

104. Industry participants, such as insurers, valuers, and property managers, should ensure that they are aware of earthquake risks and the requirements for earthquake- prone buildings in undertaking their roles, and in their advice to building owners.

105. The Ministry of Business, Innovation and Employment should support industry participants’ awareness of earthquake risks and the requirements for earthquake-prone buildings through provision of information and education.

7.8.3 Territorial authorities and subject matter experts

We have noted above that assessing and strengthening existing buildings is a task requiring specialist knowledge and expertise. We consider that territorial authorities and subject matter experts (such as academics and specialist practising structural engineers) would benefit from sharing information and research among themselves on assessing, and seismic retrofit techniques for, particular kinds of buildings. Unreinforced masonry buildings would be a particularly useful subject for such information sharing due to their specific (and common) characteristics and location throughout New Zealand. Information currently under development that would assist in respect of unreinforced masonry buildings is discussed in section 6.3.3 of this Volume.

**Recommendation**

We recommend that:

106. Territorial authorities and subject matter experts should share information and research on the assessment of, and seismic retrofit techniques for, different building types.

**References**

1. Earthquake impacts modelled were MM8 to MM11 on the Modified Mercalli Intensity scale, representing damage states from ‘heavily damaging’ to ‘devastating’. Earthquakes less than MM8 were excluded on the basis they only cause limited damage. Earthquakes above MM11 were excluded as they have a probability of occurrence near to zero for New Zealand towns and cities. We discuss the Modified Mercalli Intensity scale, as well as other measures of earthquake magnitude in section 2.6.1 of Volume 1.

2. Includes pre-1976 buildings only. If post-1976 buildings were to be included, the cost of strengthening to

67% ULS would be substantially higher, with only a small relative increase in benefits.

3. Department of Building and Housing. (2005). *Earthquake-Prone Building Provisions of the Building Act 2004: Policy Guidance for Territorial Authorities*. Wellington, New Zealand: Author.

4. New Zealand Historic Places Trust. (March 2012). *Heritage Buildings*, *Earthquake Strengthening and Damage: The Canterbury Earthquakes September 2010–January 2012: Report for the Canterbury Earthquakes Royal Commission*. Wellington, New Zealand: Author.

5. McClure, J., Wills, C., Johnston, D. and Recker, C. (2011). How the 2010 Canterbury (Darfield) earthquake affected earthquake risk perception: Comparing citizens inside and outside the earthquake region. *Australasian Journal of Disaster and Trauma Studies*, Volume 2011(2): 3-10.

6. Hudson-Doyle, E.E. (June 2010). Communicating uncertainty to the public: Brief report on key literature and recommendations. Extracted from Hudson-Doyle, E.E., (et. al.) (2011). *Communicating Uncertainty in Natural Hazard Events*. Manuscript in preparation.