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Assessment and Retrofit of Earthquake Prone Buildings - A Guide for Building Owners

This document sets out a process building owners can follow to:

- Understand the requirements of the Territorial Authority with respect to the Earthquake Prone Building Policy,
- Assess the earthquake resistant capacity of their building, and
- Identify any required strengthening works.

It covers the following topics:

Note, this guide is based on current legislation and Earthquake Prone Building Policies that are administered by the territorial authorities. As a consequence of the earthquakes in Chistchurch and recommendations from the Canterbury Eartquakes Royal Commission that may be implemented by Government, changes could occur in the next year or so with how New Zealand manages the reduction of risk associated with our building stock that are considered vulnerable to earthquake effects.

1. Earthquake Prone Building Policy

1.1 Definition of Earthquake Prone Buildings in the Building Act

Earthquakes cannot be prevented, but their impact can be mitigated. The Building Act 2004 expresses the Government's objective for earthquake-prone buildings to be strengthened to the appropriate seismic standards or alternatively demolished. It has an underlying objective to reduce the potential for injury, loss of life, or danger to other property that may result from the effects on buildings of a moderate earthquake.

Section 122 of the Building Act 2004 defines what it means for a building to be earthquake-prone:

1. A building is earthquake-prone for the purposes of this Act if, having regard to its condition and to the ground on which it is built, and because of its construction, the building:
   (a) will have its ultimate capacity exceeded in a moderate earthquake (as defined in the regulations); and
   (b) would be likely to collapse causing:
      (i) injury or death to persons in the building or to persons on any other property; or
      (ii) damage to any other property.
2. Subsection 1. does not apply to a building that is used wholly or mainly for residential purposes unless the building:
   (a) comprises 2 or more storeys; and
   (b) contains 3 or more household units.

Moderate earthquake has the same meaning as section 7 in the Building Regulations 2005 where – '...moderate earthquake means, in relation to a building, an earthquake that would generate shaking at the site of the building that is of the same duration as, but that is one-third as strong as the earthquake shaking (determined by normal measures of acceleration, velocity and displacement) that would be used to design a new building at that site.'

Buildings will need to be assessed to determine whether they are earthquake-prone. As a general guidance, **an earthquake-prone building will have strength that is 33% or less of the seismic loading that meets the standard NZS 1170.5: 2004 for the particular building site.**

1.2 Territorial Authorities and Initial Evaluation Procedure (IEP)

As setout in the Building Act 2004, each Territorial Authority (TA) is required to develop and administer an 'Earthquake Prone Building Policy'. There will be variations amongst the policies, particularly with respect to the time frame in which strengthening or demolition of the earthquake prone building is to be carried out. For a building in any particular territorial region, the Policy for that region must be complied with.

An Initial Evaluation Procedure (IEP) is carried out to determine if a building is earthquake prone or not. The IEP is described in a document[1] published by the New Zealand Society for Earthquake Engineering that can be downloaded free of charge from the NZSEE website http://www.nzsee.org.nz/publications/assessment-and-improvement-of-the-structural-performance-of-buildings-in-earthquake/

[1] 'Assessment and Improvement of the Structural Performance of Buildings in Earthquakes: Prioritisation, Initial Evaluation, Detailed Assessment, Improvement Measures' Recommendations of a NZSEE Study Group on Earthquake Risk Buildings. Published by the New Zealand Society for Earthquake Engineering in June 2006

This document is endorsed by the Ministry of Business, Innovation, and Employment [previously the Department of Building and Housing (DBH)] for the determination of earthquake prone buildings.

The Initial Evaluation Process (IEP) is a desktop study procedure that identifies the probable earthquake resistant capacity of the building in relation to the current Standard for the seismic design of buildings. This is the New Building Standard (NBS) that currently is taken as the Loadings Code NZS 1170.5: 2004[2]. Therefore, the output from the IEP process is a determination of the building's earthquake resistant capacity as a proportion of that required for a new building on the same site. This is shown as a "%NBS". Note the IEP was developed as a broad screening methodology to be used by a Territorial Authority (TA) to identify potentially earthquake prone buildings in their region. Therefore, for any particular building the accuracy limits of the %NBS assessed may be quite wide depending on the structural form of the buildings and the quality of the construction materials.

The application of the IEP process will be in accordance with each TA's Earthquake Prone Building Policy. A number of TAs have taken an 'active approach', whereas others have taken a 'passive approach'. That is:

- *Active Approach*: The TA engages and pays for engineering consultants to carry out IEPs of the buildings within the jurisdiction of the TA. The TA sends a notice to each building owner where the assessment is equal to or less than 33%NBS, noting that their building is probably Earthquake Prone and giving a time frame to confirm or refute the assessed %NBS by providing a Detailed Assessment from an engineer as noted below.
- *Passive Approach*: When the building owner makes a request for a change of use or building consent for substantial works, the TA will request the building owner engage an engineer to carry out an IEP or Detailed Assessment and provide a %NBS. If the assessment is equal to or less than 33%NBS, the TA will serve a notice to rectify.

The TA, under Section 124 of the Building Act 2004, will issue owners of buildings that are identified as earthquake-prone with individual notices. The notice will set out the percentage of New Building Standard (%NBS) that the building has been assessed at, and, if this is less than 33%NBS, the time-frame in which structural strengthening or demolition is to be carried out.

33%NBS is the minimum legal limit for a building's earthquake resistant capacity. This is a relatively low level of capacity, with a 10-fold greater risk of significant damage occurring than for a new building. The NZSEE recommend that the minimum should be 67%NBS (5-times the risk compared to a new building) to give an acceptable level of protection in a moderate to severe earthquake.

For more information on the specific Earthquake Prone Building Policy in your area, refer to your Territorial Authority.

1.3 Objective and Process for Strengthening Existing Buildings

Essentially the Earthquake Prone Building Policies, with their low legal limit of not less than 33%NBS, mitigates the risk associated with the "worst of the worst". Society, through Government legislation, has determined this limit to balance the risk of damage in an earthquake with the cost of providing a higher level of earthquake protection for existing buildings. However, as was shown in Christchurch, if a major earthquake does occur, these low strength buildings will be severely damaged with a high probability of a total loss. To mitigate the enormous cost associated with a damaging earthquake it is important that, over time, the earthquake risk associated with our existing buildings is progressive reduced by putting in place an affordable programme of retrofit work; to bring the earthquake resistant capacity of these buildings to as high a level as is practically possible.

[2] NZS 1170.5: 2004 Structural Design Actions, Part 5: Earthquake actions - New Zealand published by Standards New Zealand

Economic factors have a significant bearing on the ability of a building owner to carry out strengthening works and the level of earthquake resistant that can be provided. It is important that a process is started as soon as possible to:

- Identify if the building is earthquake prone or not.
- Determine the 'Critical Structural Weakness'.
- Design and document strengthening scheme(s) that enhances the capacity of the building to resist earthquake effects.
- Cost these strengthening schemes.
- Prepare a programme of works that is affordable. Everything does not need to be done at once, and a staged programme may work around tenant requirements.
- Reach agreement with the local Territorial Authority for the proposed programme of works.

2. Engaging Professional Services for Detailed Assessment, and Design of Retrofit

2.1 Detailed Assessment of Earthquake Resistant Capacity

If the building owner considers that the value of %NBS determined from the IEP process is too low or requires greater certainty of what the %NBS actually is, then the building owner can engage a structural engineer (experienced with the type of building under review) to carry out a Detailed Assessment of the building's capacity to resist earthquake effects. This detailed assessment will consider the form and materials of construction to obtain a more accurate value of %NBS, and identify the Critical Structural Weakness that determines the %NBS. The process of a Detailed Assessment is also setout in the NZSEE 2006 document[1]. The resultant engineer's report will provide more appropriate information on which to make investment decisions.

2.2 Selecting a Structural Engineer

The first task is to engage a structural engineer; one who is a Chartered Professional Engineer (CPEng), and who has knowledge of the structural characteristics and earthquake resistant performance of the type of building you wish to have assessed. This specialist experience is important where the building is constructed in unreinforced brick or stone masonry, and more particularly where the building has heritage values that require protection. Structural engineering is a wide discipline with knowledge and experience that covers many structural forms and material of construction. Therefore you require an engineer to have knowledge and experience with the type of building you own.

It is suggested that you interview a small number of engineers to determine where appropriate:

- Their experience with a wide range of structural types and materials.
- Their track record with retrofit of buildings similar to your building. For two or three of the engineer's projects, obtain contact details of their owners so you can check if the structural solutions suited that building, and the quality of service they received from the engineer.
- If the engineer appears to have a positive attitude and an innovative approach to finding solutions.
- What other staff members will be working on your project and their various levels of involvement and expertise.
- If the building is registered or listed as a historic place, has the engineer previous experience of working with historic buildings?
- What quality assurance systems does the engineer use?
- What will be the broad scope of work that the engineer will provide?

- Who will provide any existing documentation on the building, or does there need to be measured drawings prepared of the existing building and testing to determine engineering properties of the materials of construction.
- Will the design process be staged? Refer 'CIC Design Stages' (link provided on page 8)
- What will be the fee rates and rough order total cost to provide the scope of work? Note, greater input at the concept and detailed design stages could well be cost effective in reducing the cost of construction. Be clear on what the engineer is going to provide you with.
- Is the engineer someone you can work with and have confidence in?

When you have selected a consultant engineer, make sure a contract is drawn up that includes the outline scope of work, and is signed by both parties. The IPENZ/ACENZ Short Form Agreement for Consultant Engagement (available from the ACENZ website http://www.acenz.org.nz/Section1.aspx?Section=7&Page=7) provides appropriate protection for both parties.

2.3 Selecting an Architect and Other Consultants

You will also likely require the services of a Registered Architect, or other appropriately qualified Licensed Building Practitioner (LBP) architectural designer for your structural retrofit project.

Seismic strengthening is an investment in the long-term future of your building, so it is best to assess the future needs of the building and any other alterations you may want to make, and ensure that your structural engineer is briefed to accommodate these provisions into their structural design. An architect or appropriately qualified architectural designer will be able to guide you through this process.

There will be architectural work that will need to be carried out in most structural retrofit projects. You may also want to take the opportunity to make alterations to the building and/or bring it up to current Building Code in other respects, at the same time as the structural retrofit project.

If you have a listed heritage building or you would simply like to see the character of your building maintained, there are architects experienced in this type of work and specialist heritage consultants who can provide this service.

To select an architect or designer, you will need to follow a similar process to selecting a structural engineer, ensuring that they are experienced in the type of work that applies to your building.

The New Zealand Institute of Architects (NZIA) has a register of architects and information on scope of services and agreements for services.

www.talktoanarchitect.co.nz
www.nzia.co.nz

Information on dealing with heritage buildings is available from New Zealand Historic Places Trust websites:

http://www.historic.org.nz/Publications/HeritageGuidelines.aspx
http://www.historic.org.nz/Publications/SustainMgtSeries.aspx

There are also available documents providing guidance on earthquake strengthening of heritage buildings:

http://www.historic.org.nz/en/ProtectingOurHeritage/FAQs-Earthquake.aspx

2.4 Outline of Assessment and Retrofit Design Process

The process carried out by the structural engineer includes:

- Determine the foundation conditions at the site of the building, and the foundation dynamic characteristics.
- Review as-built drawings if available.
- Carry out investigation of building form and material properties. This may require some physical testing.
- Record geometric and construction material details on drawings and in a report.
- Identify the actions that the building will be subjected to in its life.
- Measure off and calculate the weight of the various components of the building. These weights are aggregated for each level of the building.
- Analysis the building as a whole to identify the stresses and deflections in the structural elements of the building.
- Identify the critical structural weaknesses.
- Identify the collapse mechanism for the building structure.
- Identify the effect of acceleration and displacement on the main non-structural elements.
- Prepare concept design(s) for repair and retrofit.
- Prepare rough order costs (ROC) for the concept design(s).
- Identify a possible sequence of work or programme that shows the work being carried out in stages. The most critical work with respect to earthquake mitigation or most effective return on expenditure, to be completed in the earlier stages.
- Set out the results of the analysis, concept design(s), their costs, and conclusions in a report. The report should include:
    - The scope of the report and its limitations.
    - A description of the seismicity of the site and foundation soil conditions.
    - Description of the building structure.
    - Critical loads for the assessment analysis including loads due to self-weight, wind, snow and earthquake.
    - Identify critical structural weaknesses.
    - Building Features Report that provides a summary of detailed information.
    - For heritage buildings, identify the effect the structural solution will have on the heritage fabric, and options that maximize retention of heritage character and fabric.
    - Schedule of work for construction of the repair and retrofit, with associated rough order costs.
    - Outline programme of works for the repair and retrofit.
    - A qualitative description of the damage that would probably be sustained by the existing building as the result of increasing intensity of earthquakes, and associated %NBS for each of these intensities. Alongside, provide a qualitative description of the damage that would probably be sustained by the retrofitted building at each of the intensity levels considered for the existing building.

With this information the building owner can carry out an economic analysis to determine a programme for the work to be undertaken that matches available finance for the works. Discuss with the Territorial Authority (TA) to confirm the programme meets the TA Earthquake Prone Building Policy for reduction of building risk. Also see if the TA will consider a rebate in the Building Consent

fees if you are able to keep to the staged programme of works through to completion. Other sources funding may be available such as incentive funds or grants for listed or registered heritage buildings.

A check will be required with the Territorial Authority (TA) to determine whether there are any Resource Consent requirements, and particular issues with respect to the Building Consent that the architect or engineer will be required to address in the Detailed Design phase.

Once a concept design and cost is agreed, the design and construction documentation process can proceed through to Detailed Design.

2.5 Retrofit Design Issues for Unreinforced Masonry Buildings

The retrofit scheme for a brick or stone-rubble masonry building should consider and address the following issues:

- The retrofit scheme must be for the whole building, not just the critical weaknesses.
- The retrofit scheme should enhance the earthquake resistant performance of the existing building, not necessarily replace its structural load carrying system.
- The retrofit scheme should address the relative stiffness of the load carrying members rather than totally focus on strength. This is to ensure the loads are spread out and stresses kept low.
- The retrofit scheme should enhance the facility of the structural framework to distort without failure; to allow distribution of loads.
- The retrofit scheme should enhance the integrity of the brick and stone masonry to withstand face loading during ground shaking. Design details to include:
  - Re-pointing of stone masonry.
  - Grouting of masonry rubble core.
  - Transverse tying through the thickness of the wall.
  - Enhance/provide transverse support to the walls.
  - Enhance/provide horizontal diaphragm (structural floor) support to the walls.
  - Design and detail connections between diaphragm and masonry walls for tension, shear and compression.
  - Assess requirements for enhanced in-plane shear capacity in masonry walls and piers.
  - Pay particular attention to 'L' and 'T' wall junctions, effect of window and door openings, and narrow piers. The wall junctions should be tied back into the body of the wall(s) with long horizontal dowels at close centres to hold the structure together.
  - Assess strengthening requirements for appendages: they can respond dynamically in a different mode to that of the main structure. Appendages include chimneys, parapets, turrets and gable end masonry walls.
  - If reinforced concrete 'bands' are to be provided to tie the structure together, they should:
    - Be continuous around the building perimeter.
    - Anchored at close centres into the masonry structure.
    - These anchors should be taken deep into the masonry structure.
    - Keep stresses low.
    - Endeavour not to modify the stiffness characteristics of the building.

Most unreinforced masonry buildings can be strengthened to an acceptable level of earthquake resistance. Even relatively minor securing works (securing chimneys, parapets, gable ends, appendages) can provide significant enhancement of the building's capacity to resist earthquake effects. In addition, continuing appropriate maintenance can also enhance the earthquake resistance of the building. In Christchurch a number of brick masonry facades and gable ends fell away because the flashings had not been maintained, including internal gutters, leading to water leakage rotting out the timber roof framing so that any support it may have provided for the masonry was lost.

You require good advice.

It can be done!

You need to do it now!

Win Clark
Executive Officer

25th October 2012

Further information:

"*Advice for Canterbury building owners: Assessing the seismic performance of non-residential and multi-unit residential buildings*", published by Department of Building and Housing, June 2012 available as free download from:
http://www.dbh.govt.nz/canterbury-earthquake-commercial-buildings-repair

"*Guidance for engineers assessing the seismic performance of non-residential and multi-unit residential buildings in greater Christchurch", published* by Department of Building and Housing, June 2012, available as free download from:
http://www.dbh.govt.nz/canterbury-earthquake-commercial-buildings-repair

"*Principles of Best Practice: Construction Procurement in New Zealand"* published by New Zealand Construction Industry Council, January 2006, available as free download from:
http://www.nzcic.co.nz/Design.cfm

"Design Documentation Guidelines: Notes" published by New Zealand Construction Industry Council, August 2008, available as free download from:
http://www.nzcic.co.nz/Design.cfm

"Design Documentation Guidelines: Structural" published by New Zealand Construction Industry Council, August 2008, available as free download from:
http://www.nzcic.co.nz/Design.cfm

Information on dealing with heritage buildings is available from New Zealand Historic Places Trust websites:
http://www.historic.org.nz/Publications/HeritageGuidelines.aspx
http://www.historic.org.nz/Publications/SustainMgtSeries.aspx

There are also available documents providing guidance on earthquake strengthening of heritage buildings.
http://www.historic.org.nz/en/ProtectingOurHeritage/FAQs-Earthquake.aspx

"*Guidelines on the Briefing & Engagement for Consulting Engineering Services"* published by The Association of Consulting Engineers NZ Inc. January 2004, available as free download from:
http://www.acenz.org.nz/Section1.aspx?Section=7&Page=3

The New Zealand Institute of Architects (NZIA) has a register of architects and information on scope of services and agreements for services:
www.talktoanarchitect.co.nz
www.nzia.co.nz