New Zealand Historic Places Trust Pouhere Taonga

Sustainable Management of Historic Heritage
Guidance Series (draft for consultation)

Earthquake Strengthening

Improving the Structural Performance of Heritage Buildings

13 August 2010

Contents

Earthquake Strengthening – Improving the Structural Performance of Heritage Buildings

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This document is a new guide proposed for inclusion within the Sustainable Management of Historic Heritage Guidance Series (the guidance series) published by the New Zealand Historic Places Trust Pouhere Taonga (NZHPT). The series aims to assist local authorities, owners of heritage places, iwi and hapū and other stakeholders in the protection and conservation of historic heritage under the Resource Management Act 1991 (RMA) and other related resource management and planning legislation.

This guide is an update on the 2000 NZHPT publication *Guidelines for Earthquake Strengthening* (authored by Ian Bowman and Lou Robinson). This guide differs from the earlier 2000 guide by focusing on providing links to other guidance sources, updated legislative provisions and providing a guidance framework for the assessment of proposed earthquake strengthening work relating to heritage buildings. While some of the legislative and building code information in the earlier 2000 guide has been superseded, the 2000 guide remains a valuable source of information about earthquake strengthening of heritage buildings.

Comments and feedback can be provided to the New Zealand Historic Places Trust Pouhere Taonga about this guide. Please send comments to:

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Cover photo: School of Engineering, Canterbury College, Christchurch, 1910 (now part of the Arts Centre), Source, Steffano Webb Collection, Alexander Turnbull Library, Ref No. 1/1-005448-G

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1 Introduction

Earthquake strengthening is about improving the structural performance of a building. The term 'improving structural performance' means carrying out work to an existing building that involves 'modifying' or 'strengthening' or 'retrofitting' the building structure or non-structural elements of building.

As promoted by the New Zealand Society for Earthquake Engineering (NZSEE), 'the term *improving the structural performance of* is used…rather than *strengthening* in acknowledgement of the wide range of options to modify building response to a loading that will achieve a desired outcome.'[1]

The term 'building' in this document has the same meaning as the definition of building under the Building Act 2004 which includes a range of temporary and fixed structures

In this document the term 'earthquake strengthening' is used as a collective term to mean improving structural performance of buildings, particularly with respect to withstanding the effect of earthquakes. Earthquake strengthening is also often referred to as 'seismic retrofit' to mean the seismic rehabilitation of existing buildings by earthquake strengthening.

For buildings that are found to be at risk from earthquake-related damage, the NZSEE provides guidance on the specific requirements for improving structural performance.[2]

Section 5 of this guide provides a guidance framework for assessing proposed earthquake strengthening work relating to heritage buildings. The guidance framework contains objectives or principles to be achieved in relation to four areas:

1. Sustainable management of historic heritage principles
2. Alterations of historic heritage principles
3. Best practice engineering principles
4. Other matters for consideration

The term 'heritage building' has the same meaning as 'historic building'. See Info Sheet No [add no] of the guidance series

Achieving these principles will involve the selection of the most appropriate engineering technique and seismic architectural design for each building on a case-by-case basis.

The guidance framework is further summarised in the accompanying information sheet – *Earthquake Strengthening - Improving the structural performance of heritage buildings.*

In addition to the guidance framework, this document provides detailed and technical information in relation to issues concerning earthquake strengthening and historic heritage, key information about existing sources of guidance, integrated hazards planning and management, planning and documentation, the legislative framework, and references to methods involved in the earthquake strengthening of heritage buildings.

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[1] NZSEE, *Assessment and Improvement of the Structural Performance of Buildings in Earthquakes*, Recommendations of a NZSEE Study Group on Earthquake Risk Buildings, June 2006

[2] ibid

This document does not provide detailed information about strengthening levels, establishment of intrinsic resistance and means of strengthening. Since these matters are about technical engineering practice (which continues to evolve as technology and practice continually change), such detailed information is more appropriately within the sphere of technical publications prepared by the relevant national and international associations such as US Federal Emergency Management Agency (FEMA) and the NZSEE.

The bibliography provides references to case studies relating to published articles involving earthquake strengthening of heritage buildings.

2 Earthquake Strengthening Heritage Issues

2.1 Background

From the earliest period of building and construction, engineers and architects in New Zealand have grappled with the issue of architectural compatibility of earthquake-related engineering. As an example Ian Lochhead, in his authoritative account of Benjamin Mountfort and the Gothic Revival provides insight on the influence of earthquakes on the design of the Christchurch Cathedral.[3] Following the Wellington earthquake of 1848, George Gilbert Scott advocated for the design of the proposed Cathedral to be a 'hybrid timber-and-stone structure' which can be fabricated in Britain and be earthquake resistant.[4] While the hybrid structure was rejected in favour of a stone building, Lochhead notes that the threat of earthquakes was a continual issue from the laying of the foundation stone in 1864 to the final completion of the Cathedral in 1881. Even after completion, earthquakes required structural intervention to avoid the structural collapse of the spire during the 1880s and 1890s as accounted by Lochhead:

> Barely one month after the cathedral was constructed a sharp earthquake struck Christchurch. No serious damage resulted but the top of the cathedral spire was displaced and the stonework fractured. Writing to Bishop Harper a week later, Mountfort estimated that the lateral movement of the spire at its apex was 4-5 feet (1.2-1.5 m) and urged that every possible step be taken to secure it against further seismic damage. Repairs were carried out and the iron reinforcing increased, but a further earthquake, on 1 September 1888, dislodged the upper 29 feet (8.8 m) of the spire, leaving the iron cross and stone finial, along with some additional masonry, hanging from the iron tie rods. Mountfort, in consultation with the engineer Edward Dobson, developed a new design for the spire that allowed for greater elasticity in the structure, but this was eventually rejected in favour of a proposal by an engineer with long experience in Japan, a Mr Waters. This entailed rebuilding the apex of the spire in specially designed firebricks but incorporating the light-weight copper terminal cross recommended by

Archaeological authority process under the Historic Places Act 1993

All pre-1900 archaeological sites are protected under the Historic Places Act 1993. An archaeological authority is required from the NZHPT to destroy, damage or modify an archaeological site.

If earthquake strengthening work requires excavations around the foundations of a pre-1900 building, an archaeological authority may be required from the NZHPT.

Further information about the archaeological authorities can be obtained by contacting the NZHPT: www.historic.org.nz

[3] Ian Lochhead, *A Dream of Spires*, *Benjamin Mountfort and the Gothic Revival*, Canterbury University Press, 1999
[4] ibid, p 130

> Mountfort and Dobson. This revised design was completed on 5 August 1891, the intrepid Bishop Julius being hoisted to the top of the spire to lay the final brick…Yet event this solution proved ineffective when, on 16 November 1901, a further earthquake damaged the brickwork, rendering it unsafe. The final solution…was to dismantle the upper portion of the spire and reconstruct it in timber sheathed with copper. The distinctive cupreous green of the spire's apex acts as a conspicuous record of the cathedral's vulnerability to seismic events and also serves as a reminder of the protracted debates over its structure.[5]

Despite experiences like the building of the Christchurch Cathedral and the impact of the 1930 Hawke's Bay earthquake, it was not until 1968, that local authorities were empowered to regulate the strengthening of buildings. Under the Local Municipal Corporations Act 1968 and the Local Government Act 1974, local authorities were given the right to apply to the Minister to regulate the strengthening of buildings deemed to constitute an earthquake risk. The legislative powers were adopted by Councils such as Wellington and Auckland which took a proactive stance on the issue.[6] David Hopkins reports that Wellington City Council achieved the strengthening or demolition of 500 out of 700 buildings identified as earthquake prone between 1968 and 2003.[7] For example, in 1973 a total of 758 buildings in Wellington City had been identified by the Council as 'earthquake risk'. By 1983, 261 of these buildings had been demolished (34%) and 17 buildings had been strengthened. This activity focused on Lambton Quay and the CBD where a total of 213 buildings had been demolished of a total of 592 identified earthquake risk buildings.[8]

The small number of buildings strengthened in Wellington during the early 1970s involved pioneering engineering techniques influenced largely by the Californian experience. These buildings included the DIC, State Opera House, the Maritime Building, AMP Head Office, Public Trust Building and later the Hunter Building and the St James Theatre. Often these buildings were strengthened as a result of intense and high profile preservation campaigns.

While the main focus of protest during the 1970's was the loss of buildings from demolition, increasing public concern was also expressed about the visual impact of earthquake strengthening. David Dowrick, a structural engineer with Brickell

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[5] ibid, p 147

[6] Wellington City resolved to adopt the powers under the Municipal Corporations Act in relation to earthquake risk buildings in February 1972

[7] David C Hopkins, 'Earthquakes and existing buildings New Zealand experience 1968 to 2008' *Proceedings of the 2009 ATC & SEI Conference on Improving the Seismic Performance of Existing Buildings and Other Structures*, p 6. See also Alistair Russell & Jason Ingham, 'Prevalence of New Zealand's Unreinforced Masonry Buildings' Draft forthcoming article for *NZSEE Bulletin*, January 2010; Ian Smith records that in 1972, the Wellington City Engineer targeted Lambton Quay and recommended that all buildings be replaced by new buildings or that existing buildings be strengthened by 1982. Ian C. Smith, 'Renovation of a New Zealand City – Lessons from Refurbishment and Replacement in Wellington City Business District' unpublished paper, February 1985, HP 12001-040, NZHPT

[8] Sir Michael Fowler, 'The 1983 Dobson Lecture, The Seismic Upgrading of Buildings – Its effect on Wellington City', unpublished paper, HP 12001-040, NZHPT

Moss & Partners was one of the most prominent structural engineers to recognise the importance of earthquake strengthening for heritage buildings. Dowrick's approach, however, emphasised the need to accept the visually intrusive intervention of strengthening:

> Strengthening elements may have to be visible, and in some cases quite intrusively, because they are in unconventional places. This is exemplified by the insertion of diagonal steel members within masonry or concrete buildings. Fortunately their apparent intrusiveness can be temporary, once the users of a building become accustomed to them. The visual statement of diagonal braces is known also to be reassuring to earthquake-conscious citizens.[9]

As a result of concerns about the impact of strengthening works on historic fabric and associated costs, during the mid-1980s, the NZHPT and other heritage groups advocated for greater flexibility for heritage buildings and providing for partial strengthening, rather the aiming to achieve full code compliance. In particular, the NZHPT sought an exemption for heritage buildings from the 1983 Draft NZSEE *Recommendations and Guidelines for Classifying, Securing and Strengthening Earthquake-Risk Buildings*.[10]

As a result of public pressure, it became accepted that flexibility was required for heritage buildings and that it should be more difficult to demolish a heritage building. For example, in 1991, Wellington City Council adopted a change in the bylaw that removed the demolition option from Building Act notices on earthquake-risk heritage buildings. Instead the Council started to proactively promote the strengthening of heritage buildings.[11]

With the shift from demolition to strengthening, attention focused on the most appropriate methods of strengthening heritage buildings. As outlined by Ian Smith in February 1985, the experiences of strengthening heritage buildings in Wellington stimulated the need for new research into examining the structural aspects of unreinforced masonry buildings (URM), new techniques for structural strengthening and recommended approaches for heritage buildings.[12] This research, in New Zealand and overseas, has now provided guidance on appropriate methods for strengthening heritage buildings. In terms of earthquake strengthening design compatibility, issues often revolve around the visibility of the new work and reversibility.

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[9] David Dowrick, 'Conserving our Building Heritage', *New Zealand Engineering*, 1 October 1982, p 3

[10] NZSEE, *Draft for Comment*, *Recommendations and Guidelines for Classifying, Securing and Strengthening Earthquake-Risk Buildings*, April 1983. Note, the draft document became known as the 'Red Book', published by the NZSEE, entitled *Earthquake Risk Buildings Recommendations and Guidelines for Classifying, Interim Securing and Strengthening*, December 1985

[11] *The Evening Post*, 23 May 199, HP 12001-040, NZHPT

[12] Ian C. Smith, 'Renovation of a New Zealand City – Lessons from Refurbishment and Replacement in Wellington City Business District' unpublished paper, February 1985, HP 12001-040, NZHPT

2.2 Earthquake Strengthening Transparency

In order to minimise intervention, earthquake strengthening work is often 'hidden' within the existing structure or it is made to be 'transparent'. Dunning Thornton Consultants state that transparency of earthquake strengthening involves discernible work without destructive investigation:

> Transparency in the detailing (separating in material, technique or form) aids the reading of the heritage structure after strengthening. Even if the addition is 'in keeping' with their original style it should be discernible to the educated eye without destructive investigation. It allows the building to be seen in the future as a history built up in layers without relying on retained documentation to describe the picture.[13]

Transparency allows for a 'degree of architectural expression of some aspect of earthquake action or resistance.'[14] This approach is closely aligned with the earthquake architecture movement.

Earthquake architecture is a term to describe architectural expression of seismic design in earthquake-prone regions.[15] Architectural expression of earthquake architecture aims to expose the seismic design, rather than hiding it in both new and old buildings. Charleson and Taylor outline three main reasons for earthquake architecture:

- The open acknowledgement of the necessity to safeguard against seismic damage.
- The development of a regional architectural style in earthquake-prone areas.
- The potential for 'aesthetic richness through a celebration of seismic technology.'[16]

The exposure of seismic work also aims to reveal engineering as a form of art work to the public.[17] Charleson and Taylor provide a number of examples of earthquake architecture such as the design of Te Papa Tongarewa (Wellington), exterior cross-bracing (Wool House, Wellington), roller staircase joints (IRD building, Wellington), reduced fenestration (Telephone Exchange, Wellington).[18]

With regards to historic buildings, earthquake architecture challenges the assumption that earthquake strengthening should be designed to 'imitate or conform as closely to the historic character' in order to 'respect' historic fabric.[19]

Shed 13 Wellington Waterfront (Photo, Wellington Waterfront Ltd)

Shed 13 on the Wellington waterfront has been strengthened using post-tensioned concrete columns, steel capping truss and the refixing of existing sarking. Research compares the recent strengthening of Shed 13 with the earlier historical seismic retrofit of Shed 11.

A.G. Cattanach, G.W. Alley, A.W. Thornton (Dunning Thornton Consultants Ltd), 'Appropriateness of Seismic Strengthening Interventions in Heritage Buildings: A Framework for Appraisal', unpublished conference paper, NZSEE 2008

[13] A.G. Cattanach, G.W. Alley, A.W. Thornton (Dunning Thornton Consultants Ltd), 'Appropriateness of Seismic Strengthening Interventions in Heritage Buildings: A Framework for Appraisal', unpublished conference paper, NZSEE 2008
[14] Christopher Arnold, quoted in Andrew W. Charleson and Mark Taylor, 'Towards an Earthquake Architecture', *Proceedings 12th World Conference on Earthquake Engineering*, NZSEE, January 2000, p 1
[15] ibid
[16] ibid, p 2
[17] A. W. Charleson, M. Taylor and J. Preston, 'Envisioning Earthquake Architecture in New Zealand', Paper presented to the NZSEE Conference, 2001, p 2
[18] ibid
[19] ibid, p 3

To illustrate, Charleson and Taylor give the example of Turnbull House, a 1917 Edwardian historic building in Wellington. The proposed strengthening scheme focused on the interior to reduce impacts on views of the east façade and to make use of the internal longitudinal spine wall.[20] For the interior, the proposed strengthening methods included steel rib mullion, perforated sheet steel shear wall, steel framed plywood walls or frame, timber clad steel mullion and steel stressed skin panel mullion.[21] The proposed strengthening work for Turnbull House was not, however, progressed at the time.

The earthquake strengthening of Shed 13 on the Wellington waterfront also provides an example of earthquake architecture of a historic building. The earthquake strengthening, by Dunning Thornton Consultants Ltd, involved the installation of six primary frames of concrete post-tensioned columns with steel capping truss adopted to tie the wall longitudinally.[22] The result is that the interior space of Shed 13 is enhanced by the six columns which add a feature of distinction, but retaining compatibility with the existing heritage fabric.

The NZHPT considers that earthquake strengthening design is not just a matter of distinguishing 'new work from old'. All earthquake strengthening, hidden and exposed, must be of a compatible design. The NZHPT is supportive of compatible design which may involve aspects of earthquake architecture. It is beneficial that the public and users of historic buildings gain an understanding of its earthquake engineering. If aspects of the earthquake strengthening cannot be revealed, then interpretation can be provided to explain earthquake strengthening techniques and methods.

2.3 Earthquake Strengthening Reversibility

The NZHPT has promoted the concept of reversibility with regard to earthquake strengthening. In 2000, the NZHPT's *Guidelines for Earthquake Strengthening* stated that 'strengthening work should be reversible and aim to achieve structural effectiveness at reasonable cost'.[23] This principle is also outlined by the US National Park Service which states that 'seismic work should be 'reversible' to the greatest extent possible to allow removal for future use of improved systems and traditional repair of remaining historic materials.'[24]

Dunning Thornton Consultants Ltd further promotes the concept of 'reversibility':

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[20] ibid, p 6
[21] ibid
[22] A.G. Cattanach, G.W. Alley, A.W. Thornton (Dunning Thornton Consultants Ltd), 'Appropriateness of Seismic Strengthening Interventions in Heritage Buildings: A Framework for Appraisal', unpublished conference paper, NZSEE 2008, p 7
[23] Lou Robinson and Ian Bowman, *Guidelines for Earthquake Strengthening*, NZHPT, 2000, p 4
[24] David. W. Look, AIA, Terry Wong, PE, and Sylvia Rose Augustus, 'The Seismic Retrofit of Historic Buildings', *Preservation Briefs*, No.41, National Park Service, US Dept' of the Interior, October 1997, p 4; See also, Cass Goodwin, Garry Tonks and Jason Ingham, 'Identifying heritage value in URM buildings' Downloaded from Seismic Retrofit Solutions website, October 2009; FEMA, *Techniques for the Seismic Rehabilitation of Existing Buildings*, 547, 2006 Edition, p 3-10

> Reversibility is an acknowledgement of the fallibility of our work; techniques may change sufficiently in the future that the proposed strengthening may become seen as inappropriate relative to the heritage fabric. More importantly in the short term, reversibility can encourage greater transparency between old and new elements and less interventional detailing. This is especially so when a structure has many uses over its preserved life. Strengthening members may need to change in size and position, e.g. strengthening walls moved or exterior additions added or removed. Heritage buildings, if treated sensitively, are best conserved when they are used/occupied and hence the economic means are provided for their upkeep. The planning flexibility around the structure contributes much to the usability and reusability of a building.[25]

Installation of base isolators at Parliament Buildings, 1993

Photo, Alexander Turnbull Library, Evening Post Collection, Reference EP/1993/1584-F. Photograph by Melanie Burford

While the NZHPT is supportive of the general concept of reversibility, the approach requires a careful assessment within the wider principle of ensuring least possible loss of heritage significance. In reality, alterations change a building and once changed it is impossible to return a 'building to how it was'. Alterations, instead, become part of the building and its historical record. In fact, trying to return a building to some previous period ignores the dynamic nature of buildings as they are adapted and changed for new uses. Possibly, the more important concept is one of 'removability' which implies that earthquake strengthening could be upgraded and replaced as techniques and technology evolves.

Unfortunately, a large number of historic buildings have been strengthened using exterior steel cross braces or K braces on the basis that the work is 'reversible'. In some cases, this work has obstructed views of significant elements such as windows and fenestration. This approach is unacceptable and should not be argued on the basis of reversibility.

Further, many important earthquake strengthening techniques are not strictly 'reversible' For example, base isolators in the Parliament Buildings and General Assembly Library in Wellington cannot be removed without major structural changes to the foundations.

The NZHPT considers that the concept of reversibility needs to be carefully managed with regard to earthquake strengthening. While it remains a relevant matter, it needs to be considered in the context of all relevant factors, especially an approach that aims to achieve least loss of heritage significance.

2.4 Historic Row Buildings

Many historic commercial buildings do not stand alone, but are often made up of multiple row buildings with common walls. The effect of earthquakes on row buildings can be severe since collapse can result from misalignments between adjacent floor or ceiling diaphragms, especially concrete floors. Further, different heights in common walls can result in punching shear wall failure or diaphragm

[25] A.G. Cattanach, G.W. Alley, A.W. Thornton (Dunning Thornton Consultants Ltd), 'Appropriateness of Seismic Strengthening Interventions in Heritage Buildings: A Framework for Appraisal', unpublished conference paper, NZSEE 2008, p 6

detachment while buildings with a similar height have generally greater structural enhancement.[26]

The risk to historic row buildings was illustrated from the Gisborne Earthquake of 20 December 2007 which resulted in damage caused by 'the failure of transverse parapets (north-south axis) which had been unaffected by previous earthquakes. Up to 90% of the building damage in Gisborne was attributed to over-topped parapets.'[27]

The experience of the Gisborne Earthquake reinforces the need to ensure earthquake strengthening work is undertaken not only for isolated buildings, but for entire rows of buildings as a comprehensive project. Achieving earthquake strengthening of very large row buildings will require intensive project management and support from local authorities.

3 Sources of Guidance

3.1 Department of Building and Housing

The Department of Building and Housing is responsible for the administration of the Building Act 2004 and Government policy with regards to the building and housing sector. The relevant provisions of the Building Act 2004 are outlined below in section 4 below.

In addition to legislative and Building Code-related documents, the Department of Building and Housing provides information on earthquake-related issues.[28] In particular, the Department of Building and Housing has published guidance for the preparation of earthquake-prone building policies by territorial authorities under the Building Act 2004.[29]

3.2 New Zealand Standards

The building control guidance framework includes non-mandatory standards. The New Zealand standards (NZS), are established by Standards New Zealand, are often referred to in building code compliance documents as acceptable solutions or verification methods. The most relevant NZS for improving structural performance will include:

AS/NZS 1170	Structural Design Action
NZS 3101	Concrete Structures Standard
NZS 3402	Steel Bars for the Reinforcement of Concrete
NZS 3603	Timber Structures Standard
NZS 3604	Timber-framed Buildings
NZS 4230	Design of Reinforced Concrete Masonry Structures

[26] Alistair Russell & Jason Ingham, 'Prevalence of New Zealand's Unreinforced Masonry Buildings' Draft forthcoming article for *NZSEE Bulletin*, January 2010, p 9
[27] Ian Petty, Revision to Earthquake-Prone Building Policy, Report to Council, 11 November 2008
[28] http://www.dbh.govt.nz/bomd-earthquake-prone-buildings
[29] Department of Building and Housing, *Earthquake-Prone Building Provisions of the Building Act 2004 Policy Guidance for Territorial Authorities*, June 2005

3.3 New Zealand Society for Earthquake Engineering

The New Zealand Society for Earthquake Engineering (NZSEE) is the primary source of non-statutory guidance for improving structural performance. In 2006, the NZSEE updated the *Assessment and Improvement of Structural Performance of Buildings in Earthquakes.*[30] The recommendations provide important guidance with regards to identifying earthquake-prone buildings and methods to improve the earthquake resistant performance of existing earthquake-prone buildings.

Section 13 provides guidance on ways to improve structural performance of buildings. The guidance states that 'while the range of approaches and solutions is reasonably comprehensive, the lists do not claim to cover every possible approach or technique. General approaches include:

- Local modification of components.
- Removing or lessening of irregularities and discontinuities.
- Global structural strengthening and stiffening.
- Seismic isolation.
- Supplementary energy dissipation.
- Removal of unnecessary seismic mass.
- Widening seismic joints.
- Linking buildings together across seismic joints.
- Seismic emergency gravity supports
- Strength and stiffness criteria.

The guidance provides a detailed list of options for Global strengthening, strengthening building elements and strengthening unreinforced masonry or concrete buildings.

The NZSEE have also published draft guidance for building safety evaluation during a declared State of Emergency.[31] This draft guidance is currently being finalised by the Department for Building and Housing. Information about this guidance is available from the NZSEE website: www.nzsee.org.nz

The NZSEE Bulletin contains a number of articles and case studies about the strengthening of heritage buildings.[32] In particular, there were a number of heritage buildings case studies published during the mid-1980s. The case studies include the Old Customhouse, Auckland; AMP Office, Wellington; Auckland Ferry Building, Auckland; Christchurch Government Buildings, Christchurch;

Supreme Court of New Zealand. Wellington
Holmes Consulting Group was recently awarded the international IstructE Heritage Award in recognition of the seismic retrofit upgrade work on the former High Court Building. The award recognised the high level of structural performance while having minimal impacts on the heritage values of the building.
www.istructe.org
Photo: Ministry of Justice

[30] NZSEE, *Assessment and Improvement of the Structural Performance of Buildings in Earthquakes*, Recommendations of a NZSEE Study Group on Earthquake Risk Buildings, June 2006
[31] NZSEE, *Draft Building Safety Evaluation During a Declared State of Emergency – Guidelines for Territorial Authorities*, December 2008
[32] NZSEE Bulletin website: http://db.nzsee.org.nz/The%20Bulletin.xml

Wellington Town Hall, Wellington; Parliament Buildings, Wellington; and the Auckland Town Hall, Auckland. References to these case studies are included in the bibliography at the end of this document.

3.4 New Zealand Historic Places Trust Pouhere Taonga (NZHPT)

The NZHPT published guidelines for earthquake strengthening of heritage buildings in 2000.[33] As outlined above, this guide provides an update to the NZHPT's 2000 guidelines.

In 2007, the NZHPT published the *Sustainable Management of Historic Heritage Guidance Series* (the guidance series). The guidance series includes a guide for the Building Act 2004 and historic heritage and a guide to heritage provisions for earthquake-prone buildings policies prepared by territorial authorities. The guidance is available from the NZHPT's website: www.historic.org.nz. It is proposed that this guide will be included within an updated guidance series.

An accompanying research paper is also available from the NZHPT that covers a range of issues relating to earthquake-prone heritage buildings.[34]

3.5 US Federal Emergency Management Agency (FEMA)

The US Federal Emergency Management Agency is one of the most important sources of guidance, adopted internationally, for earthquake strengthening, including strengthening of heritage buildings. One of the most relevant guides is FEMA, *Techniques for the Seismic Rehabilitation of Existing Buildings*, 547 (2006 Edition) is a comprehensive guide to earthquake strengthening in relation to the FEMA model building types. Each chapter provides a description of the model building type, the seismic response characteristics, common seismic deficiencies and applicable rehabilitation techniques. As an example, the following detailed techniques are outlined for Building Type URM: Unreinforced Masonry Bearing Walls:

- Brace or remove URM Parapet.
- Add wall to diaphragm ties.
- Add reinforced cores to URM walls.
- Add concrete overlay to masonry wall.
- Add fibre-reinforced polymer overlay to masonry wall.
- Infill opening in a URM wall.
- Add concrete or masonry shear wall (connected to a wood diaphragm).
- Add steel moment frame (connected to a wood diaphragm).

[33] Lou Robinson and Ian Bowman, *Guidelines for Earthquake Strengthening*, NZHPT, 2000

[34] Robert McClean, 'Toward improved national and local action on earthquake-prone heritage buildings', Historic Heritage Research Paper No.1, NZHPT, 3 March 2009

- Add or enhance cross walls.
- Add supplemental vertical support for truss or girder.
- Add veneer ties in a URM wall.

FEMA also provides a general overview of rehabilitation techniques for deficiencies common to multiple building types, including foundations and reducing seismic demand.

FEMA, *Designing for Earthquakes, A Manual for Architects*, 454 (December 2006) is a comprehensive guide for earthquake strengthening for architects. The main chapters include site evaluation and selection, seismic issues in architectural design, the regulation of seismic design, seismic design, and the evaluation and earthquake strengthening of existing buildings.

Other relevant FEMA guidance includes:

- FEMA, Seismic Retrofit Incentive Programs, A Handbook for Local Governments, 2004, FEMA 254.[35]
- FEMA, *Guidelines and Commentary for the Seismic Rehabilitation of Buildings* (FEMA 273 and 274).
- FEMA, *Planning for Seismic Rehabilitation: Societal Issues*, 1997c, FEMA 275.
- FEMA, *Next-Generation Performance-Based Seismic Design Guidelines, Program Plan for New and Existing Buildings*, 2006, FEMA 445.

There is a range of other International guidance for managing earthquake-risk and heritage buildings. An overview is provided in a separate NZHPT research paper.[36] Key guidance includes:

- American Society of Civil Engineers, *Pre-standard and commentary for the seismic rehabilitation of buildings*, FEMA 356, November 2000.
- US Department of Housing and Urban Development, *Nationally Applicable Recommended Rehabilitation Provisions* (NARRP).
- International Code Council, *International Existing Building Code*, 2006.
- International Conference of Building Officials, *Guidelines for Seismic Retrofit of Existing Buildings*, July 2001.
- Italian Ministry for Cultural Heritage and Activities, *Guidelines for Evaluation and Mitigation of Seismic Risk to Cultural Heritage*, June 2007.
- David. W. Look, AIA, Terry Wong, PE, and Sylvia Rose Augustus, 'The Seismic Retrofit of Historic Buildings', *Preservation Briefs*, No.41, National Park Service, US Dept' of the Interior, October 1997.
- California Building Standards Commission, *2001 California Historical Building Code* (Part 8, Title 24, C.C.R.).

The William Weir Wing of Weir House, Wellington (Photo, Victoria University, Wellington)

The walls were retrofitted using Carbon Fibre Reinforced Polymers (CFRP) using the Near Surface Mounting (NSM) technique.

Dmytro Dizhur, et al, 'In-Situ Out-of-Plane Testing of Unreinforced Masonry Partition Walls', poster presentation, NZSEE Conference 2009

[35] FEMA: US Federal Emergency Management Agency
[36] ibid

3.6 Seismic Retrofit Solutions

Seismic Retrofit Solutions is a co-jointed research programme funded by the Foundation for Research, Science and Technology (FRST). It is established at the University of Auckland and the University of Canterbury.[37] The programme aims to provide research-based retrofit solutions for existing buildings. It is divided into a number of research clusters including:

- Retrofit Decision making tools.
- Unreinforced masonry.
- Pre-1970s reinforced concrete.
- Post-1970s reinforced concrete.
- Steel and composite.
- Substructure and foundations.

These research clusters include a number of aspects relating to heritage buildings, including seismic design, decision-making processes, costs and benefits, and incentives.

3.7 Publications and books

In addition to the listed guidance, there are a range of published books and thesis available on the topic of earthquake strengthening (see bibliography). Some references are:

- Andrew Clarleson, *Seismic Design for Architects, Outwitting the Quake,* The Architectural Press, 2008.[38]
- Cass Goodwin, 'Architectural Considerations in the Seismic Retrofit of Unreinforced Masonry Heritage Buildings in New Zealand', Phd Thesis, Department of Architecture and Planning, The University of Auckland, December 2008.
- Cass Goodwin, Garry Tonks, Jason Ingham, 'Identifying heritage value in URM buildings' unpublished paper available from Seismic Retrofit Solutions website (accessed October 2009).
- Cattanach, A.G., Alley, G.W., Thornton, A.W., 'Appropriateness of Seismic Strengthening Interventions in Heritage Buildings: A Framework for Appraisal', unpublished conference paper, NZSEE 2008.
- David C Hopkins, 'Earthquakes and existing buildings New Zealand experience 1968 to 2008' *Proceedings of the 2009 ATC & SEI Conference on Improving the Seismic Performance of Existing Buildings and Other Structures*'.

The PhD thesis of Cass Goodwin provides an overview of strengthening techniques including URM material stabilisation, falling hazards and parapets, floor connection upgrades, outer layer fixing, plane strengthening, inter-floor wall supports, post tensioning and outer core reinforcement, frames, diaphragms, foundations, base isolation and torsion. The methods are illustrated using two case studies – Shed 13 (Wellington waterfront) and the Former Campbell Free Kindergarten building, Auckland.

Cass Goodwin, 'Architectural Considerations in the Seismic Retrofit of Unreinforced Masonry Heritage Buildings in New Zealand', PhD Thesis, The University of Auckland, December 2008

[37] http://www.retrofitsolutions.org.nz
[38] Andrew Charleson is the Associate Professor at the School of Architecture, Victoria University, Wellington

- S. E. Thomasen, 'Performance-based seismic design criteria for historic buildings', in C.A. Brebbia (ed) *Structural Studies, Repairs and Maintenance of Heritage Architecture VIII,* Wessex Institute of Technology, 2003.
- Tonks, G, Russell, A, Ingham, J, 'Heritage Unreinforced Brick Masonry Buildings in New Zealand – The Retention of Architectural Qualities in a Seismic Environment', unpublished conference paper, ECCOMAS, Greece, June 2007.
- Wessex Institute of Technology UK, Structural Studies, Repairs and Maintenance of Heritage Architecture. The Wessex Institute of Technology has hosted a series of International Conferences on structural studies for heritage architecture (STREMAH). The conferences include papers on retrofit of historic buildings and earthquakes. The proceedings of the conference are published by the WITPress.

3.8 Integrated hazards planning and management

Earthquake strengthening is only one aspect within the wider context of integrated hazards planning and management. This wider context will involve a range of management and planning actions including:

- Planning for natural hazards avoidance and mitigation under the Resource Management Act 1991 (RMA).
- National, regional and local civil defence coordination for the protection of cultural property under the Civil Defence and Emergency Management Act 2002.
- Managing earthquake-related risks associated with land subsidence, tsunami and flooding.
- Identification of earthquake-prone buildings under the Building Act 2004.
- Post-disaster response strategies.

Some of these issues have been discussed in the separate NZHPT research paper.[39]

The range of earthquake-related risks highlights the need to take a comprehensive approach to planning for hazard management. This planning should adhere to the framework provided by AS/NZS 4360, *Risk Management Guidelines.*

Other available guidance to management hazard risk and historic heritage include:

- FEMA 386-6, *Integrating Historic Property and Cultural Resource Considerations into Hazard Mitigation Planning,* May 2005.

[39] Robert McClean, 'Toward improved national and local action on earthquake-prone heritage buildings', Historic Heritage Research Paper No.1, NZHPT, 3 March 2009

- Herb Stovel, *Risk Preparedness: A Management Manual for World Cultural Heritage*, ICOROM, Rome, 1998.

Further information about hazards planning and management is available from the Ministry of Civil Defence Emergency Management and GNS Science.

4 Planning and documentation

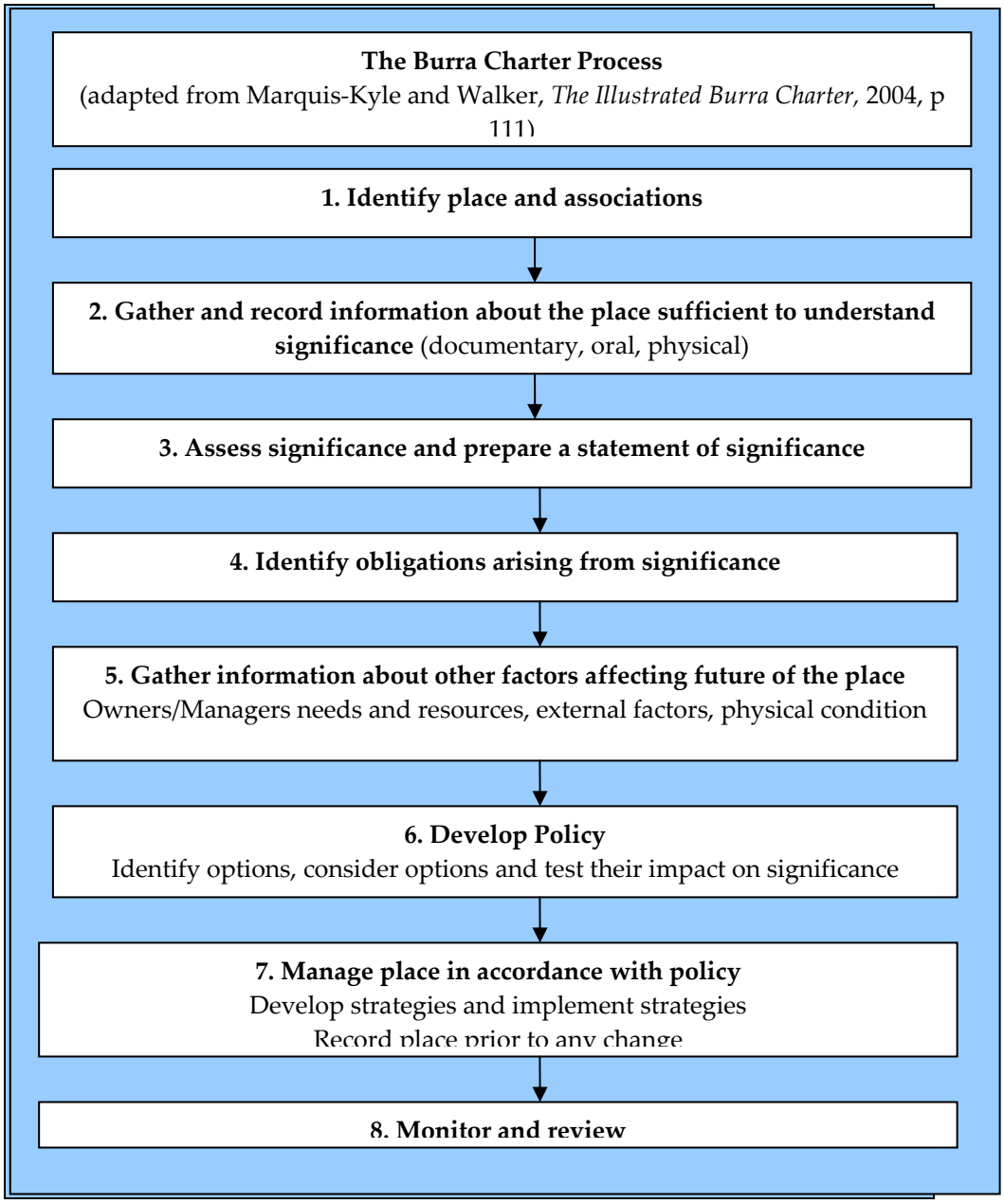
Earthquake strengthening is one of number strategies to protect heritage buildings from earthquakes. Other actions will involve:

- Identifying heritage significance.
- Preparing a conservation plan, including a cyclical maintenance schedule.
- Making an inventory of historic fabric, outline drawings, supported by photographs and photogrammetric records.
- Maintaining adequate insurance.
- Undertaking regular maintenance and repair.
- Mitigation planning for the surroundings associated with historic heritage, including contents and landscapes.[40]

4.1 Identification of heritage significance

All work involving heritage buildings should be coordinated in an integrated manner as part of the values-based approach (see diagram below). This approach emphasises that strategies for heritage buildings are developed by firstly understanding significance and then developing policy that respects the significance of the place. Understanding the significance of a place will determine those parts of the place that are to be conserved and those other parts of the place that can be changed or altered. Guidance on identification of heritage significance is available from the NZHPT.

[40] Adapted from Sir Bernard M Feilden, *Between Two Earthquakes, Cultural Property in Seismic Zones*, ICCROM and the Getty Conservation Institute, 1987, pp 15-16



4.2 Conservation plan and documentation

A conservation plan is a document that provides a statement of significance and outlines number of policies to manage a place in accordance with its significance. If a conservation plan is being prepared for an earthquake-prone heritage building, the conservation plan should be informed by an expert engineering assessment that provides guidance on strategies and appropriate methods for improving structural performance. Guidance on preparing a conservation plan is available by contacting the NZHPT.

As indicated above, the preparation of an inventory of historic fabric is an important aspect for the management of heritage buildings. Accurate records of work, including measured drawings, involving strengthening or alterations, carried out on a heritage building should be prepared, duplicated and safely stored as archives. These records will assist future owners or developers to

understand the history of structural interventions and any works to remedy any adverse effects from historical strengthening work.

4.3 Insurance

Insurance does not provide protection from earthquake-related damage. Instead, insurance is a system that provides recompense to owners in the event of loss or damage. Adequate insurance cover is an essential aspect for heritage buildings to assist with the cost of recovery. Guidance about earthquake-related insurance is available from the Earthquake Commission (www.eqc.govt.nz) and guidance about insurance and heritage buildings is available from the NZHPT.[41]

4.4 Regular maintenance and repair

There is a relationship between building damage and building maintenance in relation to earthquakes. Generally, well-maintained buildings will survive to a greater degree than poorly-maintained buildings. In fact, it has been estimated that some 50 percent of the damage that occurs in an earthquake may be attributed to lack of proper maintenance.[42] For this reason, repair and maintenance programmes for heritage buildings is a core and basic requirement and is one of the principles of risk management for heritage places.[43]

All maintenance work on heritage buildings should be guided by a cyclical maintenance schedule. This schedule should be prepared regardless of whether or not there is a conservation plan. The maintenance schedule should be kept up to date, with a log of all work undertaken.

4.5 Funding assistance

Earthquake strengthening of heritage buildings can involve significant costs for an owner or developer. The costs and benefits of earthquake strengthening and associated need for incentives are discussed in the separate NZHPT research paper.[44] The Seismic Retrofit Solutions research programme, as noted above, is investigating cost modelling in detail and examining incentives and motivators for seismic retrofit.

The NZHPT provides an incentives toolkit for historic heritage. This toolkit identifies potential sources of regulatory and non-regulatory incentives. The toolkit, for example, provides guidance on funding assistance, especially funding support available from national agencies and local authorities. For further information, contact the NZHPT.

School of Engineering, Canterbury College, 1910 (now part of the Arts Centre), Source, Steffano Webb Collection, Alexander Turnbull Library, Ref No. 1/1-005448-G

Arts Centre Seismic strengthening (www.artscentre.org.nz)

The Holmes Consulting Group is leading the arts centre seismic strengthening project. The primary approach is the use of Carbon Fibre Reinforced Polymers (CFRP).

[41] http://www.historic.org.nz/publications/SustMgt_guidance_series.html
[42] ibid. Quoted in Robert McClean, 'Toward improved national and local action on earthquake-prone heritage buildings', Historic Heritage Research Paper No.1, 3 March 2009, pp 8-9
[43] Herb Stovel, *Risk Preparedness: A Management Manual for World Cultural Heritage*, ICCROM, Rome, 1998, p 20. Quoted in Robert McClean, 'Toward improved national and local action on earthquake-prone heritage buildings', Historic Heritage Research Paper No.1, 3 March 2009, p 10
[44] ibid

5 Legislative framework

5.1 Building Act 2004

The Building Act 2004 is the latest in the generation of over 40 years of legislation that has attempted to address issues relating to earthquakes, new building construction and existing buildings.[45]

The Building Act 2004 (the Building Act) regulates all building work in New Zealand. Building work includes improving the structural performance of buildings, including heritage buildings. As an overview:

- All new building work in New Zealand must comply with the building code prepared under the Building Act 2004. All alterations and change of use to existing buildings must comply as is reasonably practicable with the Building Code.

- The Building Code is a performance-based code, which means it states how a building and its components must perform as opposed to describing how the building must be designed, constructed or altered.

- Compliance documents (previously known as approved documents) provide one means of complying with the clauses of the building code. Buildings built to the method (acceptable solution or verification method) described in the compliance document are automatically deemed to comply with the code.

The Building Act contains a number of provisions related to the structural performance of buildings. Importantly, the purpose of the Building Act means that, in exercising functions under the Building Act, building consent authorities need to ensure that buildings are safe. Further, buildings are to be designed, constructed and able to be used in ways that promote sustainable development.[46]

Safety and sustainable development are critical principles for the improvement of structural performance of heritage buildings.

Section 4 of the Building Act also contains a number of principles to be applied in performing functions or duties, or exercising powers, under this Act. These principles, which must be taken into account, apply to the Minister responsible for the administration of the Building Act, Chief Executive of the Department of Building and Housing and territorial and regional authorities.[47] The principles

[45] For an overview of previous building and earthquake legislation, see David C Hopkins, 'Earthquakes and existing buildings New Zealand experience 1968 to 2008' *Proceedings of the 2009 ATC & SEI Conference on Improving the Seismic Performance of Existing Buildings and Other Structures*

[46] Section 3, Building Act 2004

[47] The principles only apply to territorial and regional authorities when they are performing functions or duties, or exercising powers, in relation to the grant of waivers or modifications of the building code and the adoption and review of policy on dangerous,

cover matters relating to household units, preventing harmful effects, durability, building costs, standards, innovation, fire mitigation and safety, protection of other property, disabled access, efficient use of energy, efficient use of water, and waste reduction. Of particular relevance to historic heritage are:

> (d) the importance of recognising any special traditional and cultural aspects of the intended use of a building.
>
> (l) the need to facilitate the preservation of buildings of significant cultural, historical, or heritage value.
>
> (n) the need to facilitate the efficient and sustainable use in buildings of
> (i) materials (including materials that promote or support human health); and
> (ii) material conservation.

The key relevant compliance document for improving structural performance is Clause B1, Structure. This document is effective from 1 December 2008.

Depending on the nature of the work, other compliance documents may be relevant such as C Fire Safety, D1 Access Routes and F4 Safety from Falling.

In addition to the compliance documents, it is possible to design an alternative solution for improving structural performance. An alternative solution is a building design that demonstrates compliance with the Building Code. It can differ completely or partially from those described in the compliance document.

Always seek advice from the appropriate building consent authority before starting any structural works on a heritage building.

As noted, the NZHPT has published a separate guide to the Building Act as part of the *Sustainable Management of Historic Heritage Guidance Series.* This guide provides an explanation of matters such as heritage-related terms, project information memoranda (PIMs) notification, building consents and general guidance for making changes to heritage buildings.[48]

5.2 Earthquake strengthening under the Building Act

Earthquake strengthening will involve three basic categories of works:

- Modification of global behaviour, usually decreasing deformations (adding stiffness in the form of shear walls and braced frames).
- Modification of local behaviour, usually increasing deformation capacity by enhancing the existing shear or moment strength of an element.
- Connectivity to ensure individual elements do not become detached and fall.[49]

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earthquake-prone, and insanitary buildings or, as the case may be, dangerous dams (section 4(1), Building Act 2004)

[48] NZHPT, *Sustainable Management of Historic Heritage Guidance Series*, Guide No.6, 'Building Act 2004', August 2007

[49] FEMA, *Designing for Earthquakes*, *A Manual for Architects*, 2006, FEMA 454, p 8-46

Generally, the majority of work associated with earthquake strengthening will constitute an 'alteration' under the Building Act 2004. All alterations to existing buildings must comply as is reasonably practicable with the building code.

Minor earthquake strengthening work may also be classified as exempt building work under the 1st Schedule of the Building Act. This work, therefore, does not require consent under the Building Act.

5.3 Change of use

The Building Act regulates changes to the use of buildings. A change of use may involve a range of conversions, especially the creation of new household units where there were none before.[50] It may also, for example, involve the conversion of a residential building into a public building.

In the case of the creation of new household units, the building, in its new use, is required to comply, as nearly as is reasonably practicable, with the building code in all respects.[51] For other changes of use, the building is required to comply, as nearly, as is reasonably practicable, and to the same extent as if it were a new building, with respect to fire safety, sanitary facilities, structural performance and disabled access provisions of the building code.[52]

5.4 Earthquake-prone buildings

The Building Act provides special provisions for certain categories of buildings considered to be either dangerous, earthquake-prone or insanitary.[53] Earthquake-prone buildings are those which will have their 'ultimate capacity exceeded in a moderate earthquake.'[54] A 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.[55]

A building may be considered earthquake-prone if it is assessed to be less than one-third of the current standard for new buildings (new building standard or 33% NBS). This provision relates to all types of buildings with the exception of residential houses unless the residential building comprises 2 or more storeys and contains 3 or more household units.[56]

If a territorial authority considers that a building is dangerous, earthquake-prone or insanitary, the territorial authority can take action to safeguard both life and

Building Act 2004 Alterations and Change of Use.

Sections 112, 114 and 115 of the Building Act 2004 means that strengthening proposals involving alterations and change of use potentially triggers other building code requirements in relation to fire safety and accessibility. In order to safeguard historic heritage values, building consent authorities can exercise a degree of discretion and flexibility with regard to what is 'reasonably practicable'. [add ref to further info]

[50] Katharine Wheeler, 'Change of Use', *Build*, August/September 2008, pp 78-79
[51] Section 115, Building Act 2004
[52] ibid
[53] See definitions of dangerous, earthquake-prone, and insanitary buildings: sections 121-123 Building Act 2004
[54] Section 122(1)(a) Building Act 2004
[55] Building (Specified Systems, Change the Use, and Earthquake-Prone Buildings) Regulations 2005
[56] Section 122, Building Act 2004

property. These actions include erecting a hoarding or fence to prevent people approaching the building, attaching a public warning notice, or issuing a written notice to the owners requiring them to reduce or remove the danger or prevent the building from remaining insanitary.[57] A copy of any such notice must be provided to the NZHPT if the building is a heritage building.[58]

Under section 131 of the Building Act, territorial authorities must adopt a policy on dangerous, earthquake-prone, and insanitary buildings. 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.

Complementary to the regional authority administered dam safety regime, under section 161 of the Building Act 2004, regional authorities must adopt policy on dangerous dams. Dangerous dam policies must state how the policy will apply to heritage dams.

Policies for dangerous, earthquake-prone, and insanitary buildings and dangerous dams must be adopted in accordance with the special consultative procedure outlined in section 83 of the Local Government Act 2002. This means the policies must be subject to public consultation processes with the opportunity for public submissions and an open hearing. A majority of territorial authorities have prepared and implemented an earthquake prone policy.

Separate guidance about the heritage-related implications of local government earthquake-prone policies is available from the NZHPT as part of the *Sustainable Management of Historic Heritage Guidance Series*.[59]

5.5 Resource Management Act 1991

The Resource Management Act 1991 (the RMA) governs the use of all land, air and water in New Zealand. The purpose of the RMA is to promote the sustainable management of natural and physical resources. The protection of historic heritage from inappropriate subdivision, use and development is a matter of national importance under section 6(f) of the RMA.

The use of any structure, including alterations and removal is regulated under section 9 of the RMA. This means that the use of a building may be regulated by a rule in a regional or district plan.

All district plans contain 'heritage schedules' that are lists of significant heritage buildings. If a building is listed in a district plan heritage schedule, then it is likely

[57] Section 124 Building Act 2004
[58] Section 125(2)(f) Building Act 2004
[59] NZHPT, *Sustainable Management of Historic Heritage Guidance Series*, Guide No.9, 'Heritage Provisions: Dangerous, Earthquake Prone, Insanitary Buildings and Dangerous Dams Policies, Building Act 2004', August 2007

that certain activities will be regulated such as demolition, relocation, alterations and additions. A building can be individually listed or as part of a wider precinct or historic area.

Nearly all district plans, prepared by territorial authorities, regulate alterations to listed heritage buildings. Alterations are normally treated as controlled or discretionary activities in the resource consent process. In many cases, the rule relating to alterations only applies to the exterior of the building and interior works are a permitted activity.

Works to improve structural performance of a listed heritage building may or may not require resource consent under the RMA. Generally, consent will not be required if the structural work is minor and classified as repair and maintenance and the structural work is limited to the interior of the building and interior work is not regulated by district plan.

If resource consent is required, the applicant may need to consult any affected parties, including the NZHPT if the building is registered under the Historic Places Act 1993.

For further guidance about historic heritage under the RMA, see NZHPT, *Sustainable Management of Historic Heritage Guidance Series*.

5.6 Historic Places Act 1993

The Historic Places Act 1993 promotes the identification, protection, preservation and conservation of the historical and cultural heritage of New Zealand. The Act provides for the establishment and maintenance of a Register of historic places, historic areas, wahi tapu and wahi tapu areas. The purposes of the Register are:

- To inform members of the public about historic places, historic areas, wahi tapu, and wahi tapu areas:
- To notify owners of historic places, historic areas, wahi tapu and wahi tapu areas where necessary for the purposes of this Act:
- To assist historic places, historic areas, wahi tapu, and wahi tapu areas to be protected under the Resource Management Act 1991.[60]

The Register is maintained by the NZHPT and is available to the public from the regional and area offices of the NZHPT. Information about the Register is also available from the NZHPT website: www.historic.org.nz

While the Register provides no statutory protection, it has a number of statutory implications including:

- The classification of 'sensitive land' in relation to the Overseas Investment Act 2005.
- The provision of a Project Information Memorandum or building consent to the NZHPT under the Building Act 1994.

The NZHPT considers that the district plan should facilitate the improvement of structural performance of heritage buildings in a manner that is compatible with historic heritage values. If the structural performance work complies with the principles and standards outlined in this guide, then the work should be supported by the territorial authority.

It is important that at the earliest stages of planning for earthquake strengthening, contact is made with the relevant local authority to gain an understanding of the relevant RMA-related rules that may apply to the building

[60] Sec 22(2) Historic Places Act 1993

- The inclusion in Land Information Memorandum under the Historic Places Act 1993.
- The inclusion of the NZHPT as an affected party under the RMA in relation to consent procedures (at the discretion of the local authority).

It is advised to contact the NZHPT at the earliest stages of planning for earthquake strengthening if the building is registered under the Historic Places Act 1993.

A building constructed before 1900 may also be an archaeological site under the Historic Places Act 1993. Under section 2 of the Historic Places Act 1993, an archaeological site is defined as any place in New Zealand that either – was associated with human activity that occurred before 1900; or is the site of the wreck of any vessel where that wreck occurred before 1900; and – is or may be able through investigation by archaeological methods to provide evidence relating to the history of New Zealand. Under section 9(2) of the Historic Places Act 1993, the NZHPT may declare any post-1900 site to be covered by the archaeological site definition in section 2 by notice in the *Gazette*.[61]

Section 10 of the Historic Places Act 1993 directs that an authority is required from the New Zealand Historic Places Trust if there is 'reasonable cause' to suspect an archaeological site (recorded or unrecorded), may be modified, damaged or destroyed in the course of any activity. An authority is required for such work whether or not the land on which an archaeological site may be present is designated, or a resource or building consent has been granted.

Prior to carrying out any earthquake strengthening work on a pre-1900 site (or a building that is suspected to date from pre-1900), it is advisable to contact the NZHPT at the early stages of the project in relation to the applicability of the archaeological authority process under the Historic Places Act 1993. Major work, for example, to the foundations of a pre-1900 building may require an archaeological authority from the NZHPT for the work to proceed.

[61] In 2004, the NZHPT declared the Napier Prison Wall an archaeological site under section 9(2) of the Historic Places Act 1993.

6 Guidance framework

Assessment Criteria 1. Sustainable Management of Historic Heritage Principles

1. Sustainable management of historic heritage principles		
Matters to consider		
1.1	Sustainability	Taking a precautionary approach in order to safeguard the options for present and future generations.
		Enabling compatible, original and new adaptive uses
1.2	Research and documentation	Ensuring interventions are informed by sufficient research, documentation and recording, where culturally appropriate
		All changes should be fully documented in drawings and photographs
2.3	Respect for physical material	The degree that the intervention involves the least possible loss of heritage significance and the least loss of material of heritage value, including any irreversible or cumulative effects
1.4	Understanding significance	Whether the values of the place are clearly understood before decisions are taken that may result in change
		Decision making, where change is being contemplated, should take into account all relevant values, cultural knowledge and disciplines
		Understanding significance should be assisted by methods such as preparation of heritage assessments and conservation plans
1.5	Respect for contents, curtilage and setting	The extent to which interventions respect the contents and surroundings associated with the place
1.6	Add other relevant values as relevant	Respect values; Diversity and community resources; Māori heritage

Assessment criteria 1 relates to determining the appropriateness of the earthquake strengthening work in relation to principles of sustainable management of historic heritage. These principles, as outlined in the NZHPT's *Sustainable Management of Historic Heritage Guidance Series,* are based on the purpose and principles of the Historic Places Act 1993, the Resource Management Act 1991, and policy documents such as the ICOMOS NZ Charter and the *Policy for Government Department's Management of Historic Heritage 2004.*

The principles of sustainability, research and documentation, respect for physical material, understanding significance, respect for contents, curtilage and setting are adopted worldwide to guide works involving heritage buildings. As indicated

above, these principles should be detailed in a heritage assessment and conservation plan. Other values may also be relevant in relation to respect for lasting values of the building, recognising diverse social and physical environments and taking into account the needs, abilities and resources of communities, including the owners of historic buildings.

Many buildings have Māori heritage values. These buildings include marae, halls, churches, dinning halls and other Māori built heritage. Marae have been identified in the National Civil Defence Emergency Management Strategy 2008 as potential emergency shelters. Any proposed work involving marae requires a partnership with the tangata whenua.

The NZHPT Māori Heritage Advisers should be contacted for advice in relation to any proposed work involving Māori built heritage.[62]

Assessment Criteria 2. Alterations of Historic Buildings Principles

2. Alterations of historic buildings principles	
Matters to consider	
2.1	Not altering, obscuring or removing significant heritage fabric and features
2.2	Retaining and conserving ceiling heights and surfaces and significant ceiling decoration. Earthquake strengthening should not alter significant interior volumes by raising floor levels or creating partitions
2.3	Significant interior finishes (i.e. original or early wall paper, paint, stencilling, marbling, wood graining, panelling plastering and ceramic tile surfaces) are retained and conserved
2.4	Discretely installing engineering work. Any earthquake strengthening using a transparent approach should be compatible with the heritage values of the building
2.5	Seismic bracing should not be visible through prominent windows
2.6	Strengthening parapets, towers and chimneys and other elements. Replacement of original elements with replicas in plastered polystyrene or glass reinforced plaster or concrete is not ideal
2.7	Reconstruction in lightweight materials is acceptable where elements such as towers and parapets have been lost over time,

Principles for altering heritage buildings provide detailed guidance for determining the appropriateness of the earthquake strengthening. As with assessment criteria No.1, these principles are outlined in the NZHPT's *Sustainable Management of Historic Heritage Guidance Series* and are based on the ICOMOS NZ Charter, Heritage Victoria Heritage Overlay Guidelines and other international best practice guidance.

The NZHPT supports earthquake strengthening to ensure historic buildings are repaired and maintained for present and future generations. Maintaining continuity of use or new uses ensures a building retains liveability and utility.

[62] http://www.historic.org.nz/heritage/maraebuildings.html

The process of change is called adaptation which means to modify a place to suit it to a compatible use, involving the least possible loss of cultural heritage value.[63]

Major earthquake strengthening work involves alterations to historic buildings. The careful design of alterations is of paramount importance. Ensuring the least possible loss of cultural heritage value will involve retaining surviving heritage fabric, respecting the historic design of the building, avoiding work that compromises or obscures heritage fabric, and making sure the appropriate recording of new work.

Assessment Criteria 3. Best practice engineering standards

3 Best practice engineering standards		
Matters to consider:		
3.1	Investigation	Investigation is required to determine the loading regime, structural system and existing beneficial strength of the structure and foundation support
3.2	Level of structural performance that is appropriate	The level of structural performance must be appropriate in terms of the legislation, public safety, cost and heritage values of the building. As appropriate, effort should be made to achieve improvement to at least 67% of the New Building Standard (NBS). Different strengthening options should be subject of detailed risk assessment
3.3	Compatibility with the existing structure	The level of structural performance should be compatible with the existing structure and consider the degree that secondary elements are secured
3.4	The existing beneficial strength of the building must be considered	
3.5	The earthquake strengthening design should reflect best use current technology	
3.6	Historic row buildings should be subject of coordinated investigation and strengthening	

Assessment criteria 3 aims to promote the adoption of best practice engineering principles for heritage buildings, especially considering existing beneficial strength and the best use of current technology. A specific seismic performance objective should be established prior to undertaking of any earthquake strengthening works.

[63] ICOMOS New Zealand Charter for the Conservation of Places of Cultural Heritage Value, 1993

The NZSEE recommendations set out a range of best practice engineering principles for the assessment and improvement of structural performance of buildings. These principles should be adopted for historic buildings.

The legal test of an earthquake-prone building under the Building Act 2004 is a strengthening level of 33% or below of the New Building Standard (NBS). This target, however, only identifies the 'worst buildings' and the NZSEE consider that 'any building below 67% NBS should be regarded as a questionable earthquake risk and therefore still an Earthquake Risk Building (ERB).'[64] Consequently, the NZSEE recommend that 'every effort be made to achieve a structural performance improvement to at least 67% NBS.'[65] The NZHPT also supports achieving an improvement level to at least 67% NBS to promote public safety and minimise potential damage to heritage fabric.

Different performance options will have different impacts in terms of effects on historic heritage, cost, disruption and engineering outcomes. The benefits and costs of these options require an assessment for each individual building on a case-by-case basis. This process requires a consultative approach. As stated by FEMA:

> In performance-based seismic design, a decision-making team that includes designers as well as stakeholders makes choices between alternative performance levels. To do this, the team must consider the appropriate level of seismic hazard to which the building should be designed as well as the acceptable risk that would guide building performance expectations. Implicit in this process is an evaluation of costs and benefits.[66]

Further, of particular importance is the assessment of existing beneficial strength and the use of best and current technology.
An assessment of existing load paths is a critical part of any detailed assessment for earthquake-prone buildings. The assessment must consider the effects of any past modifications, additions or alterations.[67]

The existing load paths assessment is particularly important for historic buildings. As highlighted by Dunning Thornton Consultants Ltd, it is important to assess the existing beneficial strength of historic buildings to ensure that change is minimised to the existing load paths as 'an inherent part of retaining the existing structural footprint of the building.'[68]

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[64] NZSEE, *Assessment and Improvement of the Structural Performance of Buildings in Earthquakes*, Recommendations of a NZSEE Study Group on Earthquake Risk Buildings, June 2006, p 2-3
[65] ibid
[66] FEMA, *Designing for Earthquakes, A Manual for Architects*, 2006, FEMA 454, p 6-22
[67] NZSEE, *Assessment and Improvement of the Structural Performance of Buildings in Earthquakes*, Recommendations of a NZSEE Study Group on Earthquake Risk Buildings, June 2006, p 4-8
[68] A.G. Cattanach, G.W. Alley, A.W. Thornton (Dunning Thornton Consultants Ltd), 'Appropriateness of Seismic Strengthening Interventions in Heritage Buildings: A Framework for Appraisal', unpublished conference paper, NZSEE 2008.

The relative stiffness between the existing structure, any earthquake strengthening support provided and that of non-structural elements require careful consideration to ensure damage is minimised at the serviceability levels considered in the design process to meet expectations of damage control.

The design of the earthquake strengthening must reflect best and current techniques that are available and that are cost effective. As explained by Dunning Thornton Consultants Ltd:

> Materials and techniques naturally evolve with time, which should make periodic interventions naturally different from each other. While engineering should not follow fashion rather than sound technical principles, designs as with architecture tend to be branded by their area. We would hope that our advancing science in analysis and simulation techniques, non-ferrous and composite materials, compute-controlled manufacture, and modern adhesives/epoxy matrices, should enable use to do better in the future as long as we do not lose the guidance of good/sensitive designs from the past.[69]

Assessment Criteria 4. Other matters for consideration

4 Other matters for consideration		
Matters to consider:		
4.1	Construction cost	Costings should also consider other economic considerations such as the cost of disruption to building users and the value of contents of the building. Cyclic repair and maintenance costs should also be considered
4.2	Disruption to the building users during construction	Work should minimise disruption by integrating strengthening work with other earthquake strengthening works, such as repairs, maintenance and alterations
4.3	Long-term effects on building space planning	Strengthening work should maintain important internal spaces that are integral to the function of the building

The design process for earthquake strengthening needs to consider all relevant matters, including construction cost, disruption to the building users during construction and long-term affects on building space planning.

The US National Parks Service highlights the importance of carrying out a thorough cost-benefit analysis and the need for financial support to owners of heritage buildings at risk:

> Each property owner has to weigh the costs and benefits of undertaking seismic earthquake strengthening in a timely manner. Owners may find that an extended engineering study evaluating a wide range of options

[69] ibid, p 6

> is worthwhile. Not only can such a study consider the most sensitive historic preservation solution, but the most cost-effective one as well. In many cases, actual earthquake strengthening expenses have been lower than anticipated because careful analysis of the existing building was made that took the durability and performance of existing historic materials into consideration. Most seismic retrofit is done incrementally or incorporated into other rehabilitation work. In large public buildings, a seemingly expensive 'high-tech' solution such as installing foundation base isolators can turn out to be justified because significant historic materials do not have to be removed, replaced or replicated. The cost for a fully retrofitted building can offset the potential loss of income, relocation, and rebuilding after an earthquake. Without careful study, these strengthening options are often not evaluated.[70]

In terms of costs, FEMA has established a seismic rehabilitation cost estimator (SRCE) which is design to assist with calculating cost estimates for seismic rehabilitation of buildings. The estimator is a web-based statistical program available from the FEMA website.[71]

In New Zealand, the Seismic Retrofit Solutions Project at Auckland University is collecting data to assist the development of a retrofit cost estimator to assist in calculating the costs incurred by retrofit.[72]

7 Published Case studies – Earthquake Strengthening of Heritage Buildings

Boardman, P. R, 'Restoration of Old Auckland Customhouse, *NZSEE Bulletin,* Vol 16, No.1, March, 1983

Buxton, F. N, 'The Upgrading of Middle School, Cnr Jed and Don Streets, Invercargill' *NZSEE Bulletin*, Vol. 16, No. 1, March, 1983

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