Wellington City Council guide

EARTHQUAKE PRONE BUILDINGS
Wellington’s historic St James Theatre is a steel-frame and masonry building dating from 1912. It was strengthened in the late 1990s as part of a major refurbishment.
New Zealand is situated on the Pacific Rim of Fire, straddling a major fault between the Australasian and Pacific tectonic plates - meaning we are prone to earthquakes. All areas of New Zealand are at some risk from a quake.

In recognition of this fact, national legislation has been changed to enhance our ability to cope with earthquakes, and the Building Act 2004 introduced the requirement for all local councils to develop and implement a specific policy on earthquake-prone, dangerous and insanitary buildings.

The policies relating to earthquake-prone buildings (EPBs) are intended to determine how the assessment of a local council’s buildings and private building stock will be carried out and in what priority order, strengthening requirements for any non-compliant buildings and the timeframes these buildings will need to be made compliant.

Requirements on the heritage buildings – those buildings that individually or as a cluster form part of a region’s cultural heritage. To obtain the best possible result, the authority and the community must strike a balance between the need for public safety, heritage preservation and cost minimisation.

**AIM OF THE GUIDE**

Since the devastating earthquakes that struck Canterbury in 2010/2011, public interest in how buildings perform during quakes has sharply increased. This guide aims to explain why and how Wellington City Council plans improve the seismic performance of earthquake-prone buildings in the city.

**WHO SHOULD READ THIS GUIDE?**

These days, it is no longer just seismic engineers who consider these issues. Many members of the public want to know which buildings are safe to enter or occupy. Building owners are keen to understand what cost-effective techniques they can best use to make their buildings more resilient and therefore attractive for tenants and the visiting members of the public.

If you are a building owner, tenant, agent or engineer and you have an interest in why the Council is assessing buildings for their seismic performance and need for seismic retrofitting, this guide is for you. This is not, however, intended as a comprehensive guide – so for further information we recommend you refer to our Earthquake-Prone Building Policy on Wellington.govt.nz

**THIS GUIDE AIMS TO EXPLAIN WHY AND HOW WELLINGTON CITY COUNCIL PLANS TO IMPROVE THE SEISMIC PERFORMANCE OF EARTHQUAKE-PRONE BUILDINGS IN THE CITY.**
New Zealand sits across the margin between the Australasian and Pacific tectonic plates, which are moving relative to each other by about 40mm each year. In the North Island, the plates converge with each other and the Pacific Plate is subducted under (driven beneath) the Australasian Plate. In the lower South Island, the opposite occurs and it is the Australasian Plate that is being subducted. In the upper South Island and Cook Strait area, the two plates slide past each other in what is termed a strike-slip relationship.

As the plates move against each other, tension in the earth gradually builds up before eventually being released as earthquakes. Imperceptible seismic activity occurs across New Zealand (and the rest of the world) every day, but in the areas where movement is greatest along the major faults, larger earthquakes occur from time to time - such as the 1931 Hawke’s Bay quake and the 2010-2011 Canterbury events.

Earthquakes have not constituted a major hazard to life and property in New Zealand when compared with many other seismically active regions, or if we consider earthquakes in relation to other types of accident. The great Hawke’s Bay earthquake of 1931 resulted directly or indirectly in 255 deaths; a further 214 deaths from earthquakes have been recorded as due to other earthquakes since the year 1848. This number includes those who died in the Christchurch earthquakes. It is therefore sensible and prudent that various precautions are taken against the effects of possible future earthquakes. Organisations ready to deal with earthquake and other kinds of disaster are sponsored in the main centres of population by the Ministry of Civil Defence and Emergency Management.

To compare New Zealand with the rest of the Pacific, from 1918-1952, Gutenberg and Richter (for whom he common scale of earthquake magnitude was derived the common scale of earthquake magnitude was derived) measured major shallow earthquakes around the Pacific and found that Japan had the most at 39, followed by Chile with 23, New Zealand with 9 and finally California with 6. In total the whole world had about 500 such earthquakes during this period.

As shown in Figure 1.2, most earthquakes occur in two main areas - the eastern part of the North Island down to the top of the South Island, and Fiordland at the bottom of the South Island.

Several major earthquakes (magnitude 7 or greater) are known to have occurred since the European settlement. By about 1940, the seismograph network was capable of locating all local earthquakes with magnitude 6 or greater. Some 23 shallow earthquakes with magnitudes in the range 6.0–6.9 occurred in the period 1940–60.

All parts of New Zealand, with the possible exception of Northland, face some risk from quakes.

The New Zealand Building Code (NZS 1170.5:2004) regulates the design of structures to resist earthquake damage.

If you consider all the fault lines beneath our region, a major earthquake takes place every 150 years on average.
Earthquakes here are caused by movement at the boundary of the Pacific and Australian plates.

These are parts of the outer layer of the earth that move into and against each other at a rate of about 40mm per year.

The last big earthquake (about 8.2 in magnitude) was on the Wairarapa Fault in 1855. Land moved 18m sideways and 6m vertically. It affected the whole region – land and seafloor near Wellington harbour rose about 1–1.5m.

The Wellington Fault ruptures every 700–1000 years. The last big one was 300–500 years ago. The likelihood of a big earthquake on this fault in the next century is estimated to be about 10–15 percent.

**Figure 1.2: New Zealand showing plates and major fault systems (Environment Waikato).**

**THE LAST BIG EARTHQUAKE (ABOUT 8.2 IN MAGNITUDE) WAS ON THE WAIRARAPA FAULT IN 1855. LAND MOVED 18M SIDEWAYS AND 6M VERTICALLY. IT AFFECTED THE WHOLE REGION – LAND AND SEAFLOOR NEAR WELLINGTON HARBOUR ROSE ABOUT 1–1.5M.**
Push and pull

Sideways in horizontal plane
Elliptic in vertical plane
Up and down
Side to side
Compression Extension
Direction of Energy Transmission
Sideways in horizontal plane
Elliptic in vertical plane

FIGURE 1.3: Arrival of Seismic Waves at a Site

FIGURE 1.4: Motions caused by Body and Surface Waves
(Adapted from FEMA 99, Non-Technical Explanation of the NEHRP Recommended Provisions)
There are a number of active faults identified as potentially affecting the Wellington region – the closest being the Wellington Fault and the Wairarapa Fault. See Map 1.

However other faults around the Wellington region are also active and capable of generating major earthquakes - for example the Ohariu Fault. The frequency of large earthquakes affecting the Wellington Region is therefore much higher, with an average of about 150 years for a very strong or extreme ground-shaking quake.

It is well documented that the earthquake risk in Wellington and the surrounding region is the greatest in New Zealand.

The city is exposed to earthquake-induced hazards including fault rupture, liquefaction and ground shaking amplification. The geological makeup of the area is responsible for this exposure, with a variety of ground materials present. A large proportion of the central city is founded on sediments – expected to amplify strong ground motion.

The influence of local geological conditions (site effects) on the intensity of ground shaking and earthquake damage is well documented. In New Zealand, site effects are dealt with in New Zealand Standard (NZS) 1170.5:2004 – which prescribes the structural requirements needed to ensure the buildings are properly designed for ground conditions at the site.

Wellington has four subsoil classes - namely rock, shallow soil, deep or soft soil and very soft soil. As part of the ‘It’s our Fault’ programme to understand the geological conditions present in Wellington a database was compiled containing all the collated subsurface information. This was used to construct a 3D geological model and subsoil map of central Wellington (see right). The subsoil map shows the nature of the sediments at or near the ground surface in the central city. This map was created as these deposits have very different geotechnical properties and as such are likely to behave differently under earthquake loading. The map can assist in site investigations by illustrating the most likely sediments found at or just below the surface of a site.

The map should be used as a guide rather than a substitute for site-specific investigations. Previous research concluded that Wellington City is likely to experience varying levels of ground shaking during a large damaging earthquake. Areas most susceptible to ground shaking amplification and related phenomena are the reclaimed areas on the waterfront and the low-lying areas of Te-Aro.

THE CITY IS EXPOSED TO EARTHQUAKE-INDUCED HAZARDS INCLUDING FAULT RUPTURE, LIQUEFACTION AND GROUND SHAKING AMPLIFICATION. THE GEOLOGICAL MAKEUP OF THE AREA IS RESPONSIBLE FOR THIS EXPOSURE, WITH A VARIETY OF GROUND MATERIALS PRESENT.
LIQUEFACTION

The Canterbury earthquakes have illustrated the great damage that can result from liquefaction. The potential for liquefaction is not limited to Christchurch and its surrounds – several cities and towns in New Zealand are built on potentially liquefiable land.

What is liquefaction?

Liquefaction is the process that leads to a soil suddenly losing strength, most commonly as a result of ground shaking during a large earthquake. Not all soils however, will liquefy in an earthquake. The following are particular features of soils that potentially can liquefy:

- Loose sands and silts. Such soils do not stick together the way clay soils do.
- Soil that sits below the water table, so all the space between the grains of sand and silt is filled with water. Dry soils above the water table will not liquefy.

In a strong earthquake, the shaking may be so strong that the sand and silt grains try to compress the spaces filled with water, but the water pushes back and pressure builds up until the grains float in the water. Once that happens the soil has lost its strength and has liquefied.

Liquefied soil, like water, cannot support the weight of whatever is lying above it – be it the surface layers of dry soil, concrete floors, or building foundations. Liquefied soil under that weight is forced into any cracks and crevasses it can find, including those in the dry soil above, or the cracks between concrete slabs. It flows out onto the surface as boils, sand volcanoes and rivers of silt. In some cases the liquefied soil flowing up a crack can erode and widen the crack to a size big enough to ‘swallow’ a motor vehicles.
LIQUEFACTION AND ITS EFFECTS

Before the Earthquake

Area of flat, low lying land with groundwater only a few metres below the surface, can support buildings and roads, buried pipes, cables and tanks under normal conditions.

During and after the Earthquake

During the earthquake fine sand, silt and water moves up under pressure through cracks and other weak areas to erupt onto the ground surface. Near rivers the pressure is relieved to the side as the ground moves sideways into the river channels.

**Sand Boils (Sand Volcanoes)** – Sand, silt and water erupts upward under pressure through cracks and flows out onto the surface. Heavy objects like cars can sink into these cracks. Sand, silt and water cover the surface.

Power poles are pulled over by their wires as they can’t be supported in the liquefied ground. Underground cables are pulled apart.

**Lateral Spreading** – River banks move toward each other. Cracks open along the banks. Cracking can extend back into properties, damaging houses.

Tanks, pipes and manholes float up in the liquefier ground and break through the surface. Pipes break, water and sewage leaks into the ground.
All local councils in New Zealand are required by the Building Act 2004 to develop and implement a policy to determine which buildings might be prone to significant damage as the result of an earthquake.

When Wellington City Council developed and implemented its policy, it had the benefit of more than 30 years’ experience in strengthening quake-prone buildings. The Council is also applying the lessons learnt from the Canterbury earthquakes. One of our key objectives is to collaborate with the community and organisations with expertise to ensure that we are doing the best we can to strike the aforementioned balance between risk and safety in a quake-prone region.

For the purpose of consistency, there is a theoretical ‘design-level earthquake’ that all modern buildings must be built to endure. When assessing the performance of older buildings, they are deemed ‘earthquake-prone’ if during an earthquake of only one-third the intensity of that standard they can be expected to suffer partial or complete collapse, causing injury or death to people or damage to another property.

As well as the overall performance of the building, attention must be paid to those parts, such as heavy ornaments, chimneys and parapets, which constitute a greater potential hazard in of themselves. Special attention will also be given to the intact survival of essential emergency escape routes, such as stairs and ramps, and the securing of secondary systems such as suspended ceilings and ventilation ducting. It is also recommended that building owners and occupiers ensure large or delicate pieces of office furniture are properly secured.

In Wellington, the assessment process is well underway. The Seismic Performance Programme being led by Wellington City Council, and by 2014 all pre-1976 buildings in the city will have been assessed.

The Council will, over time, through continued engineering assessments and associated research, further develop its database of buildings of varying ages, materials, and structural types, to allow for the targeting of resources for ‘at-risk’ buildings.

The register of confirmed quake-prone buildings, as referred to in the City Council’s policy, is a subset of that overall data.

For those interested in the state of a particular building, finished assessments and relevant associated data will be available via property files and on the Council’s website.
There are three main stages for the assessment of Wellington’s buildings.

1. **Document Review**
   In the first instance research is carried out through Council records, city archives and private documentation (where available) to determine the history of the building and what (if any) previous upgrades may have occurred.

2. **Initial evaluation procedure (IEP)**
   Developed by the New Zealand Society of Earthquake Engineering (NZSEE), the IEP provides an indication of a building’s seismic performance relative to the minimum strength to which a modern building would have to be constructed.

   The result of this assessment is a percentage score of the New Building Standard (%NBS) from which it is possible to determine whether a building is potentially quake-prone (less than 34 percent). The Council has contracted structural engineers to carry out the assessments.

   Where a building owner has already completed such an assessment or wishes to have one carried out sooner, the Council is willing to accept an independent IEP or detailed assessment report – provided the information is substantial and can be reconciled with any existing structural reports.

   The independent report may be peer-reviewed by the Council’s contracted engineers.

3. **Detailed engineering evaluation (DEE)**
   Where a building has been identified as potentially quake-prone by the IEP process, the Council contacts the owner and requests that they get an engineer to carry out a detailed assessment.

   Any detailed assessment should provide an accurate measure of % NBS, which will supplement any IEP scores held on file.

   The detailed assessment will make use of relevant materials standards and New Zealand and/or overseas publications. Average known or measured strengths of materials may be used when assessing ultimate capacities of structural elements.

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*Figure 2.2: IEP format (refer to appendix 1)*
NOTIFICATION AND REPORTING

COUNCIL ASSESSMENTS
As each IEP is completed, the result will be notified to the building owner. Buildings with a resulting NBS of less than 34 percent will be declared potentially quake-prone and owners will be given six months to provide additional information to allow for the review of the final IEP grading.

IEP details showing the percentage of NBS will be available to the public via LIM reports. The reports will also be accessible in property files. Buildings not considered quake-prone will also have the percentage of NBS and other details placed on the property file to provide a record that an assessment has been carried out.

When the Council is satisfied that a building, or part thereof, is quake-prone it will issue an Earthquake-prone Building notice.

Note:
The reference to new building standard (NBS) is likely to be replaced with reference to ultimate limit state (ULS) in the near future as a better reflection of the nature of the assessment.

IT IS THE RESPONSIBILITY OF BUILDING OWNERS TO ENSURE THEIR CONTACT AND MAILING DETAILS ARE KEPT UP TO DATE WITH WELLINGTON CITY COUNCIL. SEISMIC PERFORMANCE ASSESSMENTS ARE CONDUCTED ON ENTIRE BUILDINGS RATHER THAN INDIVIDUAL UNITS, AND WE SEND OUR REPORTS TO THE PRIMARY LISTED CONTACT.

FORMAL NOTICES
In accordance with s124 and s125 of the Building Act 2004, the Council will attach a written ‘Section 124’ notice (yellow notice) to the building requiring the owner, within a time stated in the notice, to adequately reduce or remove a danger so that the building is no longer earthquake-prone.

Copies of the notice will be provided to the building owner, occupier, and every person who has an interest in the land, or is claiming an interest in the land — including the Historic Places Trust, if the building is a scheduled or registered heritage building.

When the yellow notice expires (10, 15 or 20 years depending on the category of building). At the expiry of the stated time period in the orange notice, the Council contacts the owner and inspects the building to ascertain whether the notice has been complied with.

If no strengthening work has been done, a red notice is issued to the owner and attached to the building which means the building cannot be occupied until strengthening work has been carried out and failure to comply within the stated time period could result in the building being demolished.

Building owners are encouraged to approach the Council and discuss what options are available to them. The purpose of these discussions will be to develop an agreed approach for the building.

Building owners are also encouraged to obtain an IEP report to work out whether their building is quake-prone and to forward a copy of the report to the Council for inclusion on the register if one has not already been carried out and recorded through Council assessments.

The Council will keep, and update as necessary, a register of all buildings for which an initial evaluation (IEP) has been done. The register records details of the outcome of the assessments and details of any notices which may have been issued. In addition, the register will include the details of any assessments that have shown a building to not be quake-prone.

Please note that reports provided by, or on behalf of, an owner may be deemed confidential and only available with the authorisation of the building owner or responsible agency. It may be prudent for prospective owners to obtain a copy of the reports from the building owner.
The confirmed list of quake-prone buildings is published on our website Wellington.govt.nz and updated monthly. NB If the Council has received no correspondence from the owner to the contrary the building will be deemed quake-prone on the basis of the IEP findings.

Note: Receipt of reports: it is the responsibility of building owners to ensure their contact and mailing details are kept up to date with Wellington City Council. Seismic performance assessments are conducted on entire buildings rather than individual units, and we send our reports to the primary listed contact. As there are cases where that primary contact is different to the leaseholder of the building, it is important that there is good communication between all parties.

LIMS – Land Information Memoranda are issued by the Council under Section 44A of the Local Government Information and Meetings Act 1987. This legislation requires the Council to provide documents including consents, certificates, notices orders or requisitions that may affect a section of land or any building on the land. Information relating to any possible current quake-prone status is included.

In LIMs, the Council will include a copy of the initial evaluation process (IEP) assessment (if one exists) and a copy of the latest letter notifying the owner/s of what the current quake-prone status of any building. If the building owner/s has had a re-assessment done and the quake status has changed, the latest letter will mention this. In some cases, where a new IEP has been done, this may be included in a LIM. If any building is yet to be assessed or if a Sec 124 (yellow) notice has been issued against a building, this would also be mentioned in a LIM. A copy of the notice issued would be attached.

SEISMIC PERFORMANCE IMPROVEMENT

Once a building has been identified as quake-prone, the building – or its parts identified as significant hazards – will be required to be strengthened to no less than 34 percent of the New Building Standard. The Council will consider any reasonable approach proposed for improving the seismic performance of a building. The proposed work will be assessed on a case-by-case basis, taking into account the requirements of the Building Act 2004. Guidance on building assessment and strengthening is available from a number of sources, including the NZSEE.

In recognition of the NZSEE recommendations and potential recommendations or legislative changes arising from the Canterbury Earthquake Royal Commission, the Council recommends that all building owners issued with an EPB notice seek to upgrade to at least 67%NBS. Where such a recommendation is made by the Royal Commission or change made to the Building Act, the Council reserves the right to immediately and to full effect modify the policy to adopt a higher standard.

Any upgrade requirements will immediately be superseded by the new requirement – and having upgrade work carried out to bring the building to the 34%NBS will not prevent the Council issuing a new notice to a higher level.

The timeframe for strengthening or demolition starts when the notice is first issued.

High priority – 10 years
Moderate priority – 15 years
Low priority – 20 years

THE TIMEFRAME FOR STRENGTHENING OR DEMOLITION STARTS WHEN THE NOTICE IS FIRST ISSUED.
Heritage buildings are those that, individually or as part of a collective community, hold historical value for our society. Buildings with heritage value are classified in various ways; they are scheduled under the District Plan, are covered by a conservation area or special character zone under the District Plan, and or are registered under the Historic Places Act 1993.

The Council believes the survival of heritage buildings should be actively promoted. The Council does not want to see strengthening work adversely affect the intrinsic value of these buildings. If a detailed structural assessment confirms a building is quake-prone, the Council will work with the owners to develop a mutually-acceptable solution. When a heritage building is confirmed as quake-prone notices are issued regardless of its heritage status.

The Council’s role is to ensure the requirements of the 2004 Building Act and the Council’s Earthquake-Prone Buildings Policy are fairly applied.

In addition to the Council’s regulatory role our officers seek to work closely with building owners whose buildings have been found to be quake-prone exploring what options may be available to help strengthen the building.

The Council’s earthquake resilience team provide advice and guidance for building owners to obtain the necessary planning and or building approvals for construction, strengthening and refurbishment of the building.

When strengthening options are not viable, the Council will endeavour to assist the owner with the regulatory process necessary for demolition.

The earthquake resilience team is also available to help facilitate meetings between adjoining building owners to explore the possible benefits of strengthening both buildings at the same time.

The team can also help owners plan a strengthening programme and determine what work should be prioritised to improve the earthquake-resilience of the building.

The Council is also working with the Government and other institutions to see where assistance can be given to owners faced with strengthening at-risk buildings.

Overall, the Council’s goal is to be as helpful as possible while running a building-strengthening programme that helps to improve the earthquake-resilience of our city.

Council provides for owners of Heritage Buildings, the built Heritage Incentive Fund that helps fund the earthquake strengthening work. Details are available on our website.
AS PART OF THE COUNCIL’S REGULATORY ROLE OUR OFFICERS SEEK TO WORK CLOSELY WITH BUILDING OWNERS WHOSE BUILDINGS HAVE BEEN FOUND TO BE QUAKE-PRONE, EXPLORING WHAT OPTIONS MAY BE AVAILABLE TO HELP STRENGTHEN THE BUILDING.

Following the 1931 Napier earthquake, the clock tower and Roman style entrance were removed from the Wellington Town Hall to make the building safer.

The Town Hall today, which we will begin strengthening later this year.
There is no such thing as a quake-proof building. Most buildings are designed to safeguard life in an earthquake. For example, a building may end up uninhabitable and beyond reasonable repair – but the occupants will be able to get out safely.

A typical building designed and built to the building code that is exposed to a one-in-500-year earthquake is expected to withstand the effects of that earthquake (ground shaking) without collapse. The building may be damaged beyond repair but should not suffer a catastrophic collapse from shaking up to that level.

Buildings of critical importance following a quake – such as hospitals, fire and police stations and communications centres – must be designed to a higher code standard and are designed for the effects for a one-in-1000 or 2500 year quake.

For example, base isolators have been used in the construction of Wellington Hospital – this reduces the effects of an earthquake on the structure and the likelihood of significant damage that would put the hospital out of action after an earthquake.

The Christchurch quakes produced levels of shaking twice the code design level and many buildings were badly damaged. Of the buildings that did collapse, many were older unreinforced masonry buildings that were not designed to current code requirements and would have been considered quake-prone.

The Council’s earthquake resilience programme aims to determine which buildings are quake-prone and work with the owners to have their buildings strengthened where the Council’s assessment shows they are below 34 percent of NBS.

The Council encourages owners to strengthen to above the 34% NBS threshold and in some situations the Building Act 2004 may require a higher level of strengthening.

Buildings on strategic routes will be a priority for assessment and strengthening.

The Council will continue to encourage and work with owners to secure the facades, parapets, verandas and similar features and make sure that such features do not pose a risk to the building’s occupants and passers by. The Council will also work with the owners of adjoining buildings to see if there is a mutually-beneficial outcome in jointly strengthening buildings in a block rather than individually.

Building owners may find that the options to strengthen are not viable and in this situation the Council will work with the owners and assist them in the regulatory process for the demolition of the building and redevelopment of the site.

An owner’s decision on whether to strengthen a building, or to demolish and rebuild a replacement structure that complies with current earthquake-strengthening criteria, depends on the required building performance as well as the associated costs. In this section, a generic retrofit strategy is described that begins with the most basic (and important) items to address with the primary aim of ensuring public safety.

Additional retrofit measures may be taken beyond these to further improve building performance in order to minimise damage to the building and contents – with the highest performance target conceivably being to have the building and its contents suffer no damage and be immediately functional following an earthquake.

Older buildings usually have a number of inherent structural features that make them prone to quake forces. Many of these features can often be addressed without significant alteration to the building – resulting in a relatively large increase in strength. The big problem is that New Zealand’s early unreinforced masonry (usually brick) buildings or unreinforced concrete buildings were simply not designed for earthquake loads and while these early buildings can be made to perform adequately in a quake, they lack a basic degree of connection between structural components to allow all parts of the building to act together.

Therefore, the basic philosophy followed here is to first secure non-structural parts of URM buildings that represent falling hazards to the public (eg chimneys and parapets) followed by improving the connections between the structural elements (roof, floors and walls), strengthening of specific structural elements, and possibly adding new structural components to provide extra support for the masonry building.

**Chimneys and parapets**

In a strong quake, chimneys and parapets can rock on their supports and topple over. The simplest solution is to remove these elements. Another option is to tie them back into the roof structure. Implementation of this tying back is usually comparatively straightforward and inexpensive.

**Gable end walls**

Gable end walls sit at the ends of buildings with pitched roofs. If this upper triangular portion of the wall is not adequately attached to the roof, the gable end is vulnerable to collapse.

**Out-of-plane wall failure**

Unreinforced masonry walls, in particular are weak in ‘out-of-plane’ bending and therefore are susceptible to failure. Cavity walls that
are missing wall ties, or have wall ties that are badly deteriorated, are especially vulnerable. The addition of wall-to-ceiling or floor diaphragm (additional inter-storey support) anchors serves to reduce the vertical slenderness of a wall as well as make the building work together as a whole, rather than as independent parts.

**Floor and roof diaphragm failure**
In some cases, the floor and roof diaphragms, typically constructed of timber, are excessively flexible. This flexibility results in the walls connected to these diaphragms undergoing sufficiently large ‘out-of-plane’ deflections resulting in major wall damage and collapse.

**In-plane wall failures (piers and spandrels)**
When ‘out-of-plane’ failures are prevented, the building is able to act as a complete entity and in-plane wall failures can occur. It should be noted that, in this condition, building strength is often not far off the full design strength requirements. Strengthening of piers and spandrels can result in further increases in overall building strength. The seismic retrofit strategy for a building in this condition might be to improve the building’s displacement capacity, rather than institute any further increase in strength. This intervention could be achieved by locally reinforcing the masonry spandrels and/or piers. Alternatively, ductile steel or concrete frames can be inserted internally to provide the in-plane shear strength needed, while also helping with some or all the gravity load-carrying function of the masonry walls.

**Return wall separation**
This type of failure is particularly dangerous because it allows a wall over the entire building height to fall outwards. This failure mode can be prevented by the use of anchors installed along the vertical intersections between walls.

**Pounding failure**
This failure can only occur when there is insufficient space between adjacent buildings so that they bang into each other (when vibrating laterally) during an earthquake. Widespread examples of pounding damage to buildings were observed in the Canterbury earthquakes.

Owners looking at strengthening their building should talk to a structural engineer and architect in the first instance. The following are some of the questions they should consider:
- How much longer is the building’s life?
- Is it likely to have a change of use?
- What are the issues that make it earthquake-prone?
- Does it have heritage value?
- How much will it cost to do/or not do the strengthening work?

Once these questions have been addressed and the owner wishes to proceed with strengthening the following are some options/solutions.

**MATERIAL STABILISATION/MAINTENANCE**

**Aim:** to ensure the existing structural components of a building are maintained properly.

Ongoing building maintenance should be undertaken to ensure that the masonry elements (walls, parapets, chimneys and facades), and the timber roof and floor elements, are in sound condition. Deterioration of the fundamental building elements compromises the ability of the ‘as-is’.

The bricks (and particularly the mortar) used in URM buildings deteriorate in the environment over time. Occasionally this deterioration will result in local failures and cracking which affects the overall strength of the building.

Various external issues/events such as dampness, subsidence, earthquakes and external impacts can also cause cracking and damage in the masonry elements. Deterioration can often be remedied by reinstatement and re-pointing of mortar, but sometimes more substantial measures are required. There are various techniques for the repair of cracks, securing of lintels, and reinstatement of damage.

Bonding agents such as grout or epoxy can be injected into the mortar and there are also several metal-based types of inserts, such as shaped dowels or reinforcing bars, which can be used to reinstate and strengthen the brickwork.
The visual impact of reinstatement and strengthening can be minimal if done carefully, and the result is potentially far superior to a cracked and broken façade. However, such measures are often irreversible and care needs to be taken with colour matching and the concealment of holes drilled for inserting rods.

Lintels and arches will sometimes require strengthening, particularly when these elements are constructed from URM. One of the best ways to achieve this intervention is by using drilled and inserted rods which are grouted (or epoxy anchored) into place. These rods provide the requisite tensile strength to the structural element while posing little visual impact.

**PARAPETS AND OTHER FALLING HAZARDS**

**Aim:** to secure or remove falling hazards.

The greatest threat to public safety posed by URM buildings is that of falling masonry. This hazard can be due to chimneys that fail by rocking (usually at the roofline) and fall through the building’s roof or over the side of the building. Parapets that are not properly secured to the building can fail similarly. Because of their location along the front and sides of commercial buildings – and because they typically fall outwards towards the footpath/street, parapets pose a very high danger to the public. Gable-end walls are another form of this out-of-plane failure and, similar to parapets, gable walls almost exclusively fall outwards. Where the gable walls are adjacent to public spaces, they also pose extreme danger to the public.

The basic strategy to eliminate these falling hazards is to fasten them to the rest of the structure, normally through the use of ties or anchors back to the roof structure.

**Note:**

*Many of these failures were seen during Canterbury earthquakes, where parapets not only fell towards the footpath/street, but also fell onto the building’s awning or canopy that projects above the pedestrian access, and resulted in collapse of that element as well. In cases of multi-storey buildings with parapet failures, the parapets fell across the footpath and well into the street, crushing cars and buses.*

URM buildings will often feature numerous decorative elements built with brick and plaster which are important parts of the building’s architectural character – such as parapets, chimneys, gable walls, and other, smaller, decorative features. In the past, some buildings have had these elements removed wholesale, rather than the elements being strengthened or secured. Parapets and chimneys are usually the first parts of a building to fail in an earthquake. Parapets in particular are comparatively simple to strengthen. Generally, a continuous steel section running horizontally along the length of the parapet, which is fixed back to the roof structure behind, is a suitable technique (if a little crude). The back of a parapet is rarely seen, which makes the visual impact of this method low. Some would argue that chimneys contribute to the architectural form of a building and often help define the front elevation or a roof profile and, as such, should be preserved if possible. The securing of chimneys is more complex than securing parapets and gables, but can usually be achieved by fixing them to the building diaphragms at each level and, either strengthening the projecting portion, or bracing it back to the roof structure with steel members similar to the methods used for parapet restraint, or fixing steel sections to the sides to provide flexural strength. A number of strengthening solutions are available for bonding to the surface of masonry elements and may be appropriate where the exterior has been plastered.
It is also possible to replicate a chimney in lighter more earthquake-resilient materials that considerably lower the risk of failure in an earthquake. However, ideally, they should be strengthened or removed completely.

Other elements that constitute falling hazards, such as decorative plaster features on the face of a wall, can be effectively fixed with a single bolted connection. Less secure elements, such as plaster finials or balusters, can be fixed with a single adhesive anchor connected to a strand of stainless steel wire to mitigate the falling hazard. However, more complex strengthening work may be necessary in some cases.

**WALL STRENGTHENING TO RESTRAIN ‘OUT-OF-PLANE’ BENDING**

**Aim:** to prevent ‘out-of-plane’ failure of walls by increasing their flexural strength or reducing the vertical and horizontal distance between their supports.

URM walls are weak when subjected to forces other than compression. Even when fully secured to floors at each level, ‘out-of-plane’ forces can cause significant wall bending depending on the ratio of the height between levels of support to the thickness of the wall. Some walls have sufficient thickness, or have cross-walls or buttresses, that help them withstand these out-of-plane forces without modification – however many walls need strengthening. There are a number of approaches to combat this problem as further described below.

**Brick cavity walls – (outer leaf fixing)**

The outer leaf of a cavity wall is problematic as it is particularly prone to failure by peeling off outwards. Steel ties, commonly installed to connect this layer to the more robust wall behind, are subject to deterioration and are sometimes missing – requiring attention during retrofits.

The preferred approach to re-attaching the outer leaf is to use a series of proprietary corrosion-resistant ties which are drilled through the face layer and are epoxy-anchored into the structure behind.

The visual impact of these ties is minimal, although care needs to be taken when concealing drilled holes. These ties are irreversible, but their presence is visually negligible.

One approach to this problem has been to fill the cavity with reinforcing steel and a cementitious grout. This bonds the outer leaf to the inner leaf and also forms a reasonably strong shear wall which is hidden from view. However this approach fails to consider the purpose of a ventilated, drainable cavity. When a cavity is filled, not only is the ventilation route blocked, but water penetrating the outer leaf is transferred directly to the inner leaf via the grout fill, which results in moisture penetration into the building.

As a consequence, dry rot can develop in wooden areas such as doors, window frames and skirtings – causing extensive damage. While a filled cavity may seem to be an excellent strengthening solution, it is the ventilation and drainage ability of a cavity that is the main priority.

The filling of a cavity with cementitious grout does not take into account the incompatibility between rigid cementitious mortars and grouts, and the weaker lime mortars used in early buildings. These materials are incompatible in terms of both strength and permeability, with the difference in permeability potentially leading to a number of detrimental effects on the original performance of the building.

Softer, permeable materials, such as bricks and the lime bedding mortar will deteriorate over time as a result of the weathering process. Cementitious materials trap water against the more porous, softer elements causing extensive erosion of soft brickwork leading to the loss of original fabric due to the need for brick replacement.

Efflorescence can also develop in structures as a consequence of changing the way that moisture is transferred through a building, and by introducing cementitious grouts and mortars containing soluble salts. This efflorescence can cause extensive damage to both external brickwork and internal plaster finishes.
Inter-floor wall supports
A series of vertical steel sections can be bolted to the inside face of the wall with sufficient spacing to ensure that the width of wall between supports is capable of resisting the out-of-plane forces. In a quake these sections bend to transfer wall loads to the adjacent floor diaphragms, essentially breaking up a large planar wall into a number of buttressed segments. This simple method may be suitable in, for example, an industrial building where visible steel bolted to the walls is in keeping with the character of the building – or in other buildings where the steel can be made to be architecturally appealing. If there is existing internal framing with space behind for these columns, and no historic material is lost during installation, then it is a perfectly acceptable method. Sections generally fix to the historic material with bolts only, which allows a high degree of reversibility.

In the past, rather than only supporting the URM walls for out-of-plane actions, these inter-floor wall support systems have been conceived as a method to support the floors in the event that the walls fail and collapse. A technique similar to the installation of vertical steel members is to provide a horizontal steel member at the mid-height of the wall and brace this with diagonal struts up to the floor or ceiling diaphragm above. This technique might be more suitable than the installation of vertical members if there is a cornice part way up the wall which needs to be conserved, or which can be used to disguise the steelwork. However, care must be taken to ensure the struts are visually unobtrusive. Both of these techniques can also be done by substituting the steel with concrete, where this is more visually-suitable or less commonly, with timber. Steel struts can also be recessed within the width of the wall. Recessing the members results in an irrecoverable loss of material and may result in other complications such as cracking – although recesses may be preferable if used beneath a plastered surface, as it will not affect the interior space. Concrete sections will have larger cross-sections than steel sections – and will therefore be more intrusive. In addition, once cast, concrete is difficult to remove without significant damage, particularly from a porous and naturally coloured material like clay brick. The installation of in-situ concrete is a comparatively permanent measure, so any activity which requires concrete to be cast against brick should be given careful thought before being undertaken.

Post-tensioning
Post-tensioning is an effective method for increasing the out-of-plane strength of URM walls. The post-tensioning may be applied externally or installed internally by drilling vertical cores through the middle of a URM wall and then inserting steel rods into these cores. The rods may or may not be set in grout, and are then tensioned, which provides an additional compressive force in the wall.

This loading modifies the stress behaviour of the URM in bending – so instead of bending instantly, the wall remains in compression. This also results in an increase in the shear strength of the wall, making post-tensioning an attractive strengthening solution.

Internal post-tensioning has little visual impact, although its installation may be unsuitable in some buildings as access is required to the top of the wall, and walls need to be of a certain minimum thickness. Drilling cores involves some loss of historic material from the holes, though compared to some methods this is a minor impact. If the bars are fully grouted in place, post-tensioning is essentially irreversible, although this does not necessarily have to be done. The presence of post-tensioning bars is not likely to result in any negative effects to the historic material should their function no longer be required, provided care is taken with all core reinforcement to ensure that it is adequately protected from corrosion. This problem can be completely avoided by using plastic coated steel or FRP bars.
There are other methods of core reinforcement, with the most common being non-stressed steel bars set in grout, where the steel reinforcement only becomes stressed when the wall is loaded laterally. The visual impact and reversibility of these methods are the same as for fully grouted post-tensioning, although they are less effective structurally.

**Wall reinforcement (FRP and other materials)**

A number of other methods may be used to provide out-of-plane stability of unreinforced masonry walls, such as the use of strips of fibre - reinforced polymer (FRP) fitted into vertical saw cuts in URM. This technique is known as near-surface mounting (NSM). It is a relatively recent technique that involves the epoxying of FRP into saw cuts in the surface of the URM and covering the cut with a grout mixed with brick dust. This technique would have some visual impact in naked brick, but little if done within an existing grout line, and none if installed in plastered walls being re-pointed. This technique can be a particularly effective and non-intrusive method of strengthening, although the finishing of this system is noticeable and work needs to be done to conceal the inserts.

**FLOOR AND ROOF DIAPHRAGM STIFFENING**

**Aim:** to increase in-plane stiffness of horizontal diaphragms (floors and roof) so seismic forces can be efficiently transferred to masonry shear walls.

Diaphragms are useful because they provide a layer through which lateral forces can be distributed to remote resisting elements. They also act to bind the whole building together at each level. A building that acts as one rigid body rather than a number of flexible panels is far more likely to survive an earthquake.

Timber floor diaphragms consist of three main elements; chords, sheathing material, and supplementary structure. To form a diaphragm in a typical URM building, chords have to be established and mechanical fastenings added to take shear and tensile loads. Several secondary fastenings between the chord and the floor or roof may also be required depending on the technique used. Some tensile ties will penetrate to the outside of the building and others will be drilled and epoxied in place. Existing historic sheathing may prove inadequate and require strengthening or an additional layer of more rigid material.

Ties to the outside of walls may require metal load spreaders which visually impact on the exterior. Many New Zealand buildings display these, and they seem to have become somewhat accepted as part of the strengthening process. Nevertheless, care needs to be taken when considering their visual impact and invisible solutions may be preferable. Much of the additional required work can be hidden within the floor space, but if this is exposed or the connections are extensive, special attention will be required to preserve the visual character of the inter-floor space.

Diaphragm-strengthening may have some visual impact if new sheathing material is required. Historic flooring material is often a significant contributor to the character of a place and ought to be retained in view whenever possible. If the existing sheathing is inadequate, a ceiling diaphragm below, or stiffening the existing material might be preferable to covering it. Another approach is to remove the existing sheathing and install a structural layer beneath it. This exercise requires extreme care; firstly because existing sheathing, particularly tongue and groove, is very easily damaged during removal and secondly care needs to be taken to restore the boards in the correct order.
Diaphragms formed using mechanical connections have a high degree of reversibility. When ties are epoxied into walls there is less reversibility, but minimal visual intrusion. Additional sheathing may damage or alter the nature of the historic timber below, making it less desirable as a solution – although this can be mitigated. Occasionally, pouring concrete over an existing timber floor may be considered. This solution can greatly increase the stiffness of the building, but in turn increases its weight and therefore the forces acting on it. It also completely changes the material of the floor and is not a reversible action, because even if it can be removed, the concrete would essentially destroy the character of the underlying timber. This procedure is therefore not recommended except in exceptional circumstances.

Roof diaphragms where the structure is exposed are slightly different, as the inclusion of a plywood diaphragm above timber sarking is generally acceptable if this area can be accessed – for example if the roofing is being replaced. This installation can also help to protect the sarking beneath. Roofs with suspended ceilings can be made to accommodate cross bracing, struts, and more innovative solutions as they can be hidden within the ceiling space. In instances where the roof provides little diaphragm action, or the forming of a diaphragm is uneconomical or impossible, a horizontal load-resisting member at the level of the top of the walls can be used to provide stability to the walls under out-of-plane loads. However, this member has to be fixed to stiff elements at regular intervals to transfer horizontal loads, and these stiff elements may have to be installed if other structure cannot perform this task.

**CONNECTION OF STRUCTURAL ELEMENTS**

**Aim:** to ensure adequate strength of roof-to-wall, floor-to-wall and wall-to-wall connections. Good connectivity between the walls and the floor and roof diaphragms will ensure that the walls only deflect outwardly over the height of one storey of a building. This reduces the out-of-plane displacements that lead to wall collapse. Similarly, good connectivity along the vertical intersection of walls meeting at corners of a building (or internal walls meeting with an external wall) will ensure that the building responds as a single structure and not as separate, isolated components. Much better performance can be expected in an earthquake when the building responds as a single structure.

The most problematic deficiency in URM construction is inadequate connection of diaphragms to walls, as a failure of these connections can potentially lead to the total collapse of a building. The addition of a network of small ties can substantially increase the strength of a building by fixing the walls to the floor and roof diaphragms. These ties have to resist two actions: shear from the diaphragms trying to slide across the walls; and tension from the diaphragm and wall trying to separate. If these ties are missing, the walls will act as a cantilever from the ground level under lateral loads, and floors and roofs are far more likely to be dislodged from their supports, which is the most common mode of failure for URM buildings in an earthquake.

The use of simple metal anchors to connect the walls to the floor and roof diaphragms is relatively straightforward and was observed in many buildings that survived both earthquakes in Christchurch. Recently, some proprietary systems have become available. They use steel reinforcement to connect walls to the floor and roof diaphragms, and to provide wall-to-wall connection at corners and other wall intersections. Typically, the reinforcement is placed in horizontally-cored holes that pass through the entire building at each floor level and at the roof level. The reinforcement is then post-tensioned and grouted in order to clamp the walls to the floors and roof and to each other. In some applications, vertical reinforcement, sometimes with post-tensioning, is also used to increase the compressive stress in the wall which improves the wall’s quake strength when subjected to horizontal loads.
SHEAR WALLS

**Aim:** to provide additional storey/base shear strength. This could be through strengthening existing walls or by building new shear walls.

Most URM walls are required to transfer some degree of shear loading along their length. If a building has insufficient shear capacity in a particular direction, then the capacity of existing walls can be increased without the need to insert additional structure. There are various ways of achieving this strength increase which generally involve the application of an additional layer of material bonded to the surface of URM – although there are some measures which involve altering the wall itself, such as post-tensioning, as described on page 18. Most of these measures involve a plane of extra independent structure being applied over the surface of the URM, effectively forming new shear walls, which are described below.

The presence of openings in a shear wall renders that section less stiff than the surrounding full-height walls, meaning the wall above and below, or between closely spaced openings, will likely be the first areas to fail in a quake. Infilling the openings will eliminate this problem by making the wall continuous, and has been advocated as a valid solution in the past. Problems with altering the character of the building and matching brick and mortar colours mean that this approach should only be used as a last resort and, even then, preferably not in visible areas. Infilling openings is likely to be somewhat reversible if done with brick, but not completely, and visual impact will depend on the location. If in-filled with concrete, the work will be less reversible and the ductile behaviour of the wall may be affected due to incompatible stiffness. Localised steel cross-bracing near openings is another technique that can prove effective, but again this system is likely to be highly visible and should only be undertaken if it won’t detract from the character of the building.

Shear walls are used to increase the strength of existing URM walls or are added as new elements. Materials that resist shear loads can be added to the surface of the URM. These might include gypsum plasterboard, particleboard, plywood or plate steel, and are generally fixed to the URM wall with bolts. This approach leads to the surface of the URM wall generally being covered – which may interfere with decorative elements on walls and openings, although this interference can be alleviated by using stronger materials such as plate or strap steel. They can also increase the thickness of the wall which is not particularly desirable as it can reduce the scale and area of the interior. For these reasons shear walls can be visually detrimental if used indiscriminately. Stand-alone shear walls can be introduced, although these can be detrimental for similar reasons. Despite these negatives, shear walls are a practical and efficient method for strengthening and are commonly used. All of these materials can be easily removed in the future, which makes them good solutions for shear walls in two-to-three-storey buildings with moderate horizontal loads.

The shotcreting of shear walls was a common strengthening technique during the 1980s. This technique involves spraying concrete onto the surface of a URM wall to essentially cast a new wall against the existing wall. This technique provides plenty of additional strength to the wall, both in-plane and out-of-plane, but is now largely regarded as unacceptable unless absolutely necessary. The technique causes a significant increase in wall thickness and it is very difficult to remove the concrete, and even more so to restore the wall behind to any semblance of its character prior to concreting. Furthermore, the installation of shotcrete generally requires the building to be gutted, which results in the loss of much heritage material and creates an essentially new interior.
Another technique for forming strengthened shear walls is the addition of surface-bonded fibre-reinforced polymer sheets. These sheets do not require the same invasive installation as shotcrete walls, but generally are equally permanent, and have potentially limited application (although new technology may soon change this). If it is possible to provide out-of-plane strength using FRP inserts, coupled with an FRP surface layer for shear, then this solution could be far superior to shotcrete from an architectural perspective. An important consideration with the use of sheets of FRP is that it is impermeable, which can lead to problems with water trapped within the building resulting in dampness and mould issues, and potentially the de-bonding of the epoxy.

INSERTION OF INTERNAL FRAMES

Aim: to provide an alternative structural system to resist the seismic loads.

Moment frames
Moment frames are a common method of gaining additional horizontal resistance which can also be used as a local strengthening solution. The advantage of this system is that it uses beams and columns, so is fully customisable, and there is space between the vertical and horizontal elements. Moment frames allow full visual and physical access between each side of the frame, and minimal spatial disruption. In building façades with numerous openings, some form of moment frame can often be fitted to the masonry piers on the inside or outside (or both) depending on the effect on the architectural character. Moment frames can be a particularly effective solution, especially where the frame is tailored to the character of the building. Care needs to be taken with steel frames in particular to ensure stiffness compatibility with the existing structure. Steel is a ductile material, but URM is not, meaning that under quake loads the added stiffness of the steel might not come into effect until a load is reached where the URM has already been extensively cracked.

Moment frames can be an excellent strengthening technique, either to supplement an existing wall or as a new, stand-alone element. If a steel frame is erected against an existing wall where weakness exists, the frame must be fixed either directly to the URM using bolted connections into the wall or to the diaphragm. Installing concrete frames is a more complex undertaking, as these will often be constructed by thickening existing piers, although a concrete frame that is separate from the existing structure is possible. In both situations, it is important that architectural character is retained, and historic material conserved. Some creative and design strategies may need to be used to achieve this.

Steel moment frames have a high degree of reversibility, as again they rely on mechanical connections and relatively small ties to connect to the existing structure. Concrete frames are generally far less reversible, but can sometimes be better concealed when this is a requirement. Some recent buildings have very effectively used precast concrete load-resisting elements which are separate from the URM walls, solving the problem of reversibility.

Braced frames
Braced frames are available in various configurations: concentric, tension only concentric, eccentric, and ‘K’ bracing. The key functional difference between braced frames and moment frames is that due to the diagonal braces, braced frames prevent physical continuity between spaces on either side of the frame. Braced frames are also generally constructed from steel rather than concrete, and are much more rigid than moment frames.
Braced frames are a very efficient method of transferring horizontal forces but have significant setbacks. Their use in façade walls is usually precluded by the presence of windows, as diagonal braces crossing window openings are generally considered to be poor design. It is also difficult to get a braced frame to conform to an existing architectural character. However they can be used to very good effect within secondary spaces, and can be made to fit architecturally in some situations with careful consideration. Generally speaking, steel-braced frames have a good degree of reversibility and can provide excellent strengthening when used appropriately.

**REMOVAL OF MASS AND/OR GEOMETRIC/STIFFNESS IRREGULARITIES**

**Aim:** to reduce seismic forces by reducing structural mass or structural irregularities.

Another approach to seismic improvement of URM buildings derives from its weight. Seismic actions are directly proportional to the mass of the building – so if mass is reduced, so are the forces acting upon the building. A lighter building requires less lateral strength and therefore less additional strengthening. Reducing the mass of a building may seem at face value to be a sensible approach – however past experience has shown this may not necessarily be the case. The mass must be removed from somewhere, and the higher up the mass is, the stronger the forces upon it and the more difficult it is to strengthen, so the top of the building is the first place which has been looked at. Historically this logic has led to the ad-hoc removal of decorative elements such as parapets, gables, chimneys, and occasionally whole towers. These elements will almost always significantly contribute to heritage value and character, and their retention is essential to preserving these attributes. Indeed, it is often desirable to replace these features if they have been removed from buildings and still exist. While reduction of weight may be achieved in more subtle ways, such as removal of internal URM partitions or the removal of plant loads, the wholesale removal of decorative elements is strongly discouraged.

**Base-isolation**

Also known as seismic base-isolation, this is a modern approach to protect new and existing buildings from damaging earthquakes. It is considered one of the most effective ways of protecting a structure against ground shaking and was used in the design and construction of Wellington Hospital, Te Papa, the Old Bank Arcade and will be used to strengthen the Town Hall.

It is a particularly useful way of protecting heritage buildings where both the interior and exterior architecture is to be kept intact.

Base-isolation requires buildings to be de-coupled from the foundations and then base-isolators are introduced into a strengthened foundation system. The base-isolators act as super shock absorbers that absorb the energy produced by an earthquake and act to reduce and dampen the effects of the quake on the building above the foundations.

A typical base isolator in place.
What is the risk of a quake in the Wellington region?
The risk of an earthquake in Wellington is ever present so we must be prepared.

Why are buildings subject to earthquake-testing?
Wellington is in an active seismic zone and the Building Act 2004 requires the Council to develop and implement a specific quake-prone, dangerous and insanitary building policy. Residential properties (unless they have two or more stories and contain three or more household units) are not subject to the quake-prone provisions of the Building Act.

What are the seismic performance measurements for buildings?
Refer to table below.

When is a building quake-prone?
A building is considered quake-prone if it meets less than 34% of current building standards. Wellington City Council has identified pre-1976 buildings in the region and contract engineers are assessing these buildings. Buildings finally assessed as quake-prone are added to the Council’s quake-prone register.

What is an IEP?
The initial evaluation procedure (IEP) is a desktop exercise undertaken by a chartered professional engineer who reviews any available building consent plans and visits the site. It is a standardised procedure developed and used by the Society for Earthquake Engineering members to identify if a building is potentially earthquake-prone.

What do I do if I own a pre-1976 home?
Information about how you can strengthen your pre-1976 home can be found on the Earthquake Commission website – eqc.govt.nz – and in Wellington City Council’s home owners guide – Earthquake Strengthen Your House – available from Wellington.govt.nz or from Wellington City Libraries. An assessment can also be made of your home covering specific features by a registered master or certified builder and costs $160 dollars including GST. Owners could also get an architect to advise them on how to strengthen their home.

I want to find out if my building is quake-prone before the Council does an IEP assessment on it. What can I do?
Owners can get a chartered professional engineer to carry out a seismic assessment of buildings at their own cost. Completed reports should be sent to the Council for consideration.

Can I respond to the Council’s seismic assessment of my building?
Yes. Owners are given a copy of the engineer’s assessment (IEP) and have six months to respond in agreement or to provide more information for consideration. An owner may choose to use an independent structural engineer to undertake an IEP or a more detailed engineer evaluation. The Council will consider additional information and may reevaluate the seismic assessments as a result. Owners will be advised of final assessments and details will be included on the building’s Land Information Memorandum (LIM) report.

What happens if my building is quake-prone?
If a building is assessed as quake-prone, the Council will advise timeframes in which owners must strengthen the building. Building owners are responsible for all costs associated with upgrading their buildings. Any upgrade work or demolition will require a building consent.

Where can I find support advice to help me fix my earthquake-prone building?
Owners of quake-prone buildings should contact the Council’s Building Compliance and Consents team to discuss options for strengthening. Please contact the Council and speak to a member of the Earthquake Resilience team or Building Consents team.

<table>
<thead>
<tr>
<th>Grade</th>
<th>A+ Excellent</th>
<th>A Very good</th>
<th>B Good</th>
<th>C Potential earthquake - risk</th>
<th>D Potentially earthquake-prone</th>
<th>E Earthquake-prone</th>
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<td>%NBS</td>
<td>&gt; 100</td>
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<td>67-79</td>
<td>34-66</td>
<td>20-33</td>
<td>&lt; 20</td>
</tr>
</tbody>
</table>

Note: NBS refers to the New Building Standard.
How long do I have to strengthen my building?
Within 10–20 years, depending on the priority of services of the building. The Council will work with owners and tenants to develop realistic timelines for strengthening proposals. The Council’s quake-prone building policy is available on our website. Copies are also kept for reference at our libraries.

How much will it cost to strengthen my building?
The exact cost of any required work is on a case-by-case basis and depends on the engineer’s evaluation of the building. The timeframes outlined in the Council’s quake-prone building policy provides some scope for the costs to be programmed and spread over time.

Can I buy or sell a quake-prone building?
Yes. The LIM report will state a building’s quake-prone status. The new owner will be responsible for the building’s seismic upgrades within the specified timeframe. Interested buyers should do their own investigations and seek expert advice.

If my building has a heritage classification, will it need to be upgraded?
The Council’s quake-prone building policy applies to heritage buildings in the same way as it does to any other building. We encourage owners to discuss options with the Historic Places Trust, and to make every effort to meet the Council’s heritage objectives. For more information visit the Historic Places Trust – historic.org.nz

Will the Council place a red sticker on a quake-prone building?
Yes, if nothing is done to strengthen the building then the process will see a red sticker placed on the building. The IEP assessment of each earthquake-prone building will also appear on the property’s LIM report. However the Council will first try to work with building owners to improve building-safety rather than issuing formal notices.

I am changing the use of my building. Does the policy affect me?
Yes. A change of use requires any building to be upgraded to comply ‘as nearly as is reasonably practicable’ with the current Building Code, for structural performance regardless of its quake-prone status. For more information, visit the Ministry of Business, Innovation and Employment website – dbh.govt.nz/building-index

I strengthened my building prior to 2004. Does the policy affect me?
Yes, if it is confirmed as quake-prone, the building will need more strengthening work to comply as nearly as is reasonably practicable with the current Building Code.

Will the policy affect insurance?
Possibly yes, if the building is earthquake-prone. Insurance policies usually require disclosure of information contained on the property LIM report regarding a building’s quake-prone status. Building owners should contact their insurer for further information.

What is happening in regards to the Royal Commission of inquiry?
The Government is considering the remainder of the Royal Commission’s recommendations. If, as a result, there are any proposed legislative changes, these will likely occur in early 2014. Already, the Ministry of Business, Innovation and Employment (MBIE) has begun reviewing earthquake-prone building policies. To find out more, go to: canterbury.royalcommission.govt.nz

Should I take any action as a result of the Royal Commission findings to date?
The Royal Commission’s interim report recommends that owners of unreinforced masonry buildings should begin bracing parapets, installing roof ties and securing external falling hazards (eg chimneys) ‘as soon as practicable.’

What is Wellington City Council doing to ensure the region is prepared for an earthquake?
The Council is prepared with a well-developed civil defence structure that involves emergency services, local and central government, utility companies, health boards and welfare agencies. We regularly check our response systems through exercises and real life situations. For more information about the Council’s civil defence and emergency management visit getprepared.co.nz
FURTHER INFORMATION

USEFUL INFORMATION SOURCES:

- NZSEE New Zealand Society for Earthquake Engineering – nzee.org.nz
- GNS Institute of Geological and Nuclear Sciences – gns.cri.nz
- MBIE Ministry of Business, Innovation and Employment – dbh.govt.nz
- BRANZ Building Research Association of New Zealand – branz.co.nz
- WCC Wellington City Council – Wellington.govt.nz
- NZIA New Zealand Institute of Architects Inc – nzia.org.nz
- ACENZ Association of Consulting Engineers of New Zealand Inc – acenz.org.nz
- IPENZ The Institution of Professional Engineers NZ Inc – ipenz.org.nz
- EQC Earthquake Commission – eqc.govt.nz
- New Zealand Standards – standards.co.nz
- Indian Institute of Technology Kanpur – www.iitk.ac.in

FOR FURTHER INFORMATION WE RECOMMEND YOU REFER TO OUR EARTHQUAKE-PRONE BUILDING POLICY ON WELLINGTON.GOV.T.NZ
Section 122 of the Building Act 2004: meaning of earthquake-prone building

(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,

(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

Balusters – vertical posts between the handrail and stair treads or stair stringer (side of stair). In simple terms it’s a post or series of posts to support a handrail. A series of balusters is referred to as a balustrade.

Base-isolation – are a series of super shock absorbers introduced into the foundations of a building to help absorb the energy and ground shaking generated by an earthquake.

Buttress – a brick, concrete or steel structural component designed to provide lateral (side-to-side) support. A buttress doesn’t necessarily need to extend to the full height of the wall it is supporting.

Cantilever – a vertical or horizontal beam fixed at one end and unsupported at the other. For example, a gate post set down and concreted into the ground to a depth of 900mm that sticks above the ground 1200mm is a simple cantilevered member.

Cavity wall – a wall constructed with two separate thicknesses with a space between, and tied together with metal wall ties. Many of the older buildings with cavity walls do not have wall ties and are generally only fixed at the top and bottom of the wall, but not in all cases.

Cementitious – a product with a cement base. For example, a cementitious grout is cement in a liquid state for filling crevices or cavities or for forming a key for jointing together new or old concrete or brickwork. Modern grouts are chemical based and are used in specialist situations.

Cross-bracing/struts – structural components made of either steel, timber or sheet material that provide a floor, wall, ceiling or roof added structural resilience. Cross-bracing is usually placed diagonally across the element it is located in.

Chord – a top or bottom member of a wall, beam or roof truss. In a seismically-retrofitted building, the chords could be in timber or steel that the vertical wall or horizontal floor bracing members are attached to.

Diaphragm – a structural element that transmits in-plane forces, typically from wind or earthquakes (diaphragm forces), to and from shear walls or frames. Floors often act as diaphragms.

Ductile or ductility – a measure of how easily a solid material (such as steel) deforms under stress without breaking. In earthquake engineering terms ductile structures are designed to absorb earthquake energy without collapsing.

Earthquake-prone building – a building is earthquake prone if, due to its condition, the ground on which it is built, and the way it was constructed, it could be structurally undermined in a moderate earthquake and would likely collapse causing injury or death to people in the building or on nearby property or cause damage to any other property. This is commonly understood as the building meeting less than 34 percent of the New Building Standard (NBS) requirements.

Efflorescence – a white powdery crystalline deposit found on concrete, brickwork, masonry or on plasterwork caused by the evaporation and crystallization of alkaline salts which may be contained in the building material.

Epoxy – a chemical additive/adhesive made from a class of synthetic polymers containing epoxide groups.

Fault – a fracture in the Earth’s crust where the blocks on either side have moved relative to one another in a direction parallel to the fracture.
**Finials** – pointed ornamental pieces of timber, concrete, steel or other material fixed vertically at the roof apex – particularly on the gable ends of the roof or on a church spire. Some can be very ornate and are there for decorative purposes.

**Flexure strength** – the ability of a structural component to bend under a load – for example a beam when a load is applied to the top of the beam.

**FRP bars** – reinforcing bars of fibre-reinforced polymers.

**Gable end** – the triangular area of brickwork, masonry, timber and weatherboards or sheet material forming the outside wall between the sides of the end of a roof and the line of the eaves.

**Intensity** – a measure of how strongly an earthquake affects the surface, based on its observable effects on people, buildings and the environment. Intensity is usually ranked using the 12 point Modified Mercalli Intensity (MMI) scale.

**k-bracing** – steel bracing shaped like the letter ‘k’ introduced to provide additional earthquake resilience to a structure.

**Liquefaction** – the process in which water saturated sediment loses its strength and acts as a fluid.

**Load spreaders** – steel or cast-iron plates seen on the outside face of a masonry building with a threaded tie rods and large nuts protruding through the centre of the plates. Load-spreading plates are usually located at floor and ceiling levels. They help spread the load by way of the threaded steel tie rods running through the plates on the face of the external walls.

**Magnitude** – a measure of the energy released by an earthquake at its source. Magnitude is commonly determined from shaking recorded on a seismograph. Each unit of magnitude on the scale represents a substantial increase in energy, for example a magnitude 5 earthquake releases 30 times more energy than a magnitude 4 earthquake.

**Moderate earthquake** – an earthquake that would generate shaking at the site of a 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 the same site.

**Moment frame** – a box-shaped steel frame provided with special moment connections or joints that helps a building to flex as necessary to retain the buildings structural integrity. There are various types of moment frame and the type used is dependent on the building and its design.

**Mortar** – a plastic mix of binding material between brick courses (layers) usually a mixture of sand, cement and water (and sometimes additives to make it work better). The mortar in old brick work was made with lime, sand and water (lime mortar) and fails when the structure is exposed to the effects of a moderate earthquake.

**New Building Standard (NBS)** – the minimum structural performance standard that must be met by a new building based on present day design codes.

**Near Surface Mounted (NSM)** – when reinforcement is retrofitted by cutting grooves or chases into the surface of the brickwork, masonry and inserting reinforcement that is embedded in cement or an epoxy mix.

**Out-of-plane** – when a brick, masonry or concrete wall is subjected to forces acting on the face of a wall and normally at right angles – for example a brick wall that moves out of the perpendicular or buckles and bulges through the length and height of the wall because of the forces generated by the earthquake on the wall.

**Parapets** – the parts of an external wall that extend above the eaves gutter line. They are functional as well as decorative. They provide fire-protection to the adjoining building, they form part of an internal guttering system and prevent roofing or other materials sliding of the roof onto adjoining property – for example where the building abuts the public street.

**Post-tensioning** – a method for strengthening a concrete floor, wall or beam and even laminated timber structural components. For example tensile steel wires or rods are run vertically through prepared holes in brick or masonry at specified intervals along the wall. The wires or rods are then tightened (tension is applied) by a hydraulic jack. Once the required tension is applied on the wire or rod it is fixed (usually wedged) and grout is pumped into the hole to make sure the wire or rod is protected.
Shear wall – a structural wall which because of its position and shape, makes a major contribution to the resilience and strength of a building. There can be more than one shear wall in the design of a building.

Shotcrete – concrete designed to be applied to a brick, masonry or concrete wall to improve their strength and or fire-resistance rating. Shotcrete is applied by a high pressure hose with a hardened nozzle using compressed air to deliver the concrete to the appropriate position. The concrete can be reinforced with steel mesh pre-fixed to the wall to be Shotcreted. The Shotcrete can also have carbon fibres and other additives added to the mix to improve the strength of the finished mix and to make it easier to apply to the wall in layers.

Spandrel – the portion of a wall below a window from the sill to the floor level and/or the head of the window directly below. As well as serving an aesthetic function, spandrels can help prevent the vertical spread of fire up the external face of the building.

URM – an acronym for unreinforced masonry, which is a term used to describe bricks secured by mortar and/or concrete used in the construction of a building without any form of steel reinforcing. This type of construction is not permitted under modern building codes, which typically require reinforcement of building elements. URM was construction method mainly used early last century. Buildings constructed with unreinforced masonry are generally found to be earthquake-prone and need to be strengthened.

In the production of this guide Wellington City Council wishes to thank the following organisations:

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APPENDIX

Initial Evaluation Procedure

Wellington City Council
Initial Evaluation Procedure (IEP) Report

Table IEP-1 Initial Evaluation Procedure Step 1
(Refer Table IEP - 2 for Step 2; Table IEP - 3 for Step 3; Table IEP - 4 for Steps 4, 5 and 6)

<table>
<thead>
<tr>
<th>Street Number &amp; Name:</th>
<th>Lot No:</th>
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</thead>
<tbody>
<tr>
<td>AKA:</td>
<td></td>
</tr>
<tr>
<td>Name of building:</td>
<td></td>
</tr>
<tr>
<td></td>
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</tr>
</tbody>
</table>

Step 1 - General Information

1.1 Photos (attach sufficient to describe building)

1.2 Sketch of plan

1.3 List relevant features

1.4 Note information sources

Disclaimer: This initial evaluation process has been carried out solely as a screening tool in terms of the Wellington City Council's (WCC's) Earthquake-Prone Buildings Policy 2009 (Policy) and the New Zealand Society for Earthquake Engineering document 'Recommendations for the Assessment and Improvement of the Structural Performance of Buildings in Earthquakes'. It should not be relied on by anyone for any other purpose. Detailed inspections and engineering calculations, or engineering judgments based on them, have not been undertaken, and they may lead to a different result or seismic grade.
EARTHQUAKE PRONE BUILDING – DO NOT APPROACH

Notice pursuant to S124(1)(b) & S128 of the Building Act 2004

To:
The owners of the building; and
any person who has an interest in the land on which the building is situated,
under a mortgage or other security registered under the Land Transfer Act 1952; and
any person suiting on interest in the land that is protected by a
conveyance lodged and in record under section 117 of the Land Transfer Act 1952.

This notice is for the building situated at ADDRESS, more particularly being
LOT DP, and being the land described in Certificate of Title NUMBER.

The above building has been classified by the Wellington City Council as

The meaning of earthquake-prone is defined by section 112 of the Building Act
2004, in conjunction with clause 7 of the Building (Consolidated Systems, Change the

For further information please refer to the Wellington City Council’s Earthquake-
prone Buildings Policy 2009 (Policy). You can view the policy at
www.wellington.govt.nz

This notice is issued under section 124(1)(b) of the Building Act 2004. The Council
advises that people should not approach the building.

In accordance with section 128 of the Building Act 2004, as a result of this notice:

No person may:
a) use or occupy the building; or
b) permit another person to use or occupy the building.

A failure to comply with these restrictions is an offence under the Building Act
2004. In relation to such an offence, section 128(3) of the Building Act 2004 states:

A person who commits an offence under this section is liable to a fine not
exceeding $200,000 and, in the case of a continuing offence, to a further fine not
exceeding $20,000 for every day or part of a day during which the offence has
continued.

This notice will remain in effect until a code compliance certificate is issued for
building work that strengthens the building to a sufficient degree that it is not
earthquake-prone or for the demolition of all or part of the building (no further
building on the remainder of the building, if any, is not earthquake prone). A building
compliance must be obtained prior to strengthening or demolition work being undertaken.

If you disagree with the classification of this building as earthquake-prone you may
apply for a determination from the Department of Building and Housing under
section 177(e) of the Building Act 2004.

Under Section 255 of the Building Act 2004, it is an offence to remove or
deface notices.

(1) A person commits an offence if the person:
a) wilfully removes or defaces any notice published under this Act; or
b) incites another person to do so.
(2) A person who commits an offence under this section is liable to a fine not
exceeding $5,000.00

Dated: INSERT DATE

Neville Brown
Manager
Earthquake Resilience
Wellington City Council

PO Box 139, Wellington 6140, New Zealand
Ph: 544 475 4000, Email: www.wellington.govt.nz
OWNERS LOOKING AT STRENGTHENING THEIR BUILDING SHOULD TALK TO A STRUCTURAL ENGINEER AND ARCHITECT IN THE FIRST INSTANCE.