SEISMIC RISK AND BRITISH COLUMBIA'S HISTORIC STREETSCAPES

CUMMER HERITAGE CONSULTING

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CONTENTS

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DISCLAIMER

Please note that this report is meant to be a broad overview, intended for a general audience, such as property owners and policy makers, as opposed to a technical document. It is intended to help British Columbians better understand the seismic risk and rehabilitation options available to improve public safety and to illustrate some of the approaches and policies employed around the world to reduce earthquake-related losses. It is not an in-depth evaluation of the effectiveness or merits of individual approaches or policies.

This is a larger research report that explores the various approaches used for addressing seismic risk and heritage buildings, both locally and overseas. There is a Summary Brief available that provides an overview of seismic risk and rehabilitation options, followed by recommendations on how to potentially improve BC's approach to addressing seismic risk, based on this overseas comparative analysis research. Please refer to the Summary Brief for a high-level synopsis.

BRITISH COLUMBIA Heritage Branch

HeritageBC

INTRODUCTION

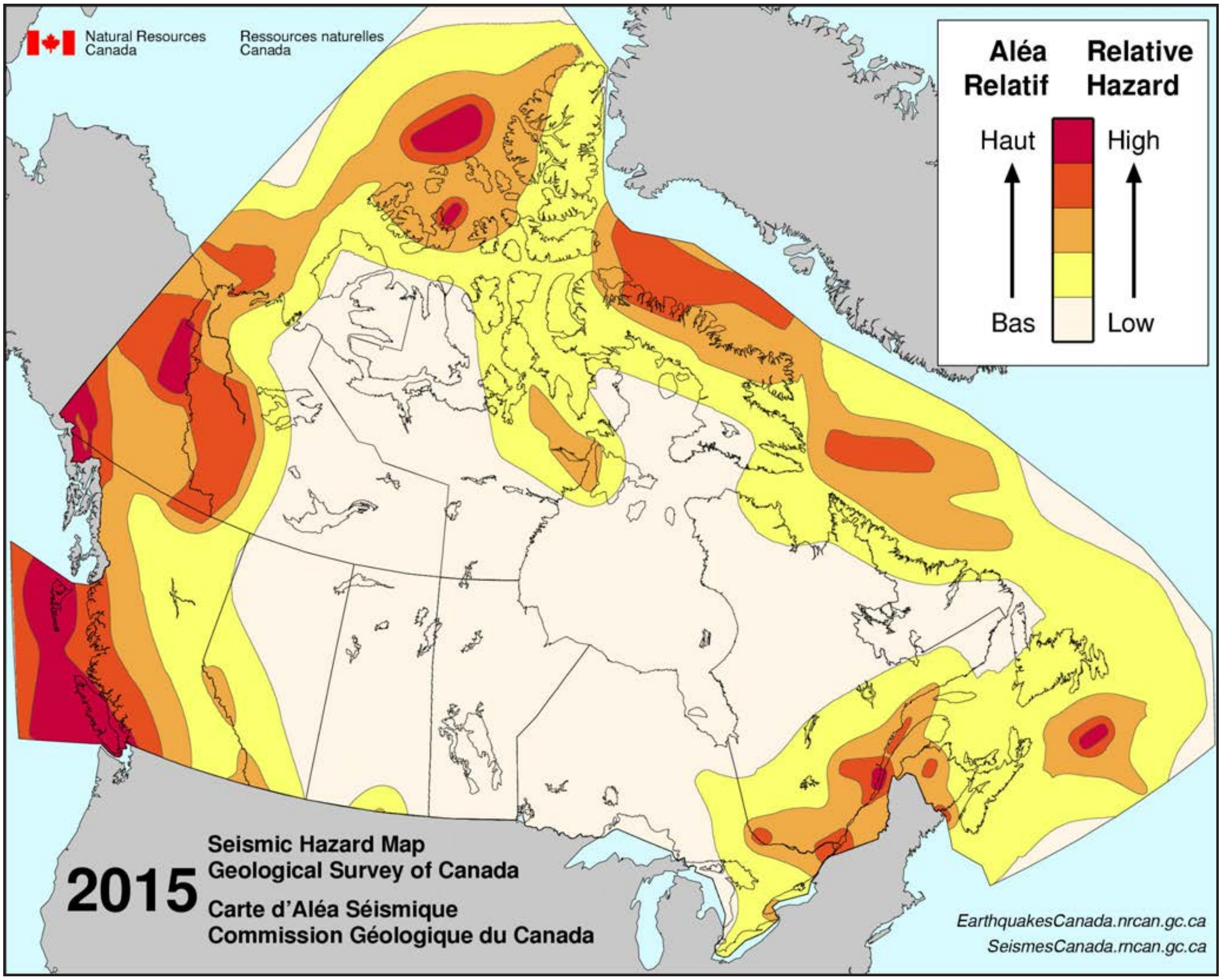


Fig. 1.1: Seismic Hazard Map of Canada, 2015. (Source: Natural Resources Canada)

The province of British Columbia is the most seismically active and seismically at-risk province in Canada (Fig. 1.1) (Bolton et al. 2015; Structural Engineers Association of BC 2013; Natural Resources Canada 2011; Canadian Seismic Research Network 2009; Onur et al. 2005 and Ventura et al. 2005). However, despite this, there is not as much public awareness or public policy with regards to how to mitigate this risk, particularly when it comes to heritage buildings.

Heritage buildings are an important part of British Columbia's built environment. They connect to the histories and identities of communities, as well as provide a sense of place, being distinctly designed using long-lasting materials. Often, such buildings add visual interest and charm to the historic streetscapes experienced throughout the province and typically provide focal points and gathering places for communities.

Unfortunately, many heritage buildings were built prior to the modern building code and are at great risk of damage or even collapsing, whenever the next large earthquake should strike (Bebamzadeh et al. 2019; Ventura et al. 2016; Paxton et al. 2015; Paxton et al. 2013; Ventura et al. 2011). This is worrisome when considering the varied uses of these buildings by so many everyday, such as galleries, homes, museums, offices, restaurants, schools, shops and more.

In addition to the concern for the lives and livelihoods in these buildings, there is also an environmental consideration. As eloquently stated by the former President of the American Institute of Architects, Carl Elefante: "the greenest building is the one that is already built." These buildings have an existing embodied energy and have already become carbon neutral through time. Investing in their on-going use and increasing their seismic resiliency to avoid their wholesale loss in a seimic event, is worthwhile from an environmental perspective as well as a financial one. Considering the cost of complete replacement, preventative investment through seismic upgrading is money well spent.

There is a surprising lack of BC published materials outlining how best to approach the mitigation of this risk with regards to heritage buildings, instead focusing primarily on this issue for new construction (Province of British Columbia 2018). Additionally, the bulk of materials available on this topic, are of a more technical nature largely intended for academics and professionals, such as engineers (Institute for Research in Construction 1995). To a non-professional, this content can be somewhat overwhelming and inaccessible.

This report aims to distill the available information into a more accessible form to help increase awareness of the need for and the options available to seismically rehabilitate heritage buildings. The following key questions are answered: 1) How is seismic upgrading approached in British Columbia, currently? 2) How is this issue addressed in other jurisdictions both in terms of techniques and financing? and 3) What conclusions can be made from the above with regards to recommending some practical improvements to BC's approach for seismically upgrading heritage buildings?

Through a comparative anaylsis of the United States and New Zealand, the hope is to provide an accessible entry point to better understanding the seismic risk being faced in British Columbia and to illustrate some of the broad solutions available (similar to materials available from other jurisdictions, such as Aguilar 2016; Horowhenua District Council 2016; Restore Oregon 2012, among others). Ultimately, this is to hopefully help save lives and livelihoods by helping to reduce all forms of loss (loss of life, loss of revenue, loss of fabric, etc.).

The target audience of this report is the general public rather than engineers or other professional individuals. And, please note that the terms seismic rehabilitation, seismic retrofiting and seismic upgrading are used interchangeably in this document.

SEISMICITY IN BRITISH COLUMBIA

SEISMIC HISTORY IN BC

As already stated, the province of British Columbia is the most seismically at-risk province in Canada. It is not a matter of if a large-scale earthquake will strike the province, but a matter of when. Southwestern BC is prone to seismic activity because of its location over the Cascadia Subduction Zone, which covers the boundary between the oceanic Juan de Fuca Plate and the continental North American Plate. This region has the potential for shallow crustal earthquakes, deep intra-slab earthquakes as well as a subduction megathrust earthquake (Fig. 2.1) (Natural Resources Canada 2011).

BC has, for the most part, been spared a large-scale seismic event in most of the current population's living memory (Lamontagne et al. 2008) (Fig. 2.2). The largest, most recent earthquakes for BC were in the 1940s (Figs. 2.3 to 2.8). In 1946, there was a magnitude 7.3 earthquake at 10:15 am on Sunday, June 23 and in 1949, there was a magnitude 8.1 earthquake on Monday, August 22. On March 28, 1964, there was a magnitude 9.2 earthquake in Alaska, which was felt on Vancouver Island and resulted in a tsunami that caused considerable damage to the island's west coast communities.

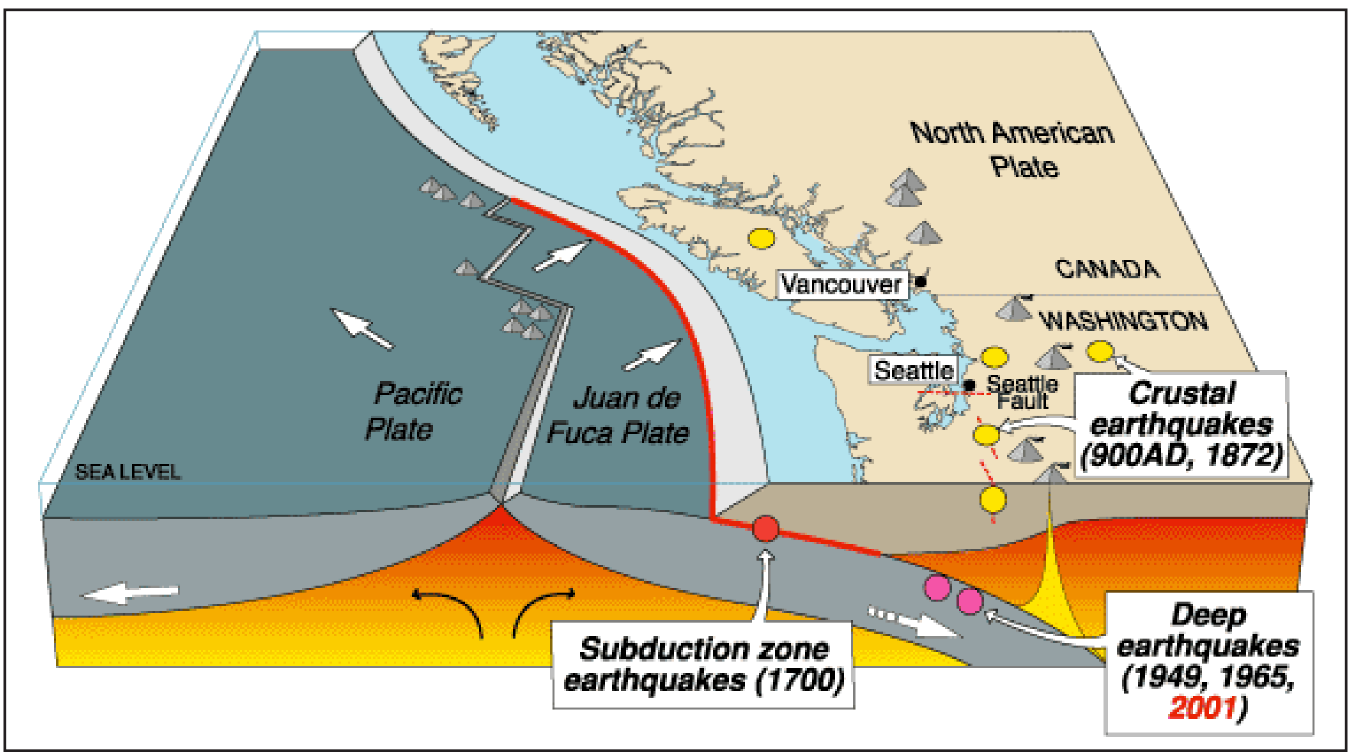


Fig. 2.1: Cascadia earthquake sources affecting British Columbia and the northwest coast of the USA. (Source: United States Geological Survey)

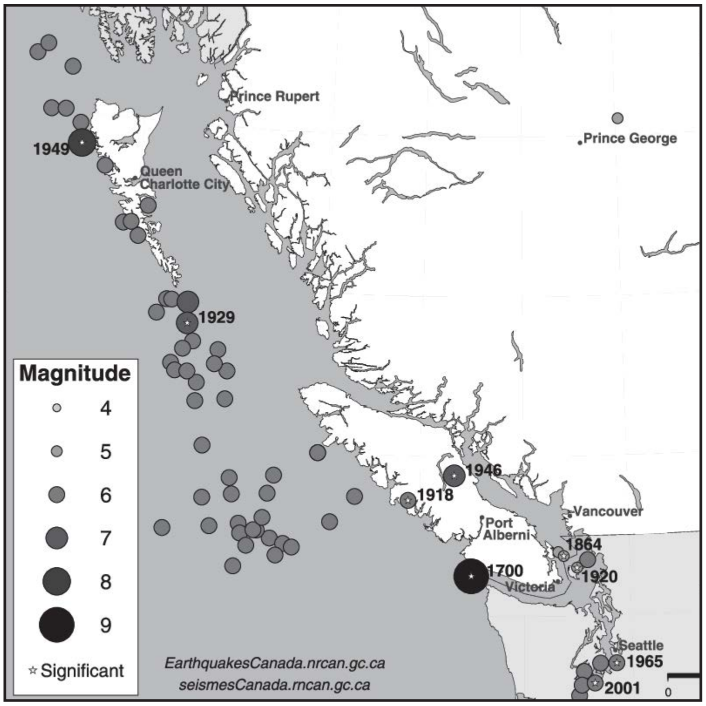


Fig. 2.2: Significant earthquakes in or near southwestern British Columbia, 1850-2006, with dates of earthquakes with some impact, including the last Magnitude 9 Cascadia earthquake in 1700. (Source: Natural Resources Canada)

Beyond living memory, the largest earthquake to impact the region was a magnitude 9 Cascadia megathrust earthquake that took place in 1700. It is generally accepted by seismologists that "in the Cascadia subduction zone 13 megathrust events have been identified in the last 6,000 years, an average one every 500 to 600 years. However, they have not happened regularly. Some have been as close together as 200 years and some have been as far apart as 800 years. The last one was [over] 300 years ago" (Natural Resources Canada 2021). This suggests that a megathrust earthquake could happen at any time now in this region and with each passing year it becomes more likely (Moorcraft 2021).

June 23, 1946
The epicentre was in the Forbidden Plateau area of central Vancouver Island, just to the west of the communities of Courtenay and Campbell River. This earthquake caused considerable damage on Vancouver Island, and was felt as far away as Portland Oregon, and Prince Rupert B.C. The earthquake knocked down 75% of the chimneys in the closest communities, Cumberland, Union Bay, and Courtenay and did considerable damage in Comox, Port Alberni, and Powell River (on the eastern side of Georgia Strait). A number of chimneys were shaken down in Victoria and people in Victoria and Vancouver were frightened - many running into the streets. Two deaths resulted from this earthquake, one due to drowning when a small boat capsized in an earthquake-generated wave, and the other from a heart attack in Seattle.

August 22, 1949
Canada's largest earthquake (magnitude 8.1) since 1700, occurred on August 22, 1949 off the coast of BC. It occurred on the Queen Charlotte Fault (Canada's equivalent of the San Andreas Fault) - the boundary between the Pacific and North American plates that runs underwater along the west coast of the Queen Charlotte Islands [Haidi Gwaii] off the west coast of British Columbia. The shaking was so severe on the Queen Charlotte Islands that cows were knocked off their feet, and a geologist with the Geological Survey of Canada working on the north end of Graham Island could not stand up. Chimneys toppled, and an oil tank at Cumshewa Inlet collapsed. In Terrace, on the adjacent mainland, cars were bounced around, and standing on the street was described as "like being on the heaving deck of a ship at sea". In Prince Rupert, windows were shattered and buildings swayed.

January 26, 1700
At 9PM on January 26, 1700 one of the world's largest earthquakes occurred along the west coast of North America. The undersea Cascadia thrust fault ruptured along a 1000 km length, from mid Vancouver Island to northern California in a great earthquake, producing tremendous shaking and a huge tsunami that swept across the Pacific. The earthquake shaking collapsed houses of the Cowichan people on Vancouver Island and caused numerous landslides. The shaking was so violent that people could not stand and so prolonged that it made them sick. On the west coast of Vancouver Island, the tsunami completely destroyed the winter village of the Pachena Bay people with no survivors. These events are recorded in the oral traditions of the First Nations people on Vancouver Island. The tsunami swept across the Pacific also causing destruction along the Pacific coast of Japan. It is the accurate descriptions of the tsunami and the accurate time keeping by the Japanese that allows us to confidently know the size and exact time of this great earthquake.

(Natural Resources Canada, 2006)

Fig. 2.3: Courtenay Post Office earthquake damage, 1946. (Source: Vancouver Public Library, 41749)

Fig. 2.4: Courtenay Post Office earthquake damage, 1946. (Source: Vancouver Public Library, 68768A)

Fig. 2.5: Courtenay School earthquake damage, exterior, 1946. (Source: Courtenay & District Museum (CDM))

Fig. 2.6: Courtenay School earthquake damage, interior, 1946. (Source: Vancouver Public Library, 41750B)

In addition to these larger events, there have been numerous smaller scale earthquakes each year throughout British Columbia (Natural Resources Canada 2022). Fortunately, these have been, for the most part, largely minor with minimal impact and damage. It has been fairly fortuitous that most of the seismic activity in the province, including those larger events in the 1940s, were in more rural locations on days and at times that minimized the amount of damage and loss.

Fig. 2.7: Port Alberni Chimney Damage, 1946, over 70 km away from the earthquake's epicenter. (Source: CDM)

As is evident from the descriptions and photographs of the 1940s earthquakes, features of heritage buildings are at great risk of collapsing in a seismic event (Figs. 2.3 to 2.8). Chimneys, parapets and certain building construction types, such as unreinforced masonry (URM) buildings, are particularly vulnerable in an earthquake (Sommer et al. 2019; Paxton et al. 2015; Paxton et al. 2013; and Ingham et al. 2012). "Elsewhere in the world, seismic risk mitigation efforts have been implemented as part of political and emotional responses to earthquake losses" (Paxton et al. 2015, p. 1). However, for British Columbia, as a result of this period of relative seismic calm, there appears to be a lack of awareness (or acknowledgement) of the substantial risk being faced here and some of the mitigation efforts that could be better employed to help minimise the potentially catastrophic impact of the eventual big one, particularly with regards to heritage buildings, as discussed in greater detail in the following sections.

Fig. 2.8: Port Alberni Bank of Montreal earthquake damage, 1946. (Source: CDM)

SEISMIC RISK

All buildings (whether a heritage one or not) are at-risk when an earthquake strikes. They need to be able to withstand the ground shaking caused by an earthquake. Seismic waves cause horizontal and vertical ground movement, which are transferred to a building through its foundation, shaking the structure, objects and people within it. An additional concern with heritage buildings is that many were built when the BC Building Code was either non-existent or not as stringent as it is today. There is therefore a need to upgrade heritage buildings to withstand seismic shaking to minimise damage and save lives (Figs. 2.9 to 2.12).

As outlined in *Peace of Mind in Earthquake Country: How to Save Your Home, Business, and Life*:

> During an earthquake, the ground waves cause lateral (horizontal) and vertical ground movements, or vibrations, which are transferred to a building through its foundation. The vertical earthquake movements cause the columns and walls of the building to contract and compress. This movement is usually not damaging, since buildings are, by their nature, designed to withstand large vertical loads. The lateral earthquake waves, however, are much more destructive because they are often the stronger waves, and horizontal strength is not the structure's prime purpose.
>
> The movement emerges from the ground and travels through the foundation to the rest of the structure. The structure will naturally resist this movement, resulting in forces and deformations generated within the structures. The points of connectivity within the structure need to be specially designed to be able to withstand these forces and deformation demands.
>
> The earthquake waves inevitably focus on any weak connections or structural members, and once these begin to fail, the behavior of the building changes drastically. It is subjected to a chaotic mixture of new stresses and loads for which it is not designed, and the damage compounds until the building fails.
>
> (Yanev and Thompson 2008, p. 77)

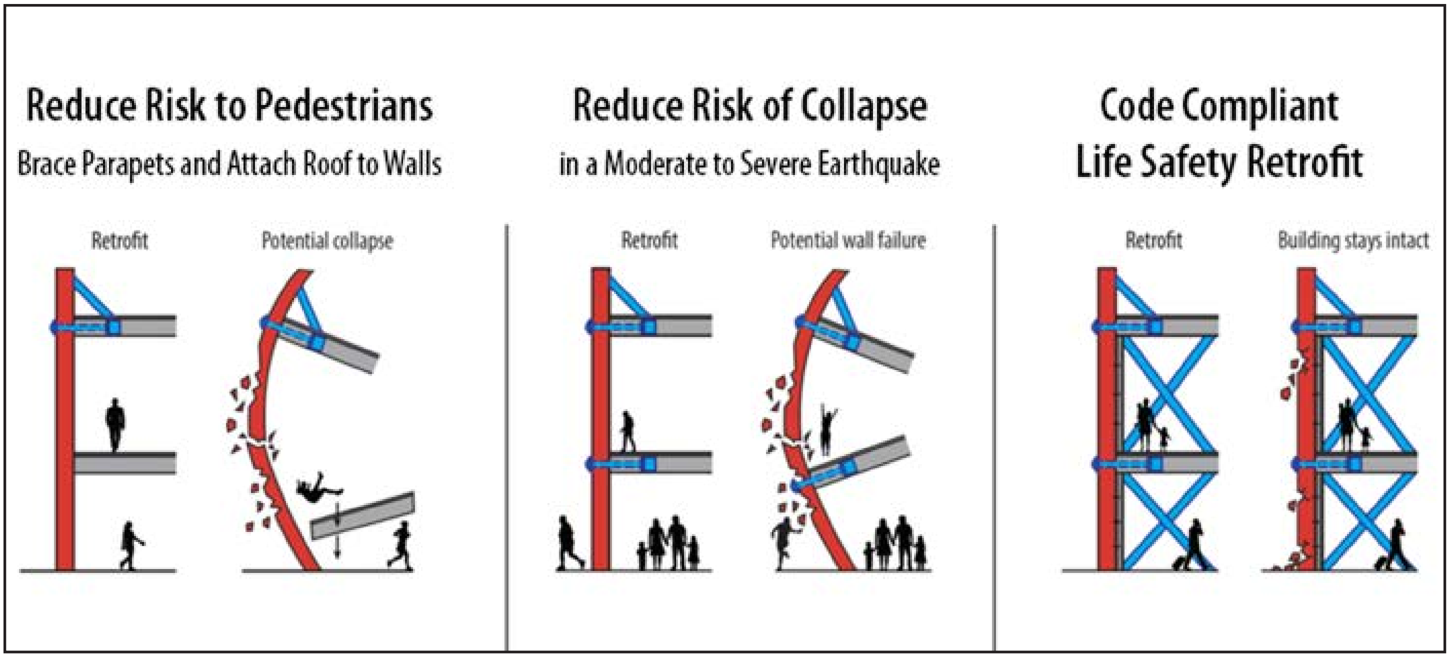


Fig. 2.9: Illustration of the risks posed by existing buildings, particularly unreinforced masonry (URM) buildings. (Source: Portland Government)

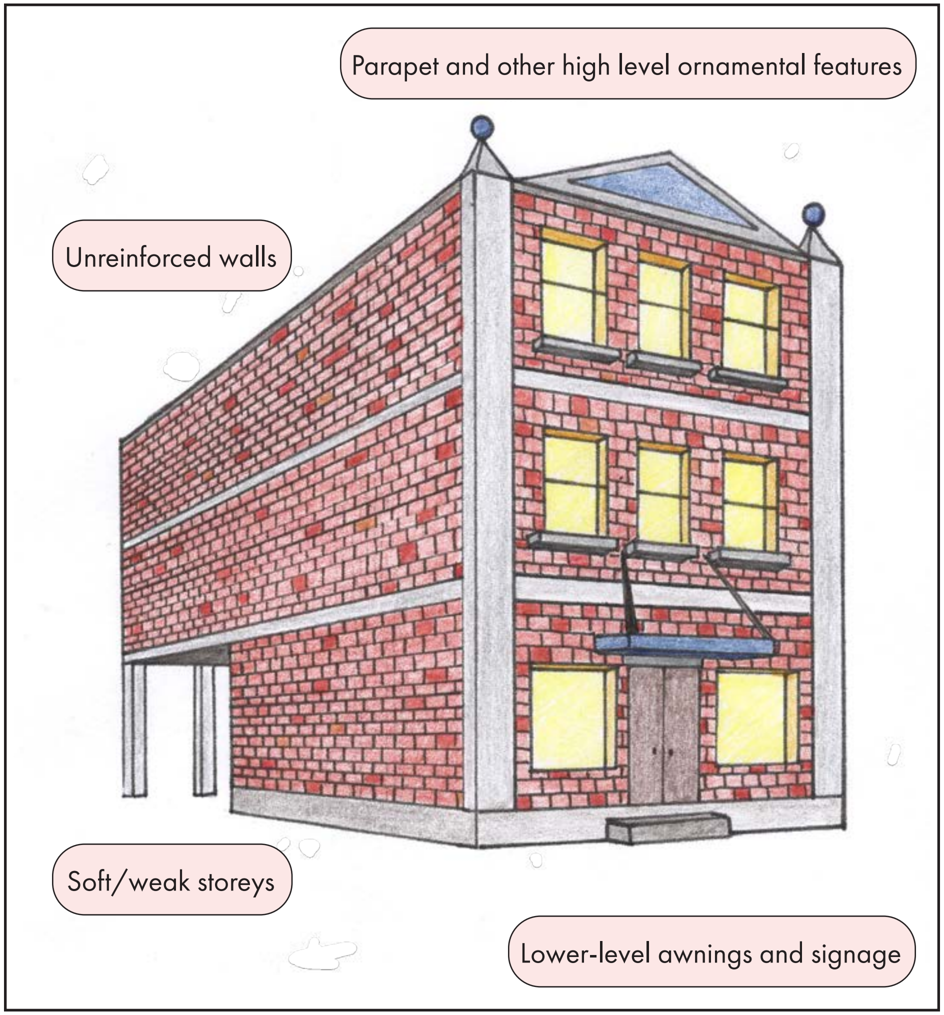


Fig. 2.10: Illustration of a heritage building with some of its potential vulnerabilities pinpointed. (Source: Ian Babbitt)

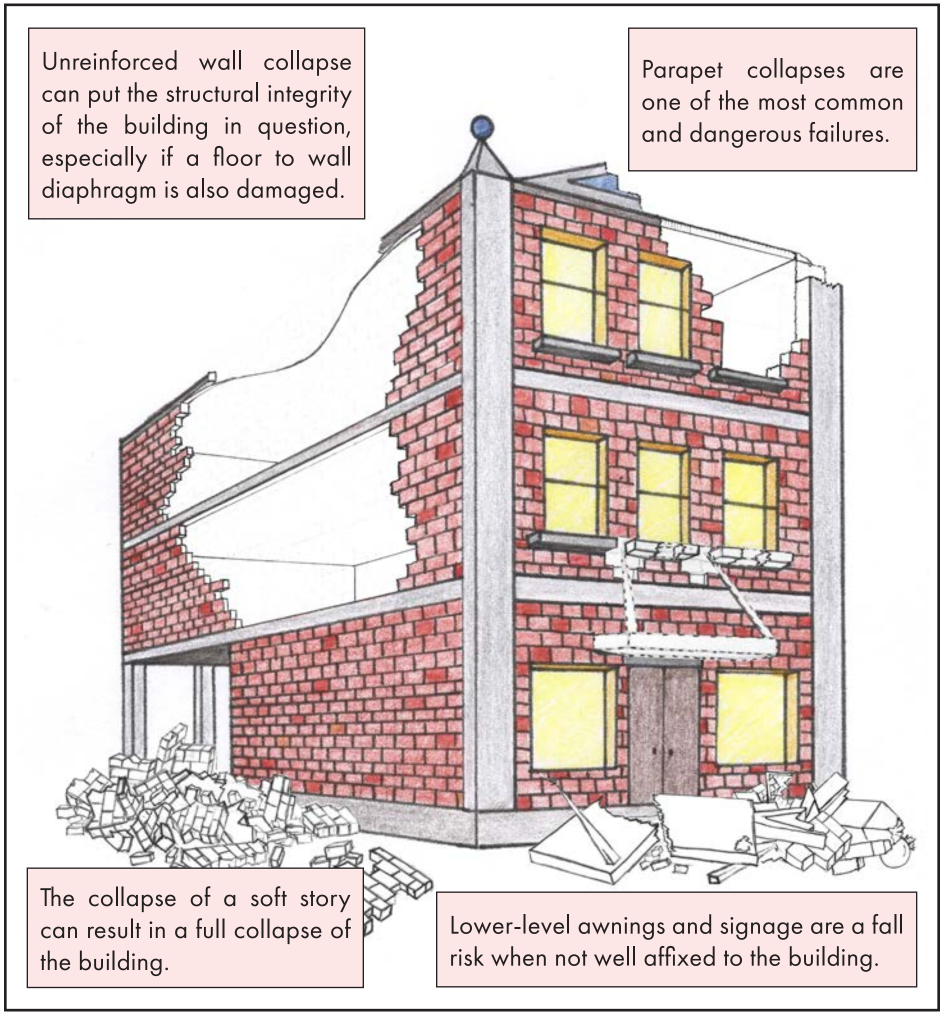


Fig. 2.11: Illustration of some of the common failure and damage potentially experienced by existing buildings during a seismic event, particularly heritage buildings. (Source: Ian Babbitt)

Fig. 2.12: Example earthquake damage, showing a partially collapsed Masonic Temple from the 1933 Longbeach earthquake in California. (Source: The LA Times Archive)

As is visible from the above, one of the biggest concerns with heritage buildings in an earthquake, is elements falling off the building. If not braced, as the building shakes in a seismic event, elements (often character-defining elements of a heritage building) become dislodged, particularly depending on the duration and force of the shaking. This often occurs with features at the roofline, whether parapets, gables and/or chimneys, or with other elements along the facades (such as cornices, windowsills, signage and/or awnings) and of course can include wall failures as well.

In all such instances, there is a life-safety threat in that these elements could collapse on pedestrians below, could block roads and sidewalks (impacting rescue efforts) and even obstruct building egress points, preventing those inside a building from getting out, potentially trapping them inside. It is with these threats in mind that it is so important to seismically upgrade heritage buildings to both save lives and livelihoods, as discussed in the following section.

SEISMIC REHABILITATION OVERVIEW

Each level of government has a role in regulating building. In Canada, the federal Constitution Act gives the provincial and territorial governments responsibility for regulating building and construction.

In British Columbia, the Building Act gives the Province the authority to set the BC Building Code and other provincial building regulations. Setting regulations at a provincial level helps foster more consistent requirements throughout BC.

The Province gives local governments the ability to administer and enforce provincial building requirements, including the BC Building Code. Local governments also have powers of their own that govern related matters such as land use, property development or heritage conservation.

In a nutshell, the Constitution Act gives the Province responsibility to regulate building and construction, and the Province gives local governments limited authority to administer and enforce the BC Building Code.

(Office of Housing and Construction Standards 2015)

As outlined above, throughout Canada there are different requirements regulating buildings at the federal level, the provincial level and at the municipal level. "The BC Building Code is a provincial regulation on how new construction, building alterations, repairs and demolitions are done. This code sets minimum requirements for safety, health, accessibility, fire and structural protection of buildings and energy and water efficiency" (Province of British Columbia 2021). While British Columbia has a robust Building Code with specific seismic safety requirements for new construction, the situation and requirements are different for existing buildings, which includes heritage buildings. In the current system, the BC Building code applies to buildings:

> *That are constructed (new buildings);*
> *That are altered or renovated;*
> *Where the use or occupancy changes;*
> *Where components or parts are replaced.*

In addition to this and, significantly, the building code states that "if there has not been any changes to an existing building, it should meet the requirements of the BC Building Code that was in place when the building was constructed. For example, if a building was constructed when the BC Building Code 2012 was in effect, it doesn't need to be upgraded to meet the requirements of the BC Building Code 2018" (Province of British Columbia 2021).

Considering that the National Building code of Canada was not introduced until 1941 and that the BC Building Code was not introduced until 1973, one can immediately appreciate the danger posed by many heritage buildings in that they were not built to any modern Building Code. Thus, in the current system, it is only with a change of use or occupancy that will trigger any additional seismic requirements with regards to heritage buildings. This is despite the fact that many such buildings were built using materials and techniques that did not account for seismic vulnerability.

This is particularly worrisome for the numerous unreinforced masonry (URM) buildings (buildings that do not contain any internal reinforcement) distributed throughout the province. These buildings are widely acknowledged to be among the most vulnerable type of building in an earthquake (Paxton et al. 2015; Structural Engineers Association of BC 2013; Paxton et al. 2013; Ingham et al. 2012; Yanev and Thomson 2008; Rutherford and Chekene 1997; Lizundia, Dong and Holmes 1993; Bruneau 1990; Deppe 1988; among many others):

> Unreinforced masonry (URM) buildings (including houses) have long been recognized as some of the most hazardous smaller structures in earthquake country. The major flaw of these structures is that they are brittle and cannot deform without being damaged by the lateral thrusts of an earthquake. Their brick is heavy and inflexible, so lateral motions create an overwhelming inertial load that cracks the usually weak mortar connections (the glue that holds individual bricks together) and causes the bricks to separate. Once this cracking occurs, the entire building can collapse progressively.
>
> (Yanev and Thompson 2008, p. 104)

Figs. 3.1a & b: Example late 19th and early 20th century brick buildings in British Columbia. The bottom building has had some retrofit work done, as visible in the store window with the black diagonal bracing. (Sources: Katie Cummer)

PERFORMANCE OBJECTIVES

There are innumerable options with regards to seismic upgrading, particularly if there is no budgetary limit to the work. Unfortunately, that is rarely the case (if ever) and so there are varying degrees of seismic rehabilitation options, dictated by the available budget and dependent upon the desired outcome and performance level of said work. Unfortunately, being reliant on and constrained by the available funds (which for many owners in the current system means paying for these things entirely out of pocket themselves), can mean that the bare minimum is done with regards to seismic upgrading.

Often, the general public is unaware of the differing "building performance levels" that seismic rehabilitation can be done to (Fig. 3.2) and that often what is being proposed for seismic upgrading is simply to the bare minimum (typically levels 3. or 4.) (Onur 2022; Paxton 2022). The performance of a building in relation to a seismic event falls into four broad categories that rank from higher performance (lower risk) to lower performance (more risk). These four categories are: 1. Operational, 2. Immediate Occupancy, 3. Life Safety and 4. Collapse Prevention. With many buildings only rehabilitated to Life Safety or Collapse Prevention, serious risks are still present for individuals in and around these buildings during a seismic event, even though they have been upgraded to a certain degree.

1. **Operational**. *Backup utility services maintain function; the building sustains very little damage.*

2. **Immediate Occupancy**. *The building remains safe to occupy. Damage and expected repairs are minor.*

3. **Life Safety**. *The building remains stable and has substantial structural reserve capacity; hazardous non-structural damage is controlled.*

4. **Collapse Prevention**. *This addresses the most serious life-safety concerns by correcting those deficiencies that could lead to serious human injury or total building collapse. The building remains standing in order for occupants to exit the building; any other damage or loss is acceptable.*

(Aguilar 2016, p. 9)

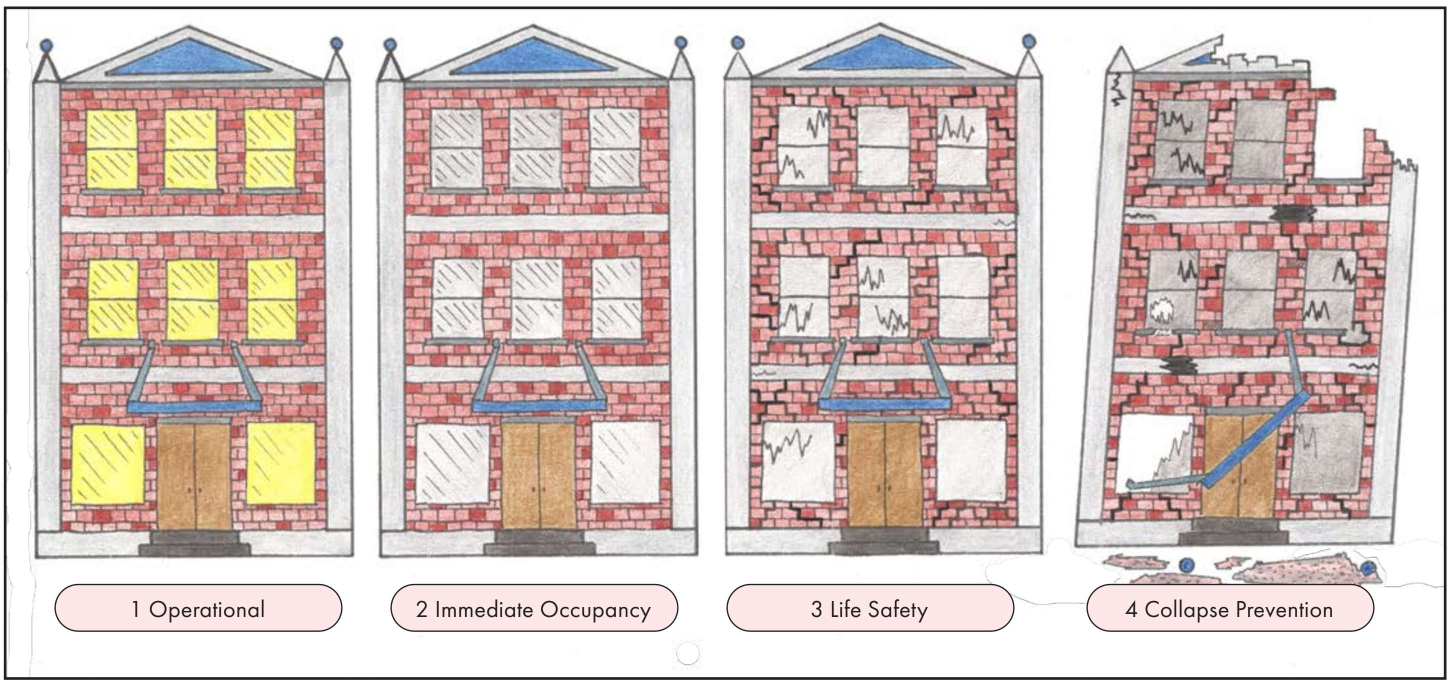


Fig. 3.2: Illustration of the different building performance levels that heritage buildings can be seismically upgraded to. (Source: Ian Babbitt, based on the American Society of Civil Engineers performance level illustration from ASCE 41)

UPGRADING OPTIONS

There is no one-size-fits-all solution with regards seismic upgrading heritage buildings (Fig. 3.3). Each building should be assessed for their specific vulnerabilities and a seismic rehabilitation plan designed with those deficiencies (and, ideally, with the building's Character-Defining Elements (CDEs) as well) in mind. For many experts, if the budget is limited there is one key area that can (and should) be addressed first and foremost:

1) Secure fall hazards

a. If funding is limited, bracing the parapet (and chimney, if present) is one of the most important things to do. It is the highest piece of mass, the tallest part of the building and is typically the first thing to fall off.

b. If possible, this should include securing all elements that could potentially fall off, such as awnings, cornices, hanging signage, ornamental features, etc.

Following this, there are varying degrees of rehabilitation work that can be done, typically budget dependent:

2) Partial rehabilitation

a. Reinforce walls to improve the overall behaviour of the building and reduce the potential for collapse, particularly addressing the connections between walls and wood diaphragms (can be done using various types of anchors, including wall diaphragm anchorages around the perimeter, tension anchors and shear anchors, among others).

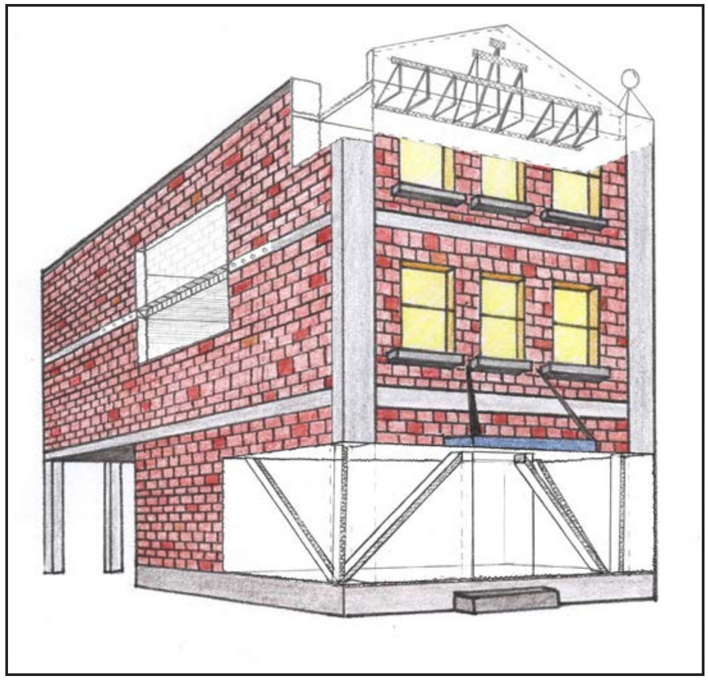
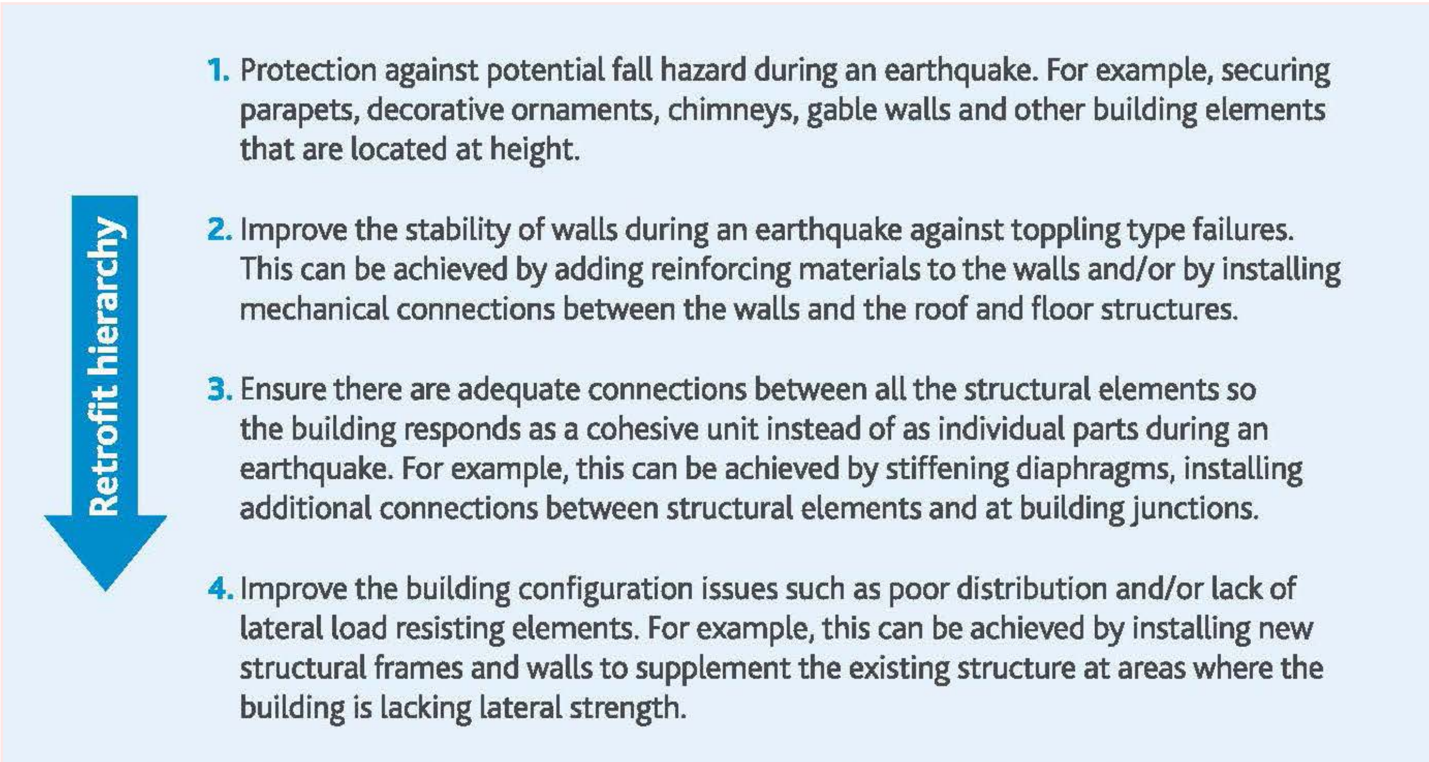


Fig. 3.3: Illustration of some of the different seismic upgrading options available. (Source: Ian Babbitt)

3) Comprehensive rehabilitation

a. Install new framing to more fully stabilize the building in a seismic event (including strong-backs for out-of-plane wall support and/or supplementary in-plane bracing). The intent being to encourage the building to respond as a cohesive unit.

b. Although not commonly practiced in Canada, yet, another more comprehensive rehabilitation option is base isolation. This technique uses ball bearings, springs and padded cylinders (Fig. 3.5), to isolate structures so that they do not sit directly on the ground and are therefore not subjected to the shocks of an earthquake. This technique is more commonly used in Japan and for some civic structures in the United States (Procter 2018).



1. Protection against potential fall hazard during an earthquake. For example, securing parapets, decorative ornaments, chimneys, gable walls and other building elements that are located at height.
2. Improve the stability of walls during an earthquake against toppling type failures. This can be achieved by adding reinforcing materials to the walls and/or by installing mechanical connections between the walls and the roof and floor structures.
3. Ensure there are adequate connections between all the structural elements so the building responds as a cohesive unit instead of as individual parts during an earthquake. For example, this can be achieved by stiffening diaphragms, installing additional connections between structural elements and at building junctions.
4. Improve the building configuration issues such as poor distribution and/or lack of lateral load resisting elements. For example, this can be achieved by installing new structural frames and walls to supplement the existing structure at areas where the building is lacking lateral strength.

Fig. 3.4: Another example hierarchy of seismic retrofitting work, as outlined by a muncipality in New Zealand. (Source: Auckland Council 2017, p. 26)

CONCLUDING REMARKS

While this is a very broad and simple overview of seismic rehabilitation, it is hoped that it at least highlights some of the areas of concern, with some insight on the upgrading options available to address the potential vulnerabilities in existing buildings. The following section provides a case study from British Columbia to illustrate some of the tools and incentives currently available to encourage the seismic upgrading of existing buildings; especially heritage buildings, which are particularly vulnerable having often been built prior to any building code.

Fig. 3.5: An example of base isolation under the Utah State Capitol Building. (Source: Mike Renlund)

BRITISH COLUMBIA CASE STUDY

Throughout British Columbia, numerous heritage buildings have been seismically upgraded, but, unfortunately, many more have not. Without any mandatory upgrade requirements, most upgrading done in the province is either on a voluntary basis or triggered by a change of use. As a point of reference for the international comparative analysis below, this section will use the City of Victoria as a case study to reveal the incentives currently available for such work and some of the rehabilitation efforts to date. Victoria is an appropriate focus since it is the jurisdiction in the province that currently has the most support available to encourage seismic rehabilitation.

Fig. 4.1: A map showing the heritage buildings in the downtown core of Victoria, the area known as "Old Town," 2022. Brown denotes a heritage-designated building and yellow denotes a heritage-registered building. (Source: VicMap)

CITY OF VICTORIA HISTORY AND HERITAGE

Situated on the land of the traditional territory of the Coast Salish and Lekwungen speaking people, specifically the Songhees and Esquimalt First Nations, the colonial history of the City of Victoria dates back to 1843, with the establishment of Fort Victoria by the Hudson's Bay Company as a trading post and fort (City of Victoria). Today, it is the Capital City of British Columbia and is one of the oldest cities in Western Canada, having been incorporated in 1862. The City of Victoria developed and grew through the 19th and early 20th centuries, using various materials and techniques to build numerous buildings, many of which are today either registered or designated heritage buildings (Fig. 4.1). There are 598 Heritage-Designated properties and 357 Registered properties in the city (City of Victoria 2022), with many of them located in the historic core area known as "Old Town" (Fig. 4.2). Many of these buildings are the aforementioned seismically at-risk unreinforced masonry (URM) types of construction.

Fig. 4.2: A compilation of fire insurance plan sheets from 1903, showing the various downtown buildings at that time, illustrating their material of construction. Blue denotes stone, red denotes brick and yellow denotes wood. Note the abundant use of brick for this area, many of which still stand today as heritage-registered or heritage-designated buildings. (Source: UVic Vault)

HERITAGE CONSERVATION AND SEISMIC REHABILITATION INCENTIVES

The City of Victoria has a long history with regards to its heritage conservation efforts. In the 1970s, the City of Victoria began its heritage programme, focusing on the conservation and management of the city's heritage assets. In 1983, the Victoria Heritage Foundation was established "to administer grants for owners of Designated Heritage houses" (Victoria Heritage Foundation 2021). Since then, VHF has been providing funds annually to support the rehabilitation and maintenance of these properties. "VHF aims to fund up to 50% of the project cost. Grant funds for any one house over a ten-year period will normally be limited to $30,000 of VHF monies. There is additional 10-year funding available for seismic work" (VHF 2022).

In 1989, the Victoria Civic Heritage Trust (VCHT) was established "to deliver a program of financial assistance to the owners of protected heritage buildings in the downtown core" (Paxton et al. 2013, p. 3). Beginning in 1990, the VCHT has helped the City of Victoria administer its Building Incentive Program (BIP), which "provides financial assistance to owners of commercial or institutional heritage designated buildings to assist with façade restoration, structural improvements, upgrading required by building codes, and other rehabilitation costs. Grants may cover up to 50% of the cost of eligible heritage work, up to a maximum of $50,000 per project" (City of Victoria n.d.). In July 2019, the grant maximum was increased (for the first time since 1990) to $100,000 per project, to account for the increased cost of construction (Crescenzi 2020) and the fact that "$50,000 in 1990 is equivalent to approximately $100,000 in 2019" (VCHT 2020 p. 1). Although not solely related to seismic rehabilitation, "seismic upgrading work is an eligible cost when allocating [these BIP] grants" (Paxton 2015, p. 64).

In 1998, taking advantage of a new planning tool introduced as part of the overhaul of the Local Government Act, the City of Victoria became the first municipality to introduce a program which allowed the City "to exempt heritage properties from municipal taxes for up to 10 years ... A program designed to stimulate the conversion of vacant or underutilized upper storeys in downtown heritage buildings to residential use" (Barber 2003, p. 20). This is known as the Tax Incentive Program (TIP) and as a result of it at least "34 buildings have received comprehensive seismic upgrading. These include former warehouses, industrial buildings, hotels, a department store, a church, and a hospital (Paxton et al. 2013, p. 4). The often prohibitively expensive cost of seismic upgrading was a direct reason behind the introduction of TIP:

> Seismic upgrading standards were the chief culprit with respect to the rapidly increasing costs of upgrading buildings to modern building code standards. The cost of making the building resistant to earthquake forces ranged from 21 to 35 percent of all renovation costs, and conversions were simply no longer economically viable. Thus, the tax incentive program was born.
>
> (Barber 2003, p. 21)

Fig. 4.3: A Tax Incentive Program (TIP) example project in Victoria, BC that was seismically upgraded when being converted into residential units above the ground floor commercial MEC store, in exchange for a 10-year tax exemption. (Source: Katie Cummer)

More recently, in 2015, the VCHT introduced the Seismic Parapet Incentive Program (PIP), the first of its kind in Canada. This program is "to assist owners with voluntary seismic upgrading of parapets, building fronts, and seismic falling hazards on their protected downtown heritage buildings" (VCHT 2020, pp. 1 to 2). PIP is offered as a sub-category of the Building Incentive Program, using the funding allocation from the City of Victoria, and similarly covers 50% of the costs up to the revised $100,000 amount. There is also funding through the BIP-Design Assistance Grants up to a maximum amount of $3,000 and PIP-Design Assistance Grants up to a maximum amount of $4,500 (VCHT 2020).

Although it was hoped to provide a more substantial list of seismically rehabilitated buildings in Victoria, the desired data was not publicly available. This is perhaps an area for further research, as it would be useful to have a better sense of the full picture of buildings that have had seismic upgrading work done on them. In particular, what specific work has been done and to which buildings (perhaps in the form of an interactive map), to hopefully further encourage other owners to follow suit. In the meantime, however, this section highlights a few example projects that illustrate some of the use and results of the seismic rehabilitation incentives available in Victoria.

HOUSE GRANT EXAMPLES

It is interesting to note that of the showcased Victoria Heritage Foundation House Grant Projects, none of those listed were used for seismic rehabilitation (Victoria Heritage Foundation 2018). From their most recent Annual Reports (Victoria Heritage Foundation 2021), only a handful of awardees in the last seven years did any seismic upgrading work:

- In 2020, one of the 24 allocations was for seismic related work;

- In 2019, again one of the 24 grants;

- In 2018, none of the 31 grants awarded appear to address seismic rehabilitation;

- In 2017, two of the 25 grants explicitly addressed seismic upgrading;

- In 2016, one of the 36 grants was for seismic rehabilitation; and

- In 2015, none of the 39 grants were used for any seismic rehabilitation work.

Considering the risk to the region, it is surprising that of the most recent awardees, a mere 2.7% used the funding available for seismic rehabilitation.

Fig. 4.4: 1270 Balmoral Rd. seismic upgrading work, partially financed by the House Grant program (Source: Victoria Heritage Foundation, 2020).

Fig. 4.5: 1260 Denman St. chimney rebuild to address its seismic vulnerability, partially financed by the House Grant program. (Source: Victoria Heritage Foundation, 2020).

BUILDING INCENTIVE PROGRAM EXAMPLES

The following list compiles some example BIP projects outlined in a conference paper looking at "Addressing URM Seismic Risk in Victoria, Canada" by Brandon Paxton, Steve Barber, Catherine Umland and Ken Elwood (2013, pp. 4 to 6), which was compiled using internal VCHT documents:

- A former grocery warehouse from 1896, the Leiser building, located at 524 Yates Street was converted along with its neighbouring property from 1900, the Earle Warehouse, into residential apartments. Completed in 2007, the cost of the project was $10.9 million and $1.2 million was spent on seismic upgrading the two structures, including using three large steel frames within the courtyard between the two buildings to provide lateral bracing.

- The Chinese Empire Reform Association Building from 1905, located at 1715 Government Street, had steel strong backs installed to brace the side brick walls; a steel frame inserted behind its façade; and replaced its roof and attic structure to facilitate seismic upgrading. It received a President's Award in 2012 from the Hallmark Heritage Society.

- In 1993, the Board of Trade building from 1892 received $50,000 to seismically brace its front brick and stone façade.

- In 2008, a commercial brick building from 1860, located at 536 Yates Street, received financial assistance to add steel bracing and seismic anchors to brace its parapet after its reconstruction.

Fig. 4.6: Illustration of the bracing installed between the Leiser Building and the Earle Warehouse as part of its seismic rehabilitation work on Yates Street in Victoria, BC. (Source: Katie Cummer)

- In 2010, the Green block from 1889, located at 1210 Broad Street, received $50,000 to assist with a roof replacement during which a reinforced concrete parapet was introduced at the top of the unreinforced brick wall to provide a partial upgrade to the building.

- In 2011, the Galpin Block from 1884, located at 1017 Government Street introduced diagonal steel bracing to reinforce the open storefront.

As for more recent data, according to a 2019 VCHT Letter to Mayor and Council, some of their accomplishments included "$161,620,000 in private investment in 153 eligible heritage buildings through $6,540,295 in 299 Building Incentive Program awards through City Capital funding;

[and] average factor of $24.71 private investment for every $1 in BIP funds awarded" (VCHT 2019, p. 3). In 2019, they awarded five BIP grants and one BIP Design Assistance Grant (DAG), with four BIP extensions as well. For 2020, they predicted twenty BIP applications and at least two BIP-DAG applications. As for 2021, they predicted at least eighteen BIP applications. Unfortunately, no further information was available to confirm the actual number of BIP and BIP-DAG applications.

TAX INCENTIVE PROGRAM EXAMPLES

The following table is summarised from the City of Victoria's website showcasing some case study projects that have been assisted by the Tax Incentive Program (TIP). All received 10 years of tax exemption, unless otherwise stated.

Building Name and Address	No. of Residential Units Provided	Total Cost of Project	Seismic Upgrading Cost	Incentives Provided
St. Joseph's Hospital, 850 Humboldt St.	70	$1,631,000	$440,967	$44,993
BC Produce Building, 529 Pandora Ave.	2	$408,891	$176,968	$25,000
Dragon Alley, 532 1/2 Fisgard St.	12	$1,262,000	$344,000	$51,000
Biggerstaff Studios, 532 Herald St.	31	$1,851,360	$415,000	$50,000
Wilson Building, 536 Herald St.	24	$2,000,000	$370,000	$21,713
Cross's Meats, 1308 Douglas St.	8	$845,580	$283,560	$26,000
Royal Victoria Suites, 1411 Government St.	8	$1,518,725	$407,920	$26,000
CITI-TV, 1420 Broad St.	n/a	$6,000,000	$217,1520	$26,000
Kinemacolour Apts., 1600 Government St.	9	$2,000,000	$317,558	7yr tax exemption
The Monaco, 1401 Government St.	18	$3,400,000	$1,025,425	$50,000
The Vogue, 595 Pandor Ave.	46	$9,500,000	$1,400,000	$100,000
The Palladian, 1600 Quadra St.	29	$8,000,000	unavailable	unavailable
The St. Leiser Building, 530 Yates St.	30	$6,300,000	unavailable	unavailable
The Hotel Rialto, 1450 Douglas St.	n/a	$9,300,000	unavailable	$50,000

Fig. 4.7: An example parapet in downtown Victoria, BC. Such parapets, if unbraced, are at a high risk of collapse during a seismic event and would be eligible for the Seismic Parapet Incentive Program (PIP) funding. (Source: Ian Babbitt)

SEISMIC PARAPET INCENTIVE PROGRAM EXAMPLES

Unfortunately, there is (currently) not much publicly available information with regards to the newer Seismic Parapet Incentive Program (PIP). Rather surprisingly, it is not even listed on the City of Victoria's website as a possible grant available for heritage buildings (City of Victoria n.d.). That being said, as outlined in a Victoria Civic Heritage Trust Letter to Mayor and Council (2019, pp. 5 to 6), there appears to be some interest in this important and unique seismic upgrading program:

- In 2019, two PIPs were awarded and one PIP-Design Assistance Grant (DAG) allocated;

- In 2020, there were six projected PIP applications; and

- In 2021, three projected PIP applications.

Considering the important nature of the seismic upgrading work that this incentive programme promotes, it would be ideal to increase the awareness of the funding available and the importance of parapet bracing to further encourage more owners to do so; thereby reducing damage and potentially saving lives.

CONCLUDING REMARKS

Although it is encouraging to see so many incentives available in the City of Victoria that can go towards seismic rehabilitation, more could and should be done to better protect the city's historic environment as well as the numerous lives and livelihoods that live and depend on these buildings.

> Overall, the efforts to identify and mitigate URM seismic risk in Victoria appear to be lacking in comparison to other regions of the Pacific Northwest. While the incentives for heritage buildings have been successful in promoting re-development, and thus comprehensive seismic upgrading, a complete inventory of URM buildings in Victoria has not been performed and risk mitigation measures are not in place to effectively address occupied buildings, nor are there currently provisions for partial seismic upgrading of buildings to address the most pressing and easily corrected issues of parapet and facade seismic restraint.
>
> (Paxton 2015, p. 66)

In particular, the limited nature of the available funding is quite worrisome. The current financial incentives are, for the most part, only available to heritage-designated buildings and often only those in a specific location (such as the downtown core). There are only 598 heritage-designated buildings in Victoria and, unfortunately, earthquakes and their associated damage do not distinguish between protected buildings and those that are not (Babamzadeh et al. 2019; VC Structural Dynamics Ltd. 2016; and Paxton et al. 2013).

Experts have predicted that "when considering the maximum credible Cascadia event, the damage results predicted become very large: 6% of the building stock would reach complete damage with 60% reaching extensive damage. This means that approximately 65% of the entire building stock [city-wide] could be 'red-tagged' after this event" (Bebamzadeh 2019, p. 5). Red-tagged means the structure of a building is damaged and the property is considered too dangerous and unsafe to enter.

The cost to seismically upgrade buildings, particularly heritage buildings, is prohibitively expensive, but desperately needed in this region. As a result, many buildings that require seismic rehabilitation are not getting the upgrading they need, due to the expense and lack of widespread financial support to encourage such work. As is outlined in the following section, other jurisdictions use different financial, legislative and policy approaches to further encourage the seismic upgrading of their buildings, including heritage ones.

INTERNATIONAL CASE STUDIES

The province of British Columbia is not unique in its seismic risk. There are tectonic plates distributed throughout the world (Fig. 5.1), which can result in earthquake shaking and varying degrees of damage. Although every jurisdiction is unique and impacted by its own complex socioeconomic issues and political systems, inspiration can be garnered from examining how others approach this issue. It is interesting and worthwhile to examine the different (and similar) ways various countries and cities approach the mitigation of the risk that comes from being in such a seismically active zone.

This section provides a broad overview of how other jurisdictions approach seismic rehabilitation and, in particular, with regards to heritage buildings. It seemed appropriate to look to our neighbours to the south, in the United States, with their long history of seismic mitigation strategies and to provide an overview on how each West Coast State approaches the issue. New Zealand also seemed an appropriate comparator in that their colonial history and historic built environment is very similar to BC, with an examination of their more recent seismic experiences and the results to date from those events.

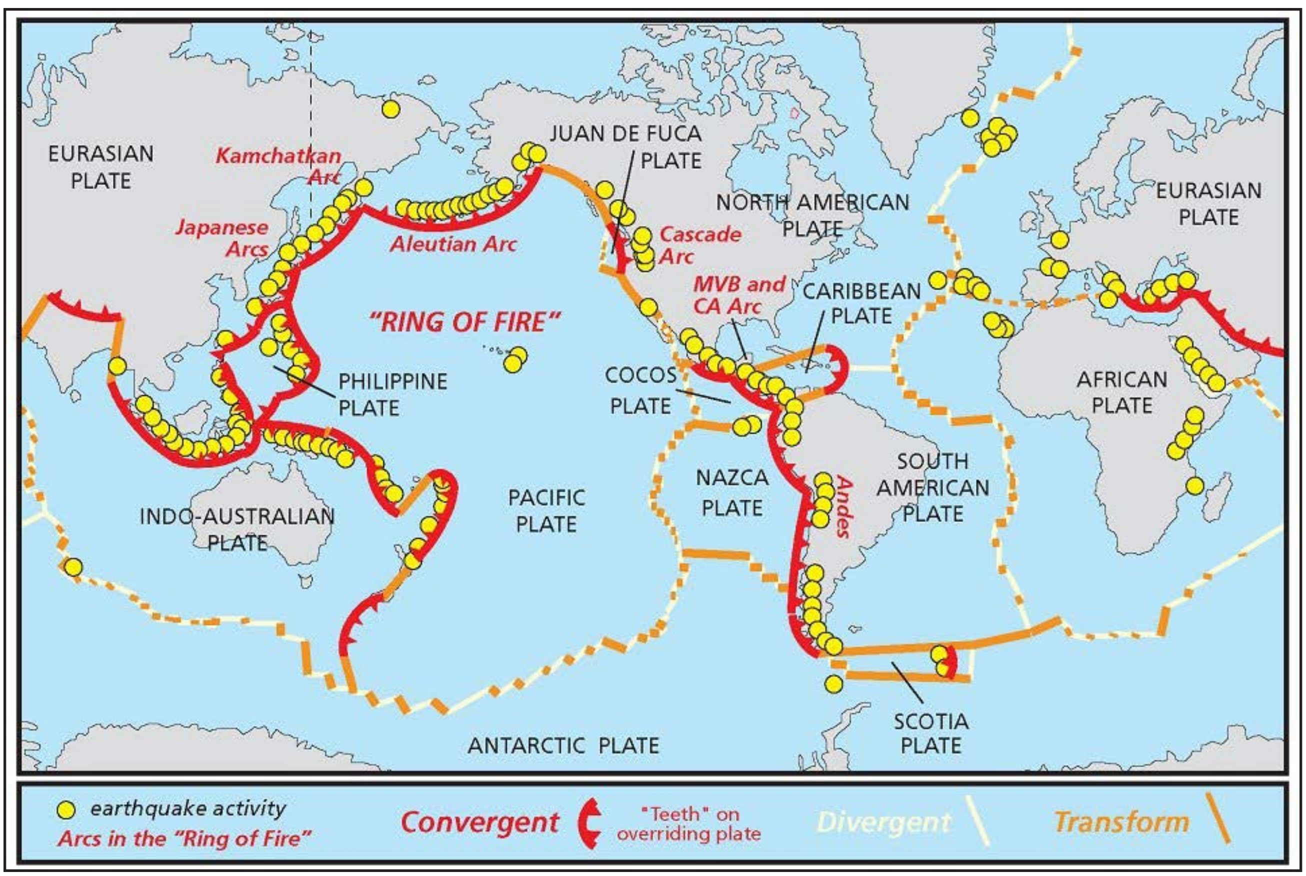


Fig. 5.1: Map showing the major tectonic plates of the world. (Source: National Park Services)

UNITED STATES OF AMERICA

Although it is worth examining how the US approaches seismic risk and rehabilitation, it is important to acknowledge how much bigger and wealthier the country is compared to Canada. With a population of 332 million (United States Census Bureau, 2022) and a 2019 GDP of $21.34 trillion (IMF), compared to Canada's 38 million people (Statistics Canada 2022) and $1.74 trillion GDP (IMF), it is not surprising that the United States has more funding available to address seismic rehabilitation. That being said, there is value in seeing how the issue is approached at the federal, state and municipal levels for possible inspiration in BC.

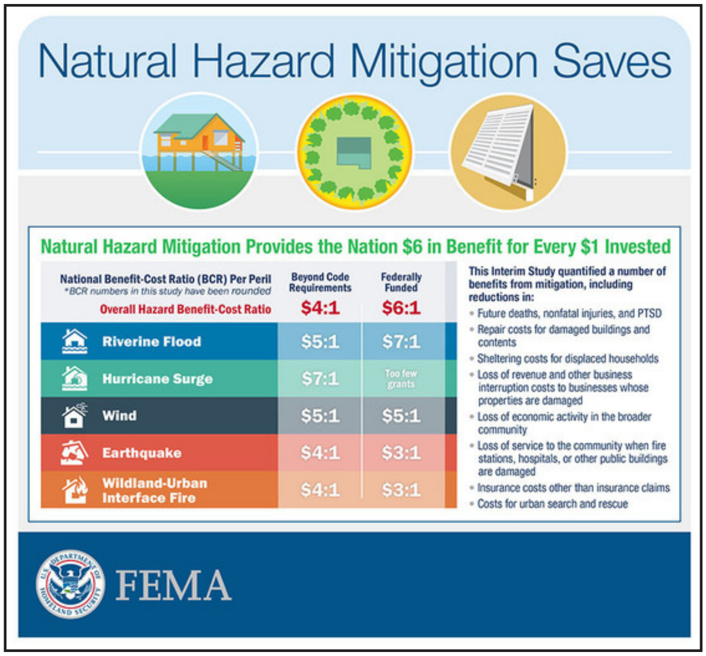
FEDERAL LEVEL SUPPORT

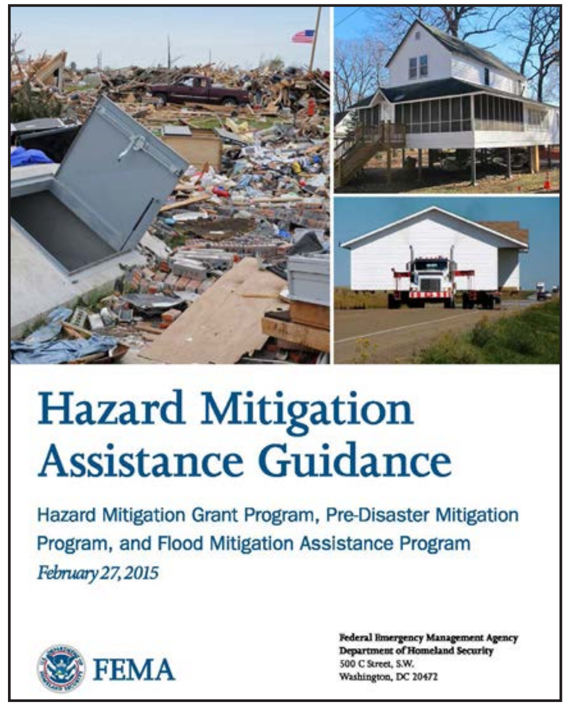
FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA)

At the federal level, Federal Emergency Management Agency (FEMA) is responsible for providing support for building, sustaining and improving the nation's capabilities "to prepare for, protect against, respond to, recover from, and mitigate all hazards" (FEMA). This agency is both a proactive and a reactive branch of government, which provides funding opportunities and useful resources.

A part of FEMA is the National Earthquake Hazards Reduction Program (NEHRP), which was established in 1977 with the Earthquake Hazards Reduction Act. It administers the Earthquake State Assistance Grant Program, which was "created to increase and enhance the effective implementation of earthquake risk reduction at the local level" (FEMA 2022) and "is designed to increase and enhance effective implementation of earthquake risk reduction at the regional, state and local level, by making funding available through annual, non-competitive grants for individual states and territories" (FEMA 2021). FEMA's NEHRP responsibilities include:

> *- Operate a program of grants and assistance to enable states to develop and implement earthquake risk mitigation activities.*
>
> *- Support implementation of a comprehensive earthquake education, outreach, and public awareness program.*
>
> *- In conjunction with the National Institute of Standards and Technology, (NIST) and other federal agencies, support the preparation, maintenance and dissemination of seismic resistant design guidance on building codes, standards and practices for new and existing buildings and lifelines.*
>
> *- Work with states, local jurisdictions and other federal agencies to establish demonstration projects on earthquake hazard mitigation.*
>
> *- Support the director of NIST in the completion of programmatic goals.*
>
> (FEMA 2021, p. 1)





Figs. 5.2a & b: Examples of FEMA publications increasing awareness of the benefits of Hazard Mitigation. (Sources: FEMA)

Another part of FEMA is the Hazard Mitigation Assistance (HMA), funded by the Disaster Relief Fund, which "provide funding for eligible mitigation activities that reduce disaster losses and protect life and property from future disaster damages" (FEMA 2022).

> *Hazard mitigation is any sustainable action that reduces or eliminates long-term risk to people and property from future disasters. Mitigation planning breaks the cycle of disaster damage, reconstruction and repeated damage. Hazard mitigation includes long-term solutions that reduce the impact of disasters in the future.*
>
> *FEMA's hazard mitigation assistance provides funding for eligible mitigation measures that reduce disaster losses. It also:*
>
> *- Reduces vulnerability of communities to disasters and their effects.*
>
> *- Promotes individual and community safety and their ability to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies (resilience).*
>
> *- Promotes community vitality after a disaster.*
>
> *- Lessens response and recovery resource requirements after a disaster.*
>
> *- Results in safer communities that are less reliant on external financial assistance.*
>
> (FEMA 2022)

In addition to its various funding opportunities, FEMA also has a long history of encouraging and increasing public awareness with regards to risk management. Over the years it has provided numerous useful resources for a range of audiences. The following are some of the most relevant FEMA publications with regards to existing buildings (which include, but are not limited to heritage buildings), from their Earthquake Engineering Research Institute, among many others:

Risk Management Series: Providing Protection to People and Buildings

FEMA 395: Incremental Seismic Rehabilitation of School Buildings (K-12)

FEMA 396: Incremental Seismic Rehabilitation of Hospital Buildings

FEMA 397: Incremental Seismic Rehabilitation of Office Buildings

FEMA 398: Incremental Seismic Rehabilitation of Multifamily Apartment Buildings

FEMA 399: Incremental Seismic Rehabilitation of Retail Buildings

FEMA 400: Incremental Seismic Rehabilitation of Hotel and Motel Buildings

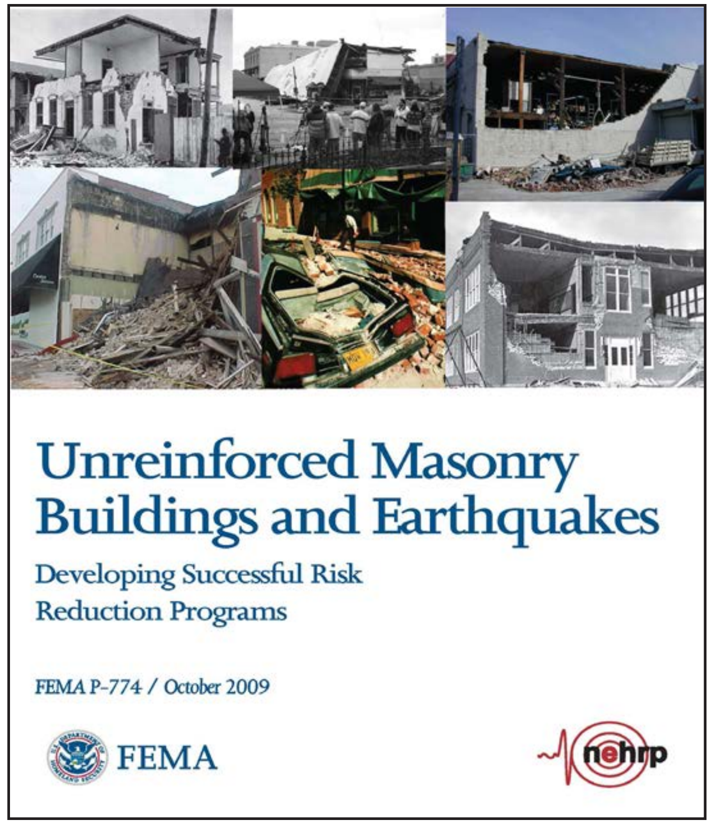


Fig. 5.3: One example of the numerous useful FEMA publications publicly available for reference and community use. (Source: FEMA)

FEMA 254: Seismic Retrofit Incentive Programs: A Handbook for Local Governments

FEMA 275: Planning for Seismic Rehabilitation: Societal Issues

FEMA 547: Techniques for the Seismic Rehabilitation of Existing Buildings

FEMA P-774: Unreinforced Masonry Buildings and Earthquakes: Developing Successful Risk Reduction Programs

TECHNICAL PRESERVATION SERVICES AND NATIONAL PARK SERVICES

As for materials and funding with regards to the seismic rehabilitation of heritage buildings, there is also the Technical Preservation Services (formerly known as the Heritage Preservation Services) of the National Park Service, which "develops historic preservation policy and guidance on preserving and rehabilitating historic buildings, administers the Federal Historic Preservation Tax Incentives Program for rehabilitating historic buildings, and sets the Secretary of the Interior's Standards for the Treatment of Historic Properties" (TPS n.d). The Federal Historic Preservation Tax Incentives Program offers rehabilitation tax credits to encourage the rehabilitation of heritage buildings (TPS n.d.), including seismic retrofit work. There is a 20% rehabilitation tax credit (which lowers the amount of tax owed), equal to 20% of the amount spent in a certified rehabilitation of a certified historic structure (as assessed by the State Historic Preservation Office and National Park Service staff). There also used to be a 10% rehabilitation tax credit, equal to 10% of the amount spent to rehabilitate a non-historic building built before 1936 (although this tax credit was repealed in 2017).

The National Park Services' Technical Preservation Services also provides knowledge and know how on various heritage conservation related topics, with currently fifty briefs available in total (TPS n.d.). Preservation Brief 41 was first published in 1997 to address "The Seismic Retrofit of Historic Buildings: Keeping Preservation in the Forefront" (Look et al., 1997). It was recently re-published by Antonio Aguilar and re-titled "The Seismic Rehabilitation of Historic Buildings" (Aguilar 2016). This document is immensely useful and relevant to property owners and policy makers here in British Columbia.u

Fig. 5.4: The Boyle Hotel, in East Los Angeles, is an example historic unreinforced masonry (URM) building that received funding from the Federal Historic Preservation Tax Incentive Program for rehabilitation to allow for continued use. (Source: Bruce Boehner)

STATE LEVEL SUPPORT

Fig. 5.5: A damaged school from the 1933 Long Beach Earthquake in California. (Source: LA Times Archive)

Beyond the federal level support provided, each individual state also has its own legislation with regards to seismic rehabilitation. It is worthwhile examining how the three US West Coast States approach the Seismic Rehabilitation of their buildings, including their heritage buildings. Beginning with California, as the furthest away from BC and the largest, then working northward examining Oregon, followed by Washington State as the closest jurisdiction to BC.

CALIFORNIA: OVERVIEW

California was the first US State to introduce any type of earthquake legislation in response to the numerous destructive earthquakes it experienced in the 20th century. Many of these resulted in severe damage and numerous deaths, particularly from collapsing unreinforced masonry buildings. As summarised by Paxton et al. (2015, p. 31), the following table outlines some of the major California earthquakes in the 20th century with statistics on their associated URM damage.

Year and Location	Damage Data
1906, San Francisco	Nearly all URM buildings in the western portions of Northern California including San Francisco, Palo Alto and Napa were severely damaged
1925, Santa Barbara	40% of unstrengthened URM buildings suffered severe damage or collapsed
1933, Long Beach	20% of unstrengthened URM buildings suffered severe damage or collapsed; 115 people died, mostly from falling unreinforced masonry
1971, San Fernando	49 deaths caused by the collapse of the URM buildings at the Veteran's Administration Hospital
1983, Coalinga	60% of unstrengthened URM buildings suffered severe damage or collapsed
1989, Loma Prieta	40% of unstrengthened URM buildings were demolished; 9 deaths were attributed to URM

Fig. 5.6: A partially collapsed school from the 1933 Long Beach Earthquake in California. (Source: LA Times Archive)

These numerous seismic events have resulted in various Californian legislation to address seismic safety. This began with the 1933 Long Beach earthquake, which saw 70 schools completely destroyed, 120 others seriously damaged and over 300 others with minor damage (WSSPC 2022). Fortuitously, the loss of life in these buildings was minimized by the timing of the event at 5:55 pm on a Friday evening. Most of the buildings were empty and "experts concluded that if children and their teachers were in school at the time of the earthquake, casualties would have been in the thousands" (California Geological Survey 2019).

The public awareness and appreciation of this scarcely avoided tragedy resulted in the speedy passage of two major pieces of legislation: the Field Act (addressing school design and construction) and the Riley Act (requiring buildings to be designed for lateral forces). It is interesting to note that there is a direct correlation between seismic events and resultant Earthquake Hazards Mitigation Legislation passed in California, a sampling of which is illustrated in the following table.

Year Passed and *Associated Earthquake*	Earthquake Hazards Mitigation Legislation
1933 1933 Long Beach Earthquake	**Field Act** - Ensure seismic safety in new public schools. - Establish regulations for the design and construction of K-12 and community college buildings.
1933 1933 Long Beach Earthquake	**Riley Act** - Require Local Governments to have building departments issue permits for new construction and alterations to existing structures and conduct inspections. - Minimum seismic safety requirements set out that have since been incorporated into all building codes
1939 1933 Long Beach Earthquake	**Garrison Act** - Apply the Field Act Standards to existing school buildings.
1967/1968/1974 1933 Long Beach Earthquake; spurred on by the 1971 San Fernando Earthquake	**Greene Acts** - Reaffirm requirements to comply with the Garrison Act. - Set inspection deadlines for pre-Field Act compliance of existing school buildings. - Following 1971, State Legislature provided additional funding to retrofit older buildings. - By 1977, majority of pre-Field Act buildings were either retrofitted or replaced.
1972 1971 San Fernando Earthquake	**Alquist-Priolo Earthquake Fault Zoning Act** - Prevent construction of buildings used for human occupancy on the surface trace of active faults. - Geologic investigation is required prior to building permit issuance to ensure construction is not on active faults.
1972 1971 San Fernando Earthquake	**Alfred E. Alquist Hospital Facilities Seismic Safety Act** - Regulates the design, construction and alteration of hospitals. - Set seismic safety standards for new hospitals. - Created an advisory Hospital Building Safety Board.
1975 1971 San Fernando Earthquake	**Seismic Safety Commission Act** - Created the independent California Seismic Safety Commission (CSSC) to provide a consistent earthquake policy framework for the state.
1986 1983 Coalinga and the 1985 Mexico City Earthquakes	**California Earthquake Hazards Reduction Act** - Called for a coordinated state program to implement new and expanded activities to significantly reduce earthquake threats. - Organized and run by the California Seismic Safety Commission, which is required to specify priorities, funding sources and amounts, schedules, and other resources.
1986 1983 Coalinga Earthquake	**Un-reinforced Masonry Building Law (the "URM Law")** - Required an inventory of URM buildings from the 365 jurisdictions in the highest seismic risk zone; and a loss reduction programme for URM buildings by 1990; with mandatory progress reporting to the California Seismic Safety Commission. -Recommended local governments establish seismic retrofit standards; adopt mandatory strengthening programmes; and enact measures to reduce the number of occupants in URM buildings.
1990 1989 Loma Prieta Earthquake	**Earthquake Safety and Public Buildings Rehabilitation Bond Act of 1990** - Authorized the state to issue bonds for the seismic retrofit of state and local government buildings.
1990 1989 Loma Prieta Earthquake	**Seismic Hazards Mapping Act** - Required the identification and mapping of areas prone to liquefaction, earthquake-induced landslides, and amplified ground shaking to help reduce the threat to public safety and minimize the loss of life and property by identifying and mitigating seismic hazards.

From the above summary, two pieces of legislation seem particularly relevant to British Columbia: the 1975 Seismic Safety Commission Act and the 1986 URM Law. The Seismic Safety Commission Act resulted in the establishment of an independent body, the California Seismic Safety Commission (CSSC), which is a key partner in California's Earthquake Risk Management:

> The mission of the Seismic Safety Commission is to provide decision makers and the general public with cost-effective recommendations to reduce earthquake losses and speed recovery. The Commission investigates earthquakes, researches earthquake-related issues and reports, and recommends to the Governor and Legislature policies and programs needed to reduce earthquake risk. Among the duties of the Commission are:
>
> - Managing California's Earthquake Hazards Reduction Program;
>
> - Reviewing seismic activities funded by the State;
>
> - Providing a consistent policy direction for earthquake-related programs for agencies at all government levels;
>
> - Proposing and reviewing earthquake-related legislation;
>
> - Conducting public hearings on seismic safety issues;
>
> - Recommending earthquake safety programs to governmental agencies and the private sector; and
>
> - Investigating and evaluating earthquake damage and reconstruction efforts following damaging earthquakes.
>
> (SSC 2022a)

The California Seismic Safety Commission has published numerous resources to help increase awareness of the seismic risk and mitigation strategies for various audiences and groups (SSC 2022b). The following is a small sampling of some of the most pertinent CSSC publications that could be of relevance to British Columbia: Homeowner's Guide to Earthquake Safety (2020 Edition); Guide to Identify & Manage Seismic Risks of Buildings for Local Governments (2017); and Commercial Property Owner's Guide to Earthquake Safety (2006 Edition), to list but a few.

The second Californian legislation of particular note is the 1986 URM Law (Senate Bill 547), which is one of California's strongest efforts to date to reduce the potential damage and losses from an earthquake, particularly with regards to heritage buildings. This required that the 365 local governments in California's highest seismic zone:

1) Complete an inventory of URM buildings within each jurisdiction;

2) Establish loss reduction programmes for URM buildings; and

3) Report on their progress to the California Seismic Safety Commission.

Part of this URM law, included a requirement that URM buildings have warning placards placed at their entrance informing the public of the risk associated with the building (Fig. 5.7), with a revised sign once seismic retrofitting had been undertaken. This law also recommended that local governments:

1) Establish seismic retrofit standards;

2) Adopt mandatory strengthening programmes; and

3) Enact measures to reduce the number of occupants in URM buildings.

Fig. 5.7: Example of a seismic hazard sign installed on URM buildings in California. (Source: Courtney Sherwood)

Many municipalities have adopted various strengthening ordinances, as discussed in the following section. As outlined by the Seismic Safety Commission, these ordinances tend to break down into the following types.

Beyond its URM Law, California is also guided by its State Historical Building Code (SHBC) and its California Historical Building Code (CHBC). "The CHBC's standards and regulations are intended to facilitate the rehabilitation or change of occupancy so as to preserve their original or restored elements and features, to encourage energy conservation and a cost-effective approach to preservation, and to provide for reasonable safety from fire, seismic forces or other hazards for occupants and users of such buildings, structures and properties and to provide reasonable availability and usability by the physically disabled (Office of Historic Preservation, California State Parks 2022).

Program	Summary
Mandatory Strengthening	These programs require owners to strengthen or otherwise reduce risks in their buildings within times prescribed by each local government. Time schedules vary and generally depend on the number of occupants. This is the most effective program type.
Voluntary Strengthening	These programs establish seismic retrofit standards and require owners to evaluate the seismic risks in their buildings. Owners then write publicly available letters to their local governments indicating when they intend to retrofit (CSSC, 1990). This type of program is slightly more effective than Notification Only.
Other Types	Variations of the other program types with unique requirements and ranges of effectiveness. (CSSC, 1995)
Notification Only	Local governments write letters to owners stating that their building type has been known to perform poorly in earthquakes. This is typically the least effective type of program. Most jurisdictions have adopted more comprehensive measures than this.

In the 1980s, it was estimated that the URM Law would result in roughly $4 billion in retrofit expenditures with activity well into the new century. The cost, although large, pales in comparison with several hundred billion dollars in anticipated damage from one major urban earthquake in California. Future earthquake losses can be greatly reduced by carrying out effective URM programme

(Seismic Safety Commission 2005, p. 3)

California: Municipal Approaches

Although not exhaustive, this discussion provides a sampling of some of the cities in California that have seismic risk mitigation legislation. It is hoped these can be used as possible inspiration for the numerous BC municipalities that similarly have seismically risky URM buildings in their streetscapes.

While this is a very simple overview and a relatively small sampling of some of the legislation and incentives being used with regards to seismic rehabilitation in California, from these, one can appreciate the long history of such measures with compelling results to date. "98 percent of the 25,945 unreinforced masonry buildings are now in mitigation programs in California's highest seismic region as a result of the state's laws" (Seismic Safety Commission 2006, p. 9). While it is recognized that mandatory strengthening programmes are the most successful, it is interesting to note the success of voluntary programmes, particularly those paired with effective economic incentives (Seismic Safety Commission 2006, pp. 8 and 9). California's more active seismic experience has directly influenced the legislation and incentives it has introduced, but one hopes British Columbia will not wait for a seismic event before it similarly acts.

Longbeach
In 1959, local amendments to the building code gave the building official authority to abate parapets and other appendages that posed falling hazards and most parapets were reportedly abated by the 1960s. In 1971 the city passed the first ordinance in the United States for mandatory comprehensive strengthening of buildings. The ordinance applied to all non-wood frame pre-1934 buildings, including buildings with non-load bearing masonry walls and concrete buildings. By 1995, 94% if buildings had been mitigated.

Los Angeles
The City of Los Angeles was the first local government in the United States to pass a retroactive URM seismic ordinance, in the form of its 1949 parapet correction ordinance. Essentially all buildings were in compliance by the 1960s. In 1981 the City of Los Angeles adopted an ordinance for comprehensive seismic strengthening, which is now known as Division 88 (of the Los Angeles Municipal Code). Varying timelines for compliance were established based on a 'rating classification' that prioritized buildings based on function and occupant load.
The owners of lower priority buildings had the option of extending the deadline for full compliance by performing partial retrofits, [which] included parapet bracing and the installation of tension anchors. The City of Los Angeles did not provide any significant incentives for the general building stock, but the city's Community Development Department (CDD) provided low-interest loans to cover project costs for residential and mixed-use buildings.

Palo Alto
In 1986 the city passed an ordinance that addressed URM buildings, pre-1935 non-URM buildings with 100+ occupants; and pre-1976 buildings with 300+ occupants). Strengthening remained voluntary and incentives were made available. However, the incentives were not widely use. The primary driving factor was the public/occupant awareness created by the publicly available assessments. Seismic improvements were marketed by building owners. Additionally, some tenants agreed to help finance upgrade costs and others voluntarily agreed to vacate the space during construction (and return upon completion).

San Francisco
In 1976, the City/County of San Francisco enacted its Parapet Safety Programme, which required owners to retain a structural engineer to provide a seismic assessment of parapets, with the programme applying to all pre-1949 URM buildings posing fall hazards to public sidewalks or occupied spaces. In 1992, the city passed ordinance 225-92, which mandated strengthening/abatement of approximately 2000 identified URM buildings. Various timelines for compliance were established based on levels of risk. In terms of incentives, low-interest loans were made available through a $350 million general obligation bond, approved by a public vote.

(Paxton et al 2015, pp. 34 to 36)

OREGON: OVERVIEW

It is interesting to note that, unlike California, Oregon has experienced far fewer devastating earthquakes in the 20th century and as a result has much less Earthquake Hazard Mitigation Legislation. After the Californian Loma Prieta Earthquake in 1989, it was recommended by the Interagency Seismic Task Force that Oregon establish an equivalent Commission to California's Seismic Safety Commission. In 1991, the Oregon Seismic Safety Policy Advisory Commission (OSSPAC) was formed, made up of 18 individuals, including six government representatives, six representatives of the public interest and six representatives of industries and stakeholders.

> The mission of the OSSPAC is to positively influence decisions and policies regarding pre-disaster mitigation of earthquake and tsunami hazards, increase public understanding of earthquake hazard, risk, exposure, and vulnerability through education, and be responsive to the new studies and/or issues raised around earthquakes and tsunamis.
>
> (OEM 2021)

The Oregon Seismic Safety Policy Advisory Commission (OSSPAC) has a relationship with the California Seismic Safety Commission as well as the Western States Seismic Policy Council (WSSPC). The WSSPC "develop seismic policies and share information to promote programs intended to reduce earthquake related losses" (WSSPC 2022). It is worth noting that the WSSPC technically includes both British Columbia and the Yukon (Fig. 5.8). However, there is currently no BC representation in the WSSPC membership. This is perhaps an area of further exploration for British Columbia going forward.

Fig. 5.8: Map of the Western States Seismic Policy Council. Note the inclusion of BC and the Yukon. (Source: WSSPC)

The formal building code for the state is the Oregon Structural Specialty Code (OSSC) and it recently adopted the International Existing Building Code (IEBC) as an alternative method to the base code (OBCD 2019). There is a robust building code in Oregon with regards to new construction, however, for existing buildings, it is a similar system as British Columbia where such requirements, including seismic upgrading, are only triggered by a change of occupancy or use. As a result, many heritage buildings are left underutilised to avoid triggering the code upgrades. This often results in deferred maintenance, which simply increases their potential risks in a seismic event, especially URM buildings. "The building code needs to be a comprehensible tool to encourage, not dissuade, the upgrade of historic URMs" (Restore Oregon 2012, p. 16).

Fig. 5.9: Redman Hall from Jacksonville, Oregon, illustrating one of its seismic at-risk URM buildings. (Source: Restore Oregon)

With regards to the riskiest buildings in Oregon, a state-wide seismic needs assessment for public buildings was completed in 2007, which identified numerous URM Buildings throughout the state in need of attention. This assessment resulted in "Recommendations to the Seismic Rehabilitation Grant Committee, Recommendations for Districts and Recommendations for Fiscal Decision Makers" (Lewis 2007, p. v and p. 53).

It is interesting that in this 2007 report, there is a section encouraging Oregon to look at the work done in British Columbia, particularly with regards to its Seismic Mitigation Program for BC schools (Lewis 2007, pp. 51 to 52). It appears the State of Oregon did introduce legislation requiring school districts to provide the Department of Geology and Mineral Industries (DOGAMI) with annual updates "on construction of new buildings and modification of existing buildings" for its School Seismic Status Reports (DOGAMI 2020).

The Seismic Rehabilitation Grant Committee was formed as part of the results from the 2007 seismic needs assessment. The Committee, as administered by the Office of Emergency Management, provides grants in the form of Bonds that can be applied for to help finance seismic rehabilitation work on either public education buildings or emergency service buildings (DOGAMI 2007). It appears this Grant Committee may no longer be functional though, as the available information has not been updated since 2020.

Beyond the 2007 state-wide assessment, there has been no state-wide legislation or policies with regards to the seismic rehabilitation of existing buildings in Oregon, including its URM buildings. As a result, in 2012, a group formerly known as the Historic Preservation League of Oregon, published a Special Report on "Resilient Masonry Buildings: Saving Lives, Livelihoods, and the Livability of Oregon's Historic Downtowns" (Restore Oregon). This report appears to have been written in a similar spirit as this report focusing on British Columbia. It highlights the issues with regards to the need for seismic upgrading URM heritage buildings and provides a series of recommendations for the State going forward.

These recommendations are equally relevant to the seismic risk and rehabilitation needed for British Columbia's heritage buildings, particularly the numerous URM buildings distributed throughout the province. Their recommendations break down as follows:

1. Educate Building Owners and Contractors on Best Practices for Historic Masonry Buildings.

2. Inventory Unreinforced Masonry Buildings so Communities Know What They Have.

3. Boost Public Demand for Seismic Upgrades by Rewarding Resilience.

4. Leverage Existing Federal Programs to Foster Upgrades.

5. Adopt Meaningful State Rehabilitation Incentives.

6. Increase Availability of Finance and Insurance Options.

7. Institute Changes to the State Building Code.

8. Government Agencies Must Take Care of Their Own URMs.

(Restore Oregon 2012, pp. 4 to 5)

Fig. 5.9: The former Broadway Hotel in Portland, Oregon, illustrating another at risk URM building. (Source: Ian Poellet)

OREGON: PORTLAND

As for the individual municipalities in Oregon, Portland is the main and largest municipality that has additional seismic design standards for existing buildings (through Chapter 24 of the Portland Building Code) as well as with specific seismic retrofit requirements for unreinforced masonry (URM) buildings, in particular. For example, in addition to a change in occupancy or use, when 50% or more of the roof of a URM building is replaced, its parapet will be required to be braced (complete with roof anchors).

> First adopted in 1994, Portland City Code Chapter 24.85 "Seismic Design Standards for Existing Buildings" contains requirements for upgrade to the lateral systems of existing buildings when the buildings are undergoing change of use or occupancy or are being altered. In addition, for Unreinforced Masonry Buildings (URM's) undergoing alterations or repair, Section 24.85.065 has triggers associated with the cost of repair or alteration which, if exceeded, would require mandatory seismic strengthening.
>
> (BDS 2022)

Fig. 5.10: Historical photograph of West Burnside Road in Portland, Oregon. (Source: City of Portland Archives, A1999-004.256)

Beginning in the 1990s, the City of Portland began compiling a list of its unreinforced masonry (URM) buildings to increase public awareness of possible seismically risky buildings. This list has existed since 1995 and is periodically updated. It appears it was previously publicly available as a searchable database, however, access is now limited through a public records request. The list classifies buildings into partially retrofitted URM buildings, fully retrofitted URM buildings or un-retrofitted URM buildings, in addition to listing different use classifications, as follows:

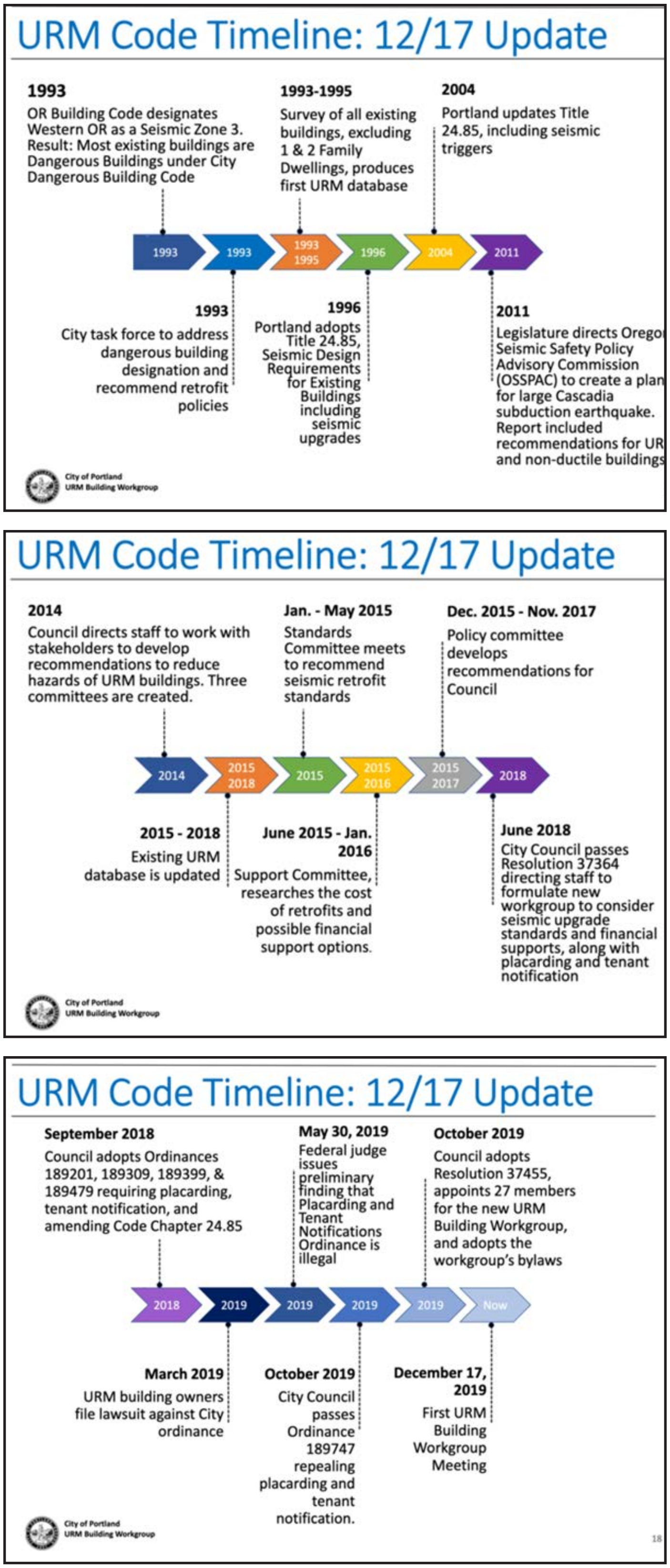
- *URM Class 1: Buildings categorized in this class are unreinforced masonry buildings that are considered critical structures and essential facilities such as hospitals, police and fire stations, power generating stations, and water treatment plants.*
- *URM Class 2: Buildings categorized in this class are unreinforced masonry buildings that include schools and other high-occupancy structures listed as Risk Category III buildings in the Oregon Structural Specialty Code such as churches and theaters.*
- *URM Class 3: Buildings categorized in this class includes all unreinforced masonry buildings not classified as URM Class 1, 2 or 4 buildings*
- *URM Class 4: Buildings categorized in this class are low-occupancy unreinforced masonry buildings. This category includes one- and two-story unreinforced masonry buildings with relatively low numbers of occupants (usually under 10), such as single-story auto garages.*

(BDS 2022)

Fig. 5.11: Union Station in Portland Oregon is a URM building that has recieved a range of seismic upgrades over a several year period. (Source: Jennifer Eggers)

Prior to the 1990s, the extent of the seismic risk facing Portland was not fully understood. However, through the 1990s, there was increased recognition of the high risk of a seismic event in the region. Since then, various task forces and committees have been tasked with recommending policies to mitigate these hazards (the URM list was one such initiative). The following summarises the main actions taken with regards to addressing URM risk in Portland (Fig. 5.12).

One of the more recent initiatives for the City of Portland involved three committees researching "URM retrofit best practices in other cities to return to Council with policy recommendations, including proposed code changes and



assistance program(s) to support implementation" (SRSC 2015, p. 3). These Committees were the Retrofit Standards Committee (RSC), Seismic Retrofit Support Committee (SRSC) and the Policy Committee. The results of their research provided a series of recommendations, broken into areas addressing Financial Assistance, Policy Support, Technical Assistance and Information Support (see SRSC 2015, Appendix A for the full list of recommendations).

Some progress has been made with regards to these recommendations since their publication in 2015. For example, one result was a URM resolution being passed in 2018, which required owners of URM buildings to place warning placards alerting occupants of the danger of the building (City of Portland 2019). A similar such policy exists in California and has existed for many years. Unfortunately, though, it was repealed the subsequent year due to pushback from the community. A new working group was established in 2019 to find a workable solution, but it was disbanded in 2020 due to the pandemic and city budget constraints.

Portland is not alone in being derailed by the pandemic and all the time, effort and resources that has gone into managing that crisis. Unfortunately, it has resulted in time being lost in preparing for the substantial risk continuously posed by the eventual megathrust earthquake that will rock this region.

Fig. 5.12: City of Portland's URM Code Timeline summary. (Source: City of Portland)

WASHINGTON: OVERVIEW

Although Washington State has experienced far fewer devastating earthquakes in the 20th century compared to California, it has experienced more than Oregon. In living memory, Washington State has been impacted by the following major earthquakes: June 23, 1946 the Strait of Georgia 7.3 magnitude earthquake; April 13, 1949 the Olympia 6.7 magnitude earthquake; April 29, 1965 the Puget Sound 6.7 magnitude earthquake; and February 28, 2001 Nisqually 6.8 magnitude earthquake.

Fig. 5.13: Damage in Seattle from the 2001 Nisqually Earthquake. (Source: Northwest Progressive Institute)

As a result, there is greater awareness of the seismic risk facing the state, particularly among building officials and design professionals (Paxton et al. 2015, p. 37). However, up until recently, Washington State has had little Earthquake Hazard Mitigation Legislation, with regards to existing buildings, including heritage buildings. Following the seismic events in the 1940s, Washington State introduced its Earthquake Construction Standards in 1955, outlining requirements for newly constructed schools, hospitals and places of public assembly to withstand specified lateral forces. This was superseded in 1974 with the State Building Code Act that mandated the use of the 1973 International Building Code throughout the State, which had different minimum requirements with regards to seismic resilience for new construction.

In 2020, the 2018 Washington State Existing Building Code (based on the International Existing Building Code) adopted *Appendix A: Guidelines for the Seismic Retrofit of Existing Buildings*, which "provides guidelines for upgrading the seismic-resistance capacity of different types of existing buildings. It is organized into separate chapters that deal with buildings of different types, including unreinforced masonry buildings, reinforced concrete and reinforced masonry wall buildings, and light-frame wood buildings" (ICC 2020). Most recently in 2022, Washington State unanimously approved a bill to help fund seismic retrofits of the school buildings at-risk in the state (Fabris 2022).

Similar to California and Oregon, Washington also has a Seismic Safety Committee. Their purpose is to "prepare and submit to the Emergency Management Council (EMC) statewide strategies, policies, and recommendations that address the seismic threat through mitigation, preparedness, response and recovery activities" (WMD 2021). Part of their work included a Gap Analysis Report (Fig. 5.14) looking at the policy gaps in Washington State, which resulted in the formation of the Resilient Washington State (RWS) Subcommittee that has been formulating a plan of action to increase and achieve desired levels of resiliency for the state in the next seismic event.

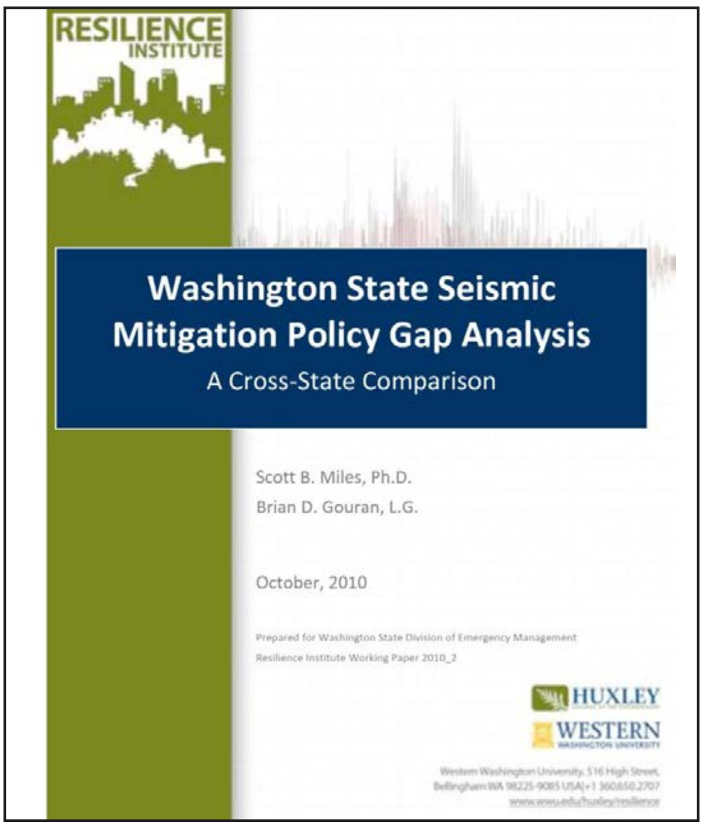
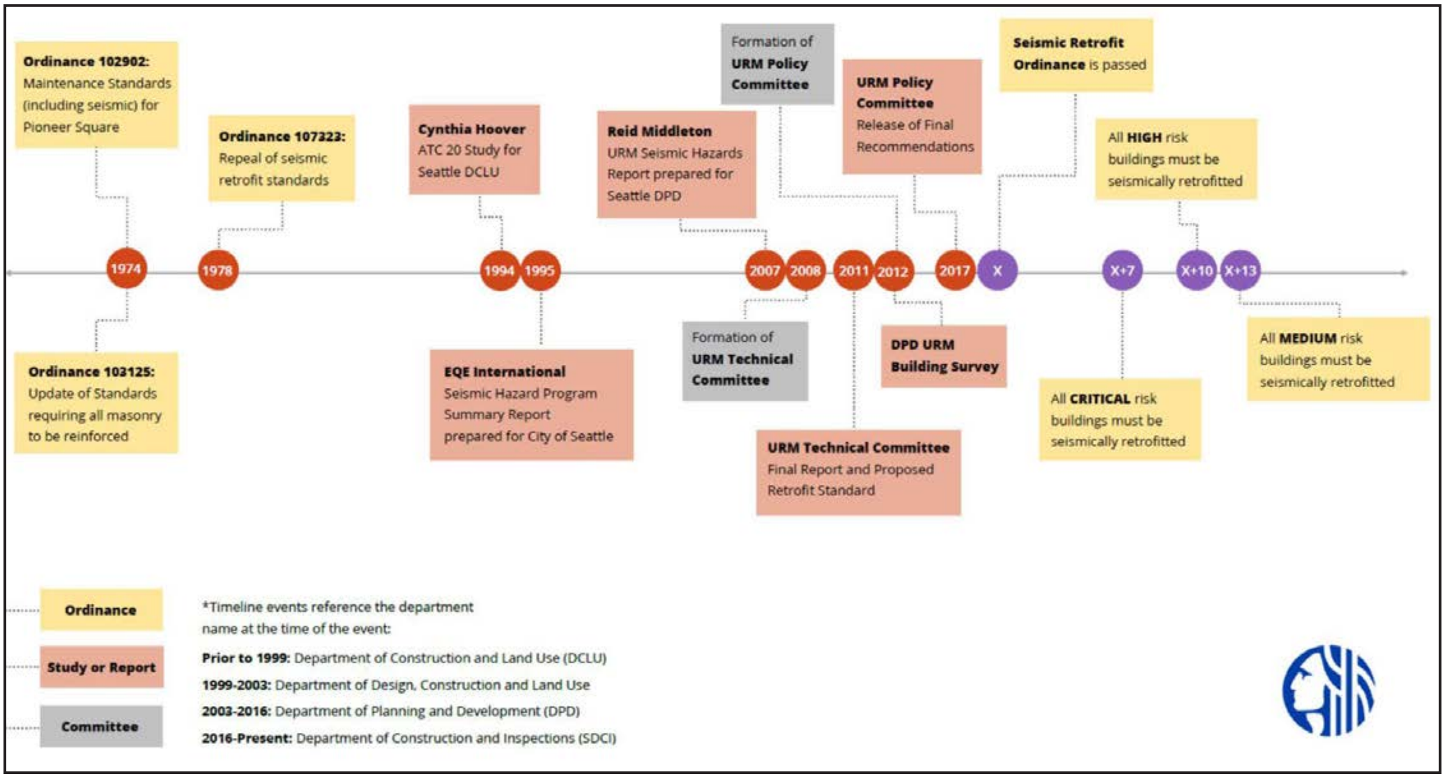


Fig. 5.14: Washington State Seismic Mitigation Policy Gap Analysis Report. (Source: Resilience Institute 2010)

> The RWS subcommittee has defined a resilient state as one that maintains services and livelihoods after an earthquake. In the event that services and livelihoods are disrupted, recovery occurs rapidly, with minimal social disruption, and results in a new and better condition. In accordance with this definition, a number of values have been established for Washington State to achieve resilience. These include:
>
> **Property Protection**: Public and private property within the State of Washington should be built, retrofitted, or rebuilt to minimize earthquake-induced damage. This includes proper design and construction of both structural and non-structural elements.
>
> **Economic Security**: Residents and businesses within the State of Washington should have access to income opportunities to meet basic needs before and soon after an earthquake. This includes sufficient employment opportunities, market access, distribution capacity, and supplier access.
>
> **Environmental Protection**: The natural resources and ecosystems of Washington State should be managed in such a way as to minimize earthquake-induced damage. This includes the use of proper growth management, accident response capacity, and industrial safety measures.
>
> **Life Safety and Human Health**: Residents of the State of Washington should not suffer life-threatening injuries from earthquake-induced damage or develop serious illness from lack of emergency medical care after an earthquake. This includes enforcing and updating building codes, eliminating non-structural hazards, and ensuring continuity of emergency health care.
>
> **Community Continuity**: All communities within the State of Washington should have the capacity to maintain their social networks and livelihoods after an earthquake disaster. This includes prevention of social-network disruption, social discrimination, and community bias.
>
> (WMD 2021)

While the efforts at the state-level have been broader, without much focus on existing heritage buildings, particularly URM buildings, certain municipalities within the state have focused on this issue, as discussed in the following section.



WASHINGTON: SEATTLE

Fig. 5.15: City of Seattle's URM Policy Timeline summary. (Source: City of Seattle)

As for the individual municipalities in Washington State, Seattle is the largest municipality and the main jurisdiction that has made any attempts at specific seismic retrofit requirements for URM buildings. Although the risk to the region and the URM building type specifically, is well acknowledged, the City of Seattle has struggled for decades to bring in meaningful legislation to address the risk.

In the early 1970s, an ordinance was passed requiring the retrofit of all URM buildings in the City, but it was quickly repealed due to public opposition and administrative difficulties (FEMA 1998). Since then, the only comprehensive seismic upgrading required of existing buildings, including URM buildings, is when it is triggered by a change of use or occupancy.

> Currently, the Seattle Building Code requires unbraced parapets on URM buildings to be abated or braced. This requirement is enforced when SDCI receives an application for a building permit for any work in the building. If a developer or owner chooses to construct a major addition or alteration to their building, or if a building sustains major damage in an event, the City building code requires a seismic report to be submitted along with the building permit. If the report indicates the building is substantially out of compliance with current engineering standards for existing buildings, seismic retrofit will be required. There is currently no policy in place that requires a major seismic retrofit of URM buildings that are not undergoing a major improvement or alteration.
>
> (URM Policy Committee 2017, p. 2)

In the 1990s, a Seismic Hazard Report was written for the city, however, it was not until the mid-2000s that interest in addressing the need for URM policy was reignited. The above timeline summarises the efforts to date (Fig. 5.15).

Similar to Portland, the Seattle Department of Construction & Inspections (SDCI) has maintained a list of its URM buildings, which is still publicly available and regularly updated, most recently in March 2022. This list categorises each building by its neighbourhood, address and year built; its occupancy type and occupant load; its retrofit level; and is given a preliminary risk category: "Critical Risk (C) is assigned to building in the Emergency and Schools occupancy groups; High Risk (H) is assigned to buildings over three stories in poor soil areas (liquefaction and slide areas); and buildings in the public assembly group with occupancies more than 100 people; and Medium Risk (M) is assigned to all other buildings" (SDCI 2022, p. 1).

A URM list is a valuable resource for a number of reasons, particularly one that is easily and publicly accessible and kept up to date. It provides critical information to the public, particularly regular users of these spaces and buildings. It can encourage greater accountability from owners and ideally an increased interest in carrying out seismic retrofit work. It also provides a strong foundation for municipalities to have a better understanding of their assets and resources, in addition to providing a foundation and starting point should a URM policy be enacted.

Although it has not happened yet, over the last two decades, Seattle has been actively exploring introducing some kind of URM retrofit policy. A Technical Committee was formed in 2008, which recommended that a modification of California's Bolts Plus retrofit be adopted for qualifying URMs, requiring that "parapets be braced; floors and roofs be structurally connected to URM walls; framing be interconnected to strengthen floors and roofs; and weak interior and exterior bearing walls be strengthened" (URM Policy Committee 2017, p. 2). Unfortunately, a policy could not be agreed upon due to the cost of retrofits.

In 2012, a new Unreinforced Masonry Policy Committee was formed with the charge that "given that a mandatory seismic retrofit policy would be enacted by the City, develop recommendations that would contribute to the most effective policy possible" (URM Policy Committee 2017, p. 3). This document, in its entirety, is an immensely useful reference for any municipality embarking on the important, but complicated work of introducing any seismic retrofit policy, particularly one for URM buildings.

> The city of Seattle's Department of Construction and Inspections (SDCI) is considering a mandate for all unreinforced masonry (URM) buildings to undergo a seismic retrofit to reduce the risk of injury and loss of life in the case of an earthquake. Unreinforced masonry buildings are typically multiple-story, redbrick structures found in many of the city's oldest neighborhoods and commercial centers. URM buildings are known to be unsafe in the case of an earthquake as they are built without steel reinforcement or sufficient structural connections between the building's walls and other structural elements. A seismic retrofit can significantly reduce a URM building's risk of collapse in the event of an earthquake. Collapsed buildings can endanger the lives of the building's occupants and nearby pedestrians, block public rights-of-way for emergency response, and delay overall recovery from the earthquake.
>
> (URM Policy Committee 2017, p. 1)

URM Policy Goals

The city of Seattle identified a primary policy goal for the URM retrofit program to improve life safety by reducing the risk of injury from collapse of URMs in the event of an earthquake. Seismic retrofits for Seattle's URM buildings would enhance the safety of the structures and reduce the threat of injury or death in the case of an earthquake.

The City's secondary goals for the program include:

- Preserving Seattle's historic and culturally significant landmarks and structures
- Preventing the collapse of buildings deemed important to a neighborhood and the surrounding community to help preserve a neighborhood's historic character
- Improving Seattle's resiliency to earthquake events, allowing for a quick recovery and cleanup and thereby benefiting both the City and community
- Minimizing an outcome that results in demolished or vacant buildings in response to passage of a retrofit ordinance

To achieve these goals identified by the City, the Policy Committee is recommending a URM program that will support several objectives. These include:

- Creating a program that is easy for building owners to understand and implement
- Reducing the cost of retrofits to building owners by providing options for financial support
- Encouraging early participation in the retrofit program
- Encouraging building owners to retrofit beyond the program's minimum requirements in order to enhance the probability that the URM building will remain standing in the event of an earthquake
- Building broad-based support for the program

(URM Policy Committee 2017, pp. 5 to 6)

Likely because of the experience in 2008, a major focus of this report addresses the financial logistics of such a policy. Some of the funding options include: "federal grants; general obligation bonds; levies, federal rehabilitation tax credits, tax abatement, revolving loan funds, local improvement districts, transfers of development rights, architecture and engineering grants, as well as building owner contributions" (URM Policy Committee 2017, p. 14).

The URM Policy Committee recognizes the importance of a seismic retrofit policy to protect human life and preserve the historic character of Seattle neighborhoods. URMs pose a substantial danger to tenants, property owners and the community at large. While there is a considerable financial impact of the policy requirements on building owners, it is important to also consider the value of these URM buildings from a historic and cultural perspective. The committee recognizes the need for a balanced policy that preserves human life and historic culture, while still making the policy fair for private and non-profit building owners.

(URM Policy Committee 2017, p. 16)

Fig. 5.16: Historical photograph of Hotel Seattle, damaged in the 1949 Olympia Earthquake and ultimately abandoned in 1961. (Source: University of Washington Archives)

After tabling the recommendations of the URM Policy Committee in 2017, additional research and consultation was done specifically with regards to Funding URM Retrofits. The Executive Summary of this research is another valuable resource for any municipality exploring seismic retrofit policy and the associated challenges of financing such work (National Development Council 2019). Through 2019 and 2020, additional internal work was done with regards to developing a policy, but it appears (similar to Portland) progress has been delayed as a result of the pandemic; at least as discernible from their online timeline, which stops at 2020 (SDCI 2022).

It appears interest in the topic may have been resumed in December 2021, when "the City of Seattle unanimously passed a landmark Resolution focused on developing a program to retrofit unreinforced masonry buildings (URMs) in the City of Seattle" (The Registry 2021). Part of the latest initiative includes a financing option through the Commercial Property Assessed Clean Energy + Resiliency (C-PACER) program, which allows property owners to secure low-interest loans for upgrading work:

> The program ties the obligation to repay seismic and upgrade improvements to the property, rather than the owner, which means no debt is added onto an owner's balance sheet. This creates long-term value with low-interest loans. If the building is sold, the loan repayment obligation stays with the property rather than the owner. The C-PACER program was introduced by the Washington State Legislature in 2021, and King County was the first county to adopt the program with the City of Seattle's commitment to a URM retrofit program.
>
> (The Registry 2021)

CONCLUDING REMARKS

Although a URM Policy has not been officially adopted by the City of Seattle yet, it seems hopeful that it may be soon enough to help get Seattle on track with increasing the seismic resiliency of its most at-risk buildings. As recognised and well articulated in the URM Policy Committee's final report, in addition to the primary concern of public safety, "another objective of the URM policy is to preserve the historic and cultural character and the economic vitality of many of the City's most vibrant neighbourhoods" (URM Policy Committee 2017, p. 1). This statement is equally relevant and of concern for British Columbia and its numerous at-risk cities. This is particularly the case for their original downtowns, many of which were built in the late 19th and early 20th centuries using URM construction.

It is vital that such work is done in advance of a seismic event, because unfortunately, in the chaos and aftermath of an earthquake, conserving heritage buildings is not a top priority. As New Zealand's Earthquake Recovery Minister was quoted saying in the aftermath of their February 2011 Christchurch earthquake "focusing on heritage buildings was undue and unacceptable in the current circumstances" (NZPA 2011). Thus, there is an urgent need for such a policy throughout this region before an event destroys so much; as is made abundantly clear when looking at the damage experienced in New Zealand in 2011, as discussed in the following section.

NEW ZEALAND

Another relevant country to look to in terms of how they approach seismic risk and rehabilitation is New Zealand. Quite the opposite to the US, New Zealand is an interesting comparator in that it is much smaller than Canada, both in terms of population size and GDP. New Zealand has a population of approximately 5 million people (Stats NZ 2022) and $212.5 billion GDP (IMF), compared to Canada's 38 million people (Statistics Canada 2022) and $1.74 trillion GDP (IMF). The following will briefly examine the federal level supports for seismic rehabilitation followed by a closer look at the Canterbury region and specifically how the city of Christchurch has previously approached and now subsequently approached following its catastrophic seismic event in 2011.

FEDERAL LEVEL SUPPORT

New Zealand is located between the Australian and Pacific tectonic plates, with the Alpine Fault running through its South Island (Fig. 5.17). As a result, New Zealand experiences a substantial amount of seismic activity. Prior to the 2010/2011 Canterbury earthquakes (to be discussed below), the most damaging earthquake in New Zealand's history was the 7.8 magnitude Hawke's Bay earthquake (also known as the Napier earthquake) that took place at 10:47 am on Tuesday, February 3, 1931. This event killed 256 people, injured thousands and caused substantial damage to the region.

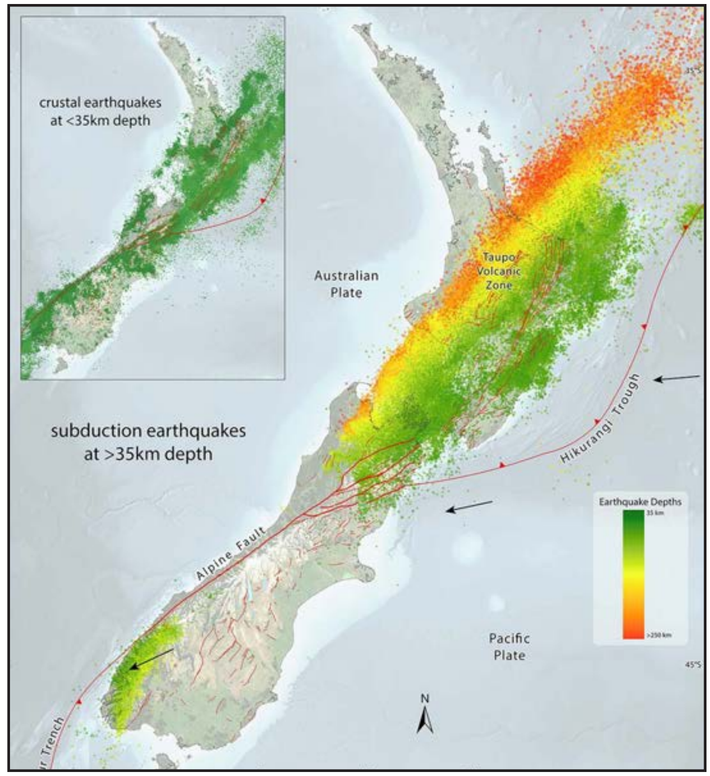


Fig. 5.17: Map of the plates and earthquake activity around New Zealand. (Source: University of Otago)

Similar to California's experience of cause-effect legislation following a catastrophic seismic event, the New Zealand Standards Institution was created in 1932 to look into introducing a nation-wide building code to guide construction and better protect its citizens. "It became evident that construction methods that worked well half a world away and had locally for some years were unsuitable for us in the Shaky Isles. The poor performance of heavy unreinforced masonry that was widespread around the country but had caused significant loss of life in Napier was cause for particular concern" (Build Magazine 2017, p. 58). URM construction rapidly decreased from that point and was prohibited by 1965 (Ingham and Griffith 2011, pp. 8 to 9).

By 1935, the Standard Model Building Bylaw was introduced to provide a uniform basis for construction for local bylaws. This was amended in 1964 and overhauled in the early 1990s. New Zealand's Building Act 1991 introduced a performance-based building code, the New Zealand Building Code. Similar to North America, this Building Code outlines the minimum performance standards buildings must meet. The current and most recent version of the Building Act is from 2004.

Although there were provisions in the Building Act with regards to earthquake-prone buildings previously, following the 2010/2011 Canterbury Earthquakes that saw numerous collapsed buildings (including "many small, URM retail buildings") amendments were made "to upgrade and improve methods of managing New Zealand's older and often earthquake-prone buildings" (Murphy 2020, p. 2). The Building (Earthquake-prone Buildings) Amendment Bill was first introduced in 2013, further amended in 2016 and came into effect in 2017.

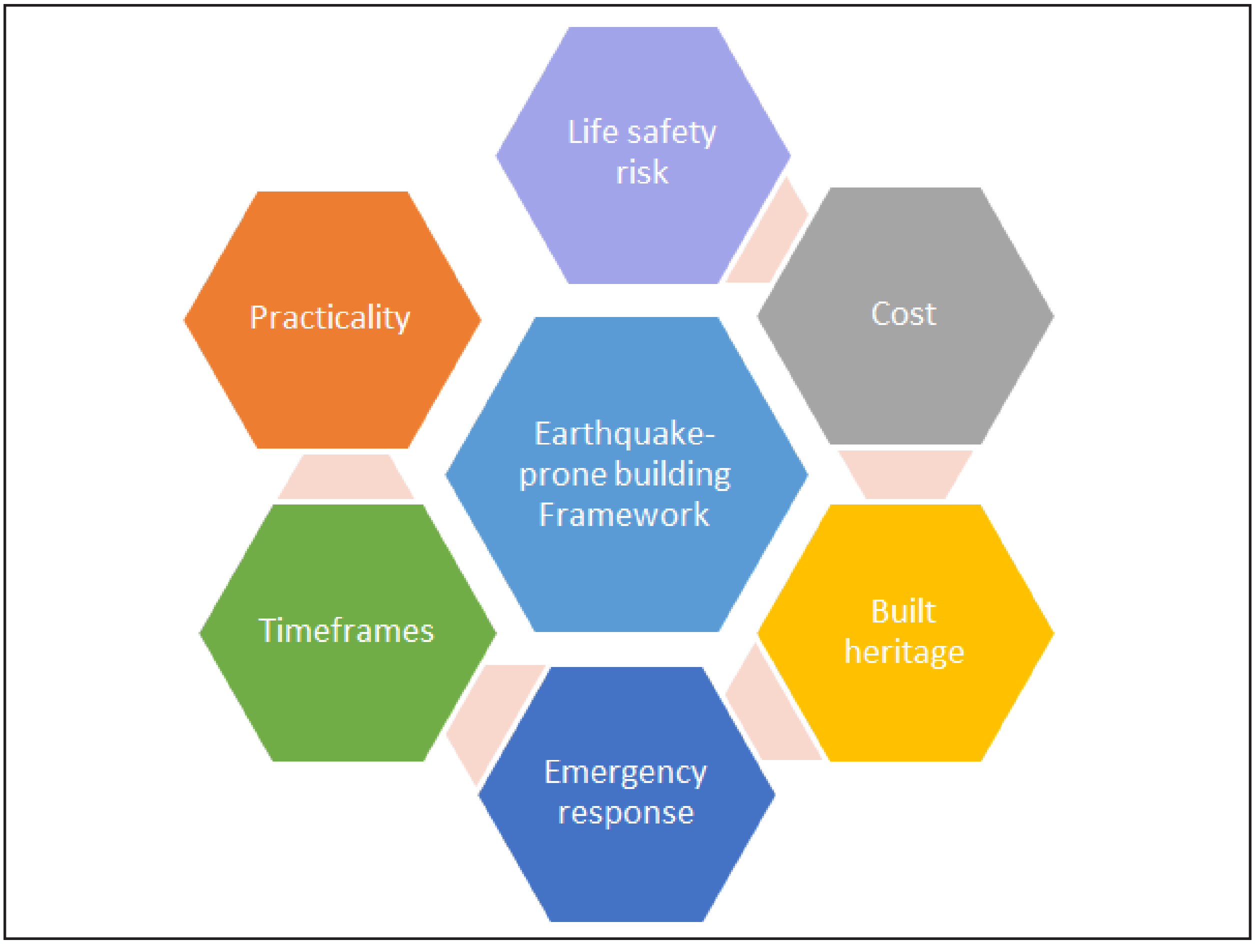


Fig. 5.18: Illustration of the Earthquake Prone Building Framework. (Source: Building Performance, Government of New Zealand)

The importance and uniqueness of this bill lies in the fact that it is one of the few pieces of legislation that is a national policy with specific timeframes and retrofit requirements for existing buildings. As a result of this bill, "each district or city council must have a policy that specifies the timeframe for earthquake-prone buildings being brought up to at least 34% of Building Code" (Anderson Llyod 2016, p. 1). In its first form, the bill applied the same timeframes for compliance nation-wide no matter the seismic risk, however, part of the amendments established different timeframes, dependent on the region's earthquake risk.

The different seismic risk categories are broken into low, medium or high and, depending on the seismic risk to the area, with different timeframes for the various councils throughout New Zealand to comply in identifying their earthquake-prone buildings and different timeframes for owner compliance in raising buildings to at least 34% of Building Code. The Councils in high seismic risk areas have 5 years to identify their EPBs; the Councils in medium seismic risk areas have 10 years; and the Councils in low seismic risk areas have 15 years.

Once the various Councils have identified their potential earthquake-prone buildings, owners will receive a council request asking them to provide an engineering assessment within 12 months of the notice to determine whether the building (or part of the building) is earthquake-prone. If the building is assessed as earthquake prone, an Earthquake Prone Building (EPB) notice will need to be issued:

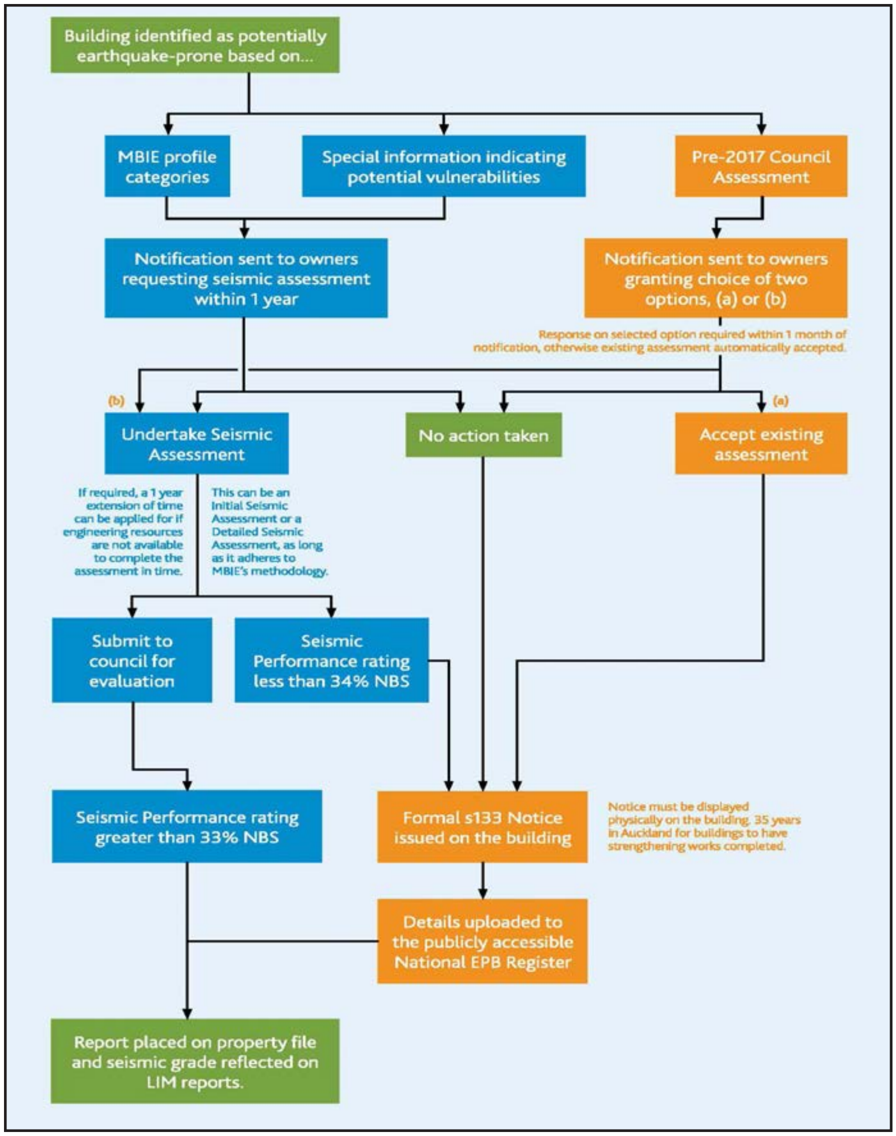


Fig. 5.19: Flow chart illustrating the identification, assessment and retrofit process of earthquake prone buildings. (Source: Auckland Council 2017, p. 11)

> The council is required to attach an EPB notice in a prominent place on or adjacent to the building. In particular, the EPB notice must: specify the building, or part of the building identified as earthquake-prone; say whether it is a priority building; state the earthquake rating; state that the owner must carry out the remedial seismic work required and the deadline for doing so; and state the option for the owner to apply for an extension if the building is a heritage building, or apply to be exempt from undertaking seismic work (if requirements are met).
>
> (Anderson Llyod 2016, p. 2)

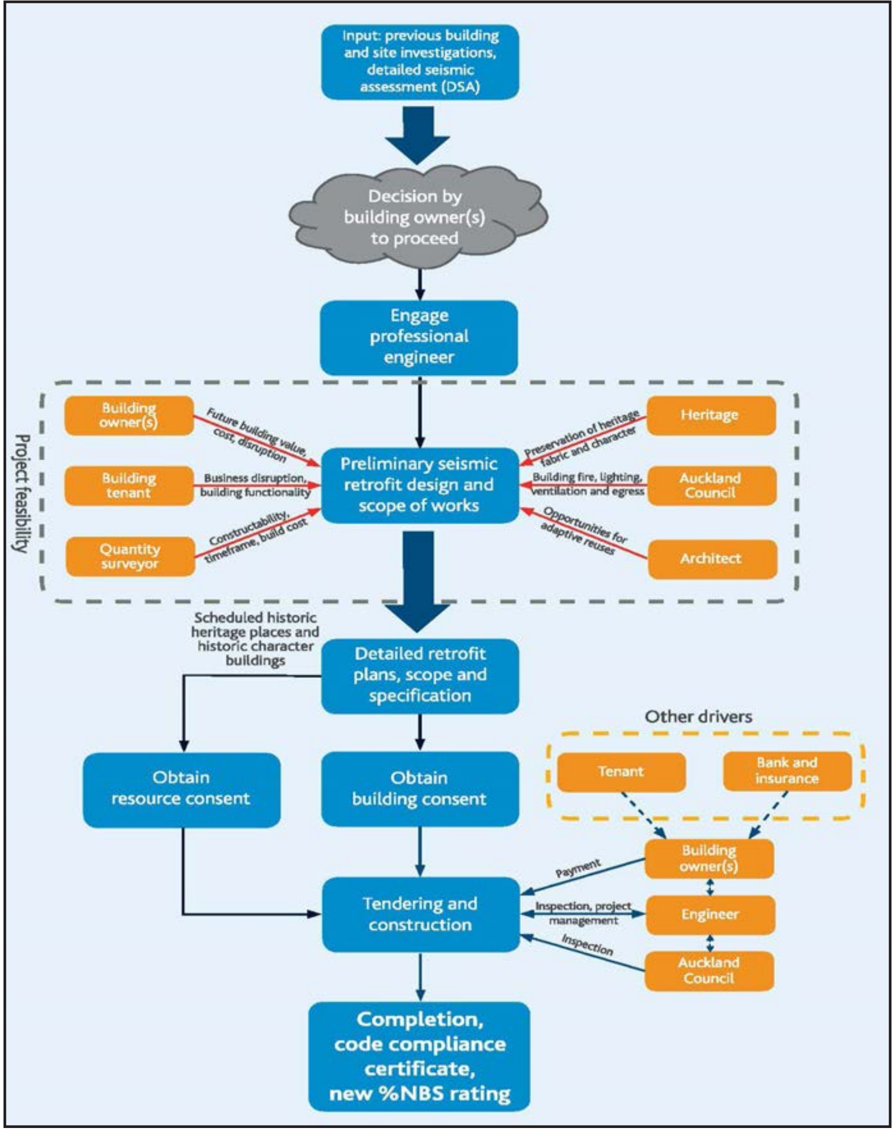


Fig. 5.20: Flow chart illustrating the earthquake retrofit process and inputs from the various stakeholders. (Source: Auckland Council 2017, p. 17)

The owners with identified earthquake-prone buildings in high seismic risk areas have 15 years to comply in raising the building to at least 34% of Building Code; owners in medium seismic risk areas have 25 years; and owners in low seismic risk areas have 35 years.

The Ministry of Business, Innovation & Employment provides a useful methodology document (*EPB Methodology: The Methodology to Identify Earthquake-prone Buildings*) guiding the various territories in identifying potentially earthquake-prone buildings, with guidance for the engineers conducting the assessments (MBIE 2017). The Horowhenua District Council also has its own District level equivalent document (*Earthquake-prone Buildings: Understanding the Building (Earthquake-prone Buildings) Amendment Act 2016*) to explain how the Act applies to their district (HDC 2017). The Auckland Council also has a very well illustrated guide (Figs. 5.19 to 5.22), "written for building owners, tenants and building managers who have been issued a council notice regarding the Potential Earthquake Prone status of their building" (Auckland Council 2017, p. 2). If British Columbia were to introduce a similar type of legislation or policy, these are immensely useful reference documents.

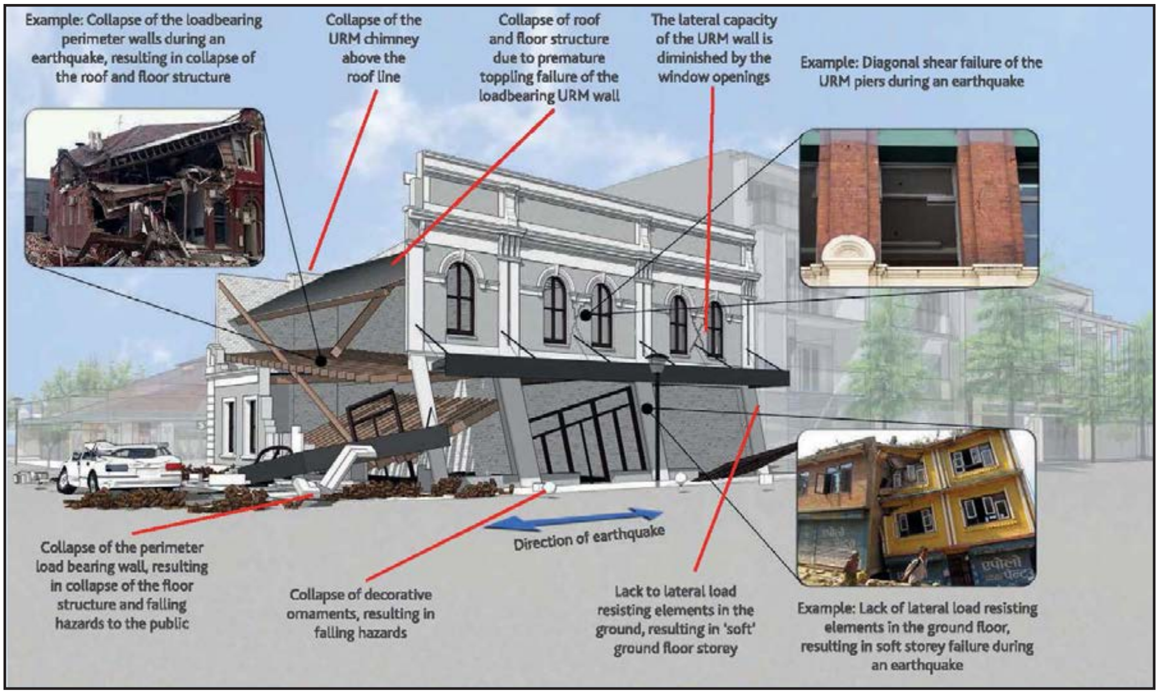


Fig. 5.21: Illustration showing one direction of earthquake forces acting on a building, with example damage. (Source: Auckland Council 2017, p. 24)

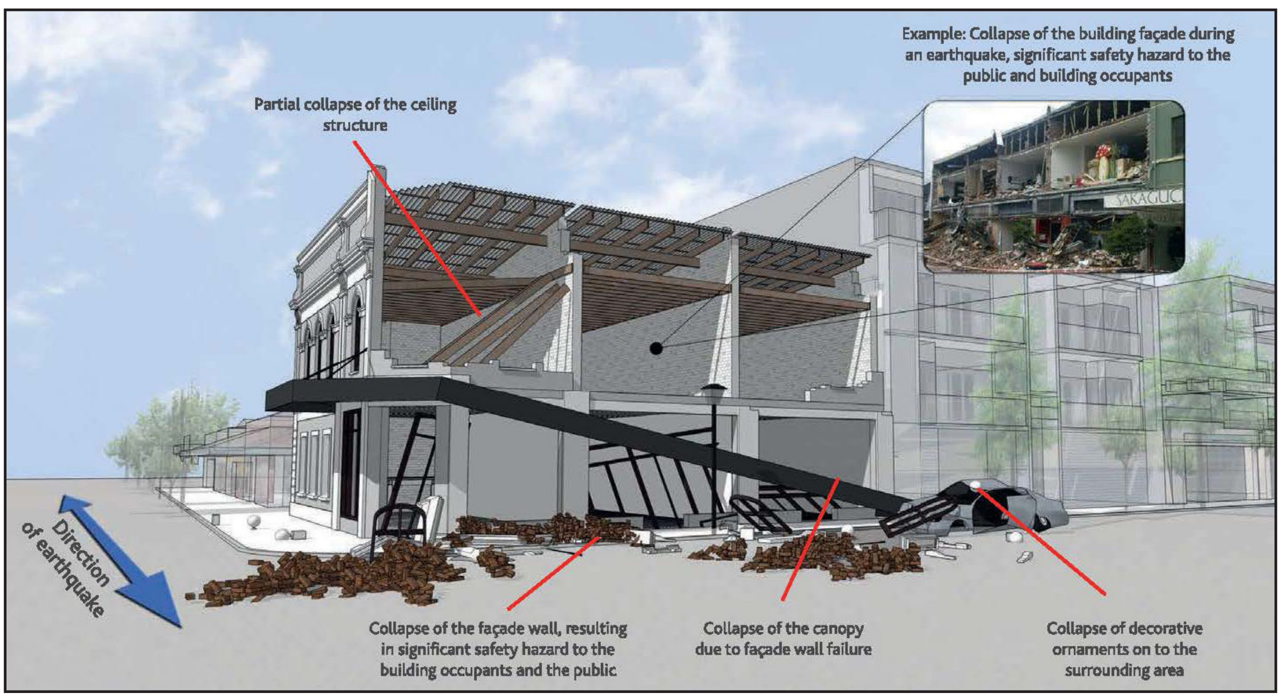


Fig. 5.22: Illustration showing the other direction of earthquake forces acting on a building, with additional example damage. (Source: Auckland Council 2017, p. 25)

Part of the EPB methodology for New Zealand includes an EPB Register, which is a "national, publicly accessible register of earthquake-prone buildings" (MBIE 2017, p. 3) (Fig. 6.X). Part of the reason behind the EPB register, is to try and increase public awareness of the risks and the need for seismic retrofitting existing buildings (MBEI 2021). "The system for managing earthquake-prone buildings targets buildings and parts of buildings that pose the greatest risk to public safety or other property in a moderate earthquake event" (Building Performance 2018a).

It is interesting and worth noting the emphasis placed New Zealand's built heritage when discussing managing its earthquake-prone buildings (Fig. 5.23):

> *The national system ensures the way buildings are managed for future earthquakes is consistent and strikes a balance between the following:*
>
> - *protecting people from harm in an earthquake*
> - *the costs of strengthening or removing buildings*
> - *the impact on New Zealand's built heritage.*
>
> (Building Performance 2018a)

Fig. 5.23: A screencapture of the Earthquake-Prone Building Register showing the matching results summary for Canterbury and an aerial view of the City of Christchurch with EPB areas pinpointed. (Source: Building Performance, Government of New Zealand)

FEDERAL FUNDING OPTIONS

Fig. 5.24: Photograph of earthquake damage used to advertise the REPB Financial Assistance Scheme. (Source: Building Perfomrance, Government of New Zealand)

New Zealand has a range of funding opportunities and financial incentives to encourage the conservation of its heritage buildings, including funding the seismic retrofit of its existing building. There is the Heritage New Zealand National Heritage Preservation Incentive Fund to encourage the conservation of nationally significant heritage places as well as a Regional Culture and Heritage Fund for not-for-profit organisations that own buildings used for culture and heritage purposes, which need seismic support.

There are also numerous, more earthquake-specific funding opportunities, such as the Residential Earthquake Prone Building (REPB) Financial Assistance Scheme, which is a loan scheme, intended to "help unit owner-occupiers in REPBs facing hardship over earthquake strengthening costs – particularly those in areas of high seismic risk" (Building Performance 2022). There is also the Unreinforced Masonry Buildings Securing Fund "to support building owners who have received a note from their council to secure their 'street-facing URM buildings'" (Building Performance 2018b). The total amount of funding available varies based on building type: "The fund will contribute up to half of the costs of the actual work involved in securing the parapet and/or facade, up to a maximum of $25,000 for buildings two storeys and below, and up to $65,000 for buildings three storeys or over" (Building Performance 2018c).

Launched in 2016, there is also the Heritage Earthquake Upgrade Incentive Programme (EQUIP) administered by the Ministry for Culture & Heritage and supported by the Ministry of Business, Innovation & Employment with Heritage New Zealand. Heritage EQUIP provides grants for both the professional advice needed (such as engineering or architectural advice, geotechnical reports and conservation reports), as well as grants to assist with the actual seismic upgrading work. Up to 50% of the cost for professional advice (up to a maximum of $50,000) is available to owners of Category 1 or Category 2 heritage buildings in medium or high seismic risk areas. And, up to 50% of the seismic strengthening cost (up to a maximum of $400,000) is available to owners of Category 1 or Category 2 heritage buildings in all seismic risk areas (Murphy 2020). "The programme contributed $12.95M for 111 projects (out of 138 applications) covering 153 buildings" (Scoop 2021).

Unfortunately, as of 2021, the Heritage EQUIP funding is no longer available. Its website is still up and running though, full of immensely useful information with regards to the seismic upgrading of heritage buildings (Heritage EQUIP). This type of funding model and information platform is a good reference for British Columbia and perhaps worth emulating, if at all possible. As Historic Places Aotearoa (HPA) President, James Blackburne, said at the time with regards to the loss of this funding opportunity: "This cut is a major blow to heritage preservation as the fund had been making extremely worthwhile grants towards seismic strengthening of heritage buildings as required by the Building (Earthquake Prone Buildings) Amendment Act of 2016" (Scoop 2021).

Fig. 5.25: Heritage EQUIP, until recently, provided much needed funding for seismic upgrading work. (Source: Heritage EQUIP)

> ICOMOS NZ Chairperson, Pamela Dziwulska, agrees with HPA – "it's an incredibly sad loss for built heritage in Aotearoa – buildings are at the forefront of everybody's day to day experiences of their town centres, cities, and even rural settings. Heritage buildings have an existing embodied energy that cannot be matched with modern materials (who's going to build in new solid masonry using limestone?), and their demolition would only send that energy to the landfills, despite their having become carbon neutral by now. Adaptation, using the right expertise, makes the most sense if the goal is to be sustainable and meet climate change targets. The government put these time limits on building owners who are acting as the kaitiaki, but have now taken away one of their main sources of monetary aid in order to protect and maintain Aotearoa's cultural heritage for future generations."
>
> (Scoop 2021)

From the above, it is clear that New Zealand, despite its size and wealth, is very actively pursuing seismic risk mitigation to save lives, livelihoods and its historic streetscapes. Much of the progress made has been a direct result of the earthquakes in the Canterbury region in 2010 and 2011 and, in particular, because of the losses experienced by the City of Christchurch. The following section examines the experience of this area to further illustrate the risks and possible outcomes.

PROVINCIAL LEVEL APPROACHES

CANTERBURY: OVERVIEW

Administratively, New Zealand is comprised of 16 regions that are subdivided into 67 Territorial Authorities (TAs). The four core regions are Auckland, Waikato, Wellington and Canterbury. The Region of Canterbury is located in the central-eastern area of the South Island of New Zealand and its capital is the City of Christchurch (Fig. 5.26). It was this area that experienced a series of earthquakes in 2010 and 2011 that highlighted the pressing need for increased seismic strengthening of New Zealand's existing buildings and resulted in the dramatic nation-wide change in approach with the Earthquake-Prone Buildings Act. "

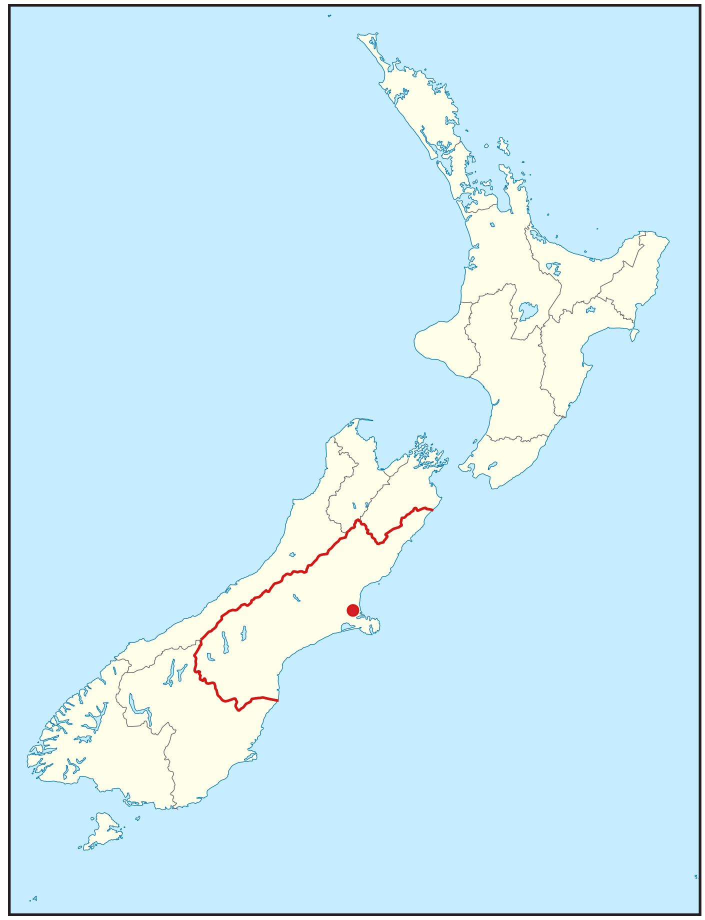


Fig. 5.26: Map of New Zealand with Canterbury outlined in red and Christchurch pinpointed with a red dot. (Source: NordNordWest, with additions by Ian Babbitt)

CANTERBURY: CITY OF CHRISTCHURCH

On September 4, 2010, at 4:35 am, there was a 7.1 magnitude earthquake that occurred in the City of Christchurch area. There was widespread damage, however, due to the timing of the event, there was fortunately minimal loss of life, as most individuals were at home in bed at the time. However, on February 22, 2011 at 12:51 pm a 6.2 magnitude earthquake struck (believed to be an aftershock of the September 2010 earthquake) that resulted in widespread damage and the loss of 185 people. 115 people were killed in the collapse of a single building (the Canterbury Television (CTV) Building) another 18 people in the collapsed Pyne Gould Corporation (PGC) Building. 50 additional people were killed by collapsing URM buildings and 70% of these deaths (35 people) were caused by the collapse of URM facades or wall portions "outside the buildings, involving pedestrians, persons in vehicles, and people who ran out of a URM building to escape" (Giaretton et al. 2016, p.2).

In addition to the heartbreaking loss of life, there was also a considerable loss of livelihoods as well. Christchurch's Central Business District (CBD) was closed and cordoned off for over two full years following the February 2011 seismic event. "Located in the area of the original town settlement (established by Royal Charter in 1856), the urban area retained numerous unreinforced masonry (URM) and other older buildings, including some 930 buildings with designated heritage status (NZHPT, 2012). Approximately 6,000 businesses employing 50,000 workers were located in the CBD, accounting for approximately 25% of the city's employment" (Chang et al. 2014, p. 8).

Beyond the lives and livelihoods lost, there was also a substantial loss of buildings and fabric, including many heritage buildings. There were, of course, the buildings that collapsed in the event itself. However, in the aftermath, any building (whether a heritage one or not) could be deemed dangerous by the Canterbury Earthquake Recovery Authority (CERA) and result in its demolition within just 10 days of the notice being issued, despite public outcry (Walton 2021). "By February 2014, 43 percent of central Christchurch heritage buildings listed with the New Zealand Historic Places Trust had been pulled down" (Anderson Lloyd 2014).

Fig. 5.27: Cathedral of the Blessed Sacrament partially collapsed in the February 2011 Chirstchurch earthquake. After eight years of debate and the site left in disarray, it was decided in 2019 to demolish the remaining sections of the Category I heritage-listed structure from 1905. (Source: New Zealand Press Association, David Wethey)

Fig. 5.28: Earthquake damage experienced in Christchurch's Central Business District, at the intersection of Lichfield, Manchester and High Streets in Christchurch, 2011. (Source: Mark Mitchell)

Figs. 5.29a & b: Aerial views of part of Christchurch's CBD showing the intersection of Lichfield, Manchester and High Streets in Christchurch. Left is from Feb. 2011, immediately following the earthquake, showing numerous collapsed buildings, and right is from Feb. 2022, over ten years later, showing the numerous buildings lost with nothing built in their stead. (Sources: Google Earth)

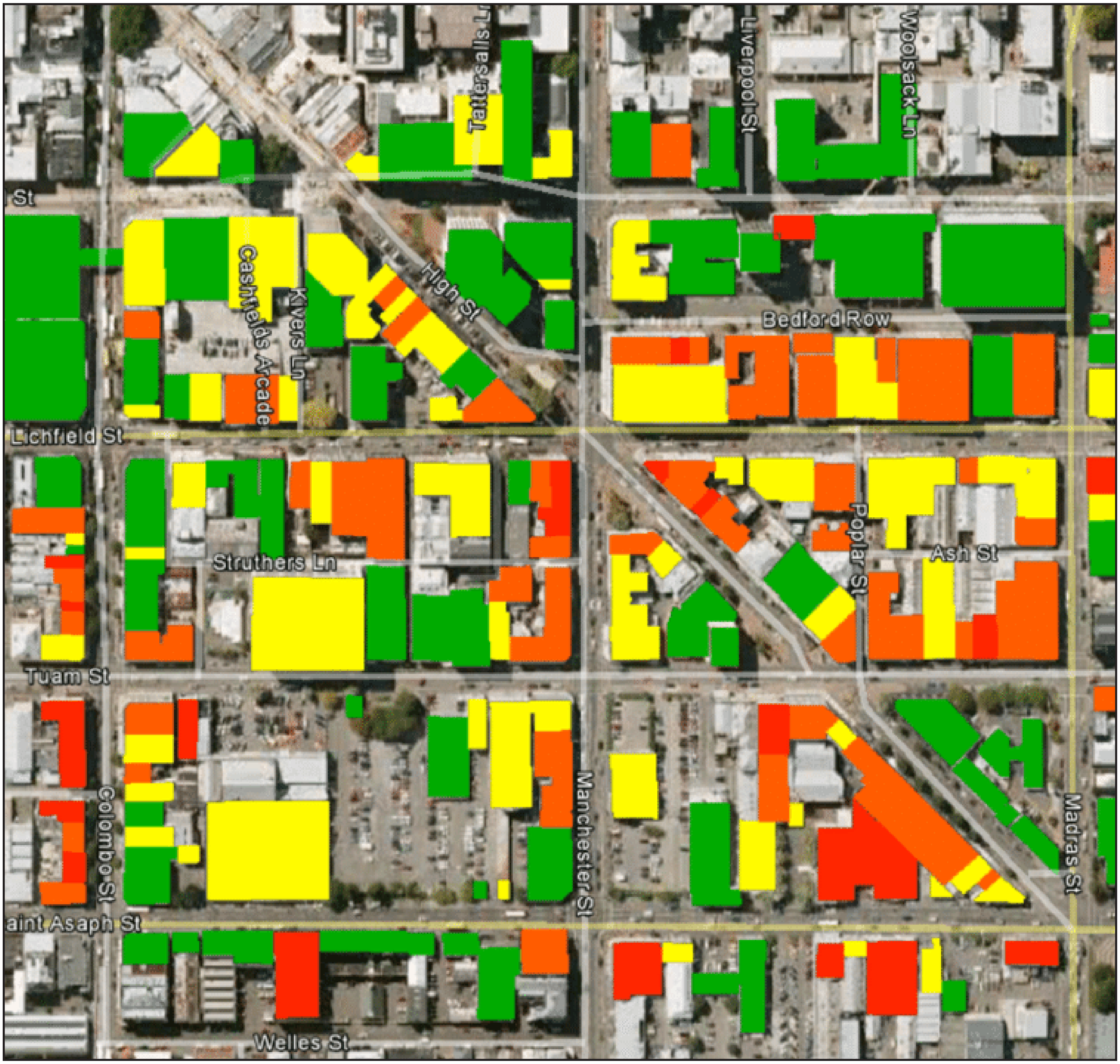


Fig. 5.30: Map showing the various degrees of damage to the Central Business District buildings in the Christchurch earthquake, 2011. Green illustrates no damage, yellow minor non-structural damage, orange severe structural damage and red is total collapse. The red rectangle in the middle, where multiple streets intersect, is the collapsed building from Fig. 5.28. (Source: Fabio Dell'Acqua)

Extensive studies have been conducted into the various buildings that failed in the Canterbury earthquakes and why. Recounting their findings is beyond the scope of this report, however, an examination of their results is highly recommended to better understand why these various buildings, including numerous URM buildings, failed. *The Report to the Royal Commission of Inquiry: The Performance of Unreinforced Masonry Buildings in the 2010/2011 Canterbury Earthquake Swarm*, by Jason M. Ingham and Michael C. Griffith, is particularly enlightening. The reasons aside, the impact that these seismic events had on Christchurch's earthquake risk mitigation was profound:

> Prior to the 2010 September earthquake, the Christchurch City Council had adopted a passive approach, whereby earthquake-prone buildings were identified but retrofits would typically only be required with a change of use or significant modifications, and a building could be deemed not earthquake-prone by raising the lateral strength above the 33% limit, although many informed owners opted to retrofit to higher than the minimum 33% of current code. After the September earthquake, the Christchurch City Council changed the earthquake-prone building policy such that the target strengthening level was explicitly stated to be 67% of current code.
>
> (Chang et al. 2014, p. 7)

Through the amendments to the Earthquake-prone Buildings Act, it is hoped that Christchurch and other municipalities in New Zealand are better prepared for the next big earthquakes. In addition to the national funding available, Christchurch has encouraged compliance with the seismic retrofitting required, particularly for its remaining heritage buildings, with its Heritage Incentive Grants Fund that provides up to 50% of the value of the scope of work outlined. There was also the Canterbury Earthquake Heritage Buildings Fund "to assist in funding insurance shortfalls for earthquake-related repairs to listed and non-listed heritage and character buildings damaged in the Canterbury Earthquakes" (Heritage New Zealand). Despite the encouragement, there are concerns that progress is moving too slowly. "New research showing a heightening risk from the Alpine Fault is seeing mounting pressure on owners to strengthen the 650 earthquake-prone buildings in Christchurch" (Walton 2021).

CONCLUDING REMARKS

Shortly after these events, there was immense interest in this topic and it galvanized some action. Unfortunately, it seems as more time has passed with new crises to focus on, the sense of urgency for action has faded. It is hoped that through this research, in particular revealing some of the more recent experience of the City of Christchurch, that the various municipalities throughout British Columbia that are equally at risk, will similarly see the need to address the seismic rehabilitation of their heritage buildings to hopefully help save lives, livelihoods and their historic streetscapes.

CONCLUSION

SUMMARY OF FINDINGS

From the various international examples, it is clear that British Columbia could be doing more with regards to its seismic preparedness and, in particular, the seismic upgrading of existing buildings, including heritage buildings. Although over the years different provincial jurisdictions have discussed this issue, such as Vancouver beginning in the 1990s and Victoria more recently in the mid-2010s, less progress has been made than is needed. BC should be commended with regards to its focus and results for encouraging the seismic upgrading and resiliency of its school buildings. However, there is much more that can and should be done to protect the built environment more broadly and the numerous lives and livelihoods within these structures throughout the province.

The recent experience in Christchurch, and other seismically active areas, opened people's eyes to our region's risk, but only for a time. Following that devastating event, BC municipal and provincial staff engaged with experts to learn from their experience (Ingham 2022). Numerous scholars researched and wrote about the risks here, in the hope of galvanizing communities and policy makers to do more (Bebamzadeh 2019; Ventura and Bebamzadeh 2016; Paxton et al. 2015; Bolton et al. 2015; Paxton et al. 2013; Ventura et al. 2005; Onur et al. 2005, among many others). Journalists wrote articles to increase awareness with dramatic titles such as "The Most Doomed City in Canada: What the Big One Will do to Victoria" (Hooper 2019) or "BC earthquake threatens Vancouver buildings" (Hoekstra 2016). Unfortunately, however, minimal progress has been made so far and other crises (such as the COVID-19 pandemic and climate related disasters) have dominated the public policy psyche in recent years, at the expense of other crises; including the looming big one.

Based on the 2004 research of Onur and Seeman (nearly 20 years ago now), the earthquake probabilities for the area are as follows. Although these percentages are technically for Victoria, this would include and also impact the numerous smaller municipalities on Vancouver Island, as well as those along the southwest coast of the mainland:

- The probability of a "structurally damaging" (magnitude 7 or more) crustal or subcrustal earthquake impacting Victoria in the next 50 years is 21%.

- The probability of a "non-structurally damaging" (magnitude 6 or less) crustal or subcrustal earthquake impacting Victoria in the next 50 years is 53%.

    o Even though this probability is categorized as "non-structurally damaging," given their nature, un-retrofitted URM buildings would likely experience some structural damage in this scenario, endangering lives and livelihoods.

- The probability of a M9 mega-thrust earthquake in the next 50 years is 11%.

(Paxton 2015, p. 4)

The probability of such seismic events has only increased as more time has passed without incident. Considering the geography of the region, it is not a matter of *if* a major earthquake strikes BC, but a matter of *when*. Looking at how earthquakes impact the built environment, and in particular historic streetscapes, more needs to be done in BC to save lives and livelihoods. This is particularly the case for the province's numerous heritage buildings, which are some of the most at risk, having been built prior to our modern building code (and in some instance, prior to any building code), using materials and techniques that do not account for seismic vulnerability, such as the numerous unreinforced masonry (URM) buildings throughout the province.

> Many unretrofitted buildings lack sufficient connection at one or more points in the seismic load path and this is the greatest seismic vulnerability of URM buildings. Several post-earthquake reconnaissance reports have cited a lack of sufficient connection between diaphragms and walls as a common reason for damage and collapses (Deppe 1988, Bruneau 1990, LATF 1994, Ingham and Griffith 2011b).
>
> (Paxton 2015, p. 14)

Fig. 6.1: Historic streetscapes such as this are distributed throughout BC and are at possible risk whenever the next large earthquake should strike. (Source: Ian Babbitt)

From this research, there are some key findings to highlight:

- It is inevitable that a major earthquake will strike BC, it is simply a matter of time.

- Greater public awareness is needed of the risks and the mitigation strategies available.

- More needs to be done in BC to save lives and livelihoods, particularly those located in the province's numerous heritage buildings, especially its unreinforced masonry (URM) buildings.

- Funding is the biggest obstacle for effective seismic upgrading. Investment is needed to further encourage the effective retrofitting of vulnerable structures throughout the province, not just in the largest municipalities.

- There are policy tools available, not currently used, to help encourage more widespread seismic upgrading activity (such as mandatory retrofit legislation).

o It is preferable to introduce such requirements before a large-scale event to minimise the damage and losses, but unfortunately more often than not, seismic risk mitigation legislation is enacted following an earthquake as a result of widespread damage and loss of life.

- Preparedness can help reduce all forms of losses (loss of life, loss of revenue, loss of fabric, etc.) and more could be done to better prepare BC.

> State and local seismic policy regimes do not necessarily correlate to regions of greater seismic risk. Risk perception and awareness results in regional differences in the development and implementation of earthquake policies and preparedness. Although seismic risks are commonly recognized and acknowledged in regions with moderate to high seismic, there is relatively little active policy engagement or attention from stakeholders and decision makers with the exception of the immediate aftermath of major events.
>
> (Resilience Institute 2010, p. 7)

RECOMMENDATIONS

With the issues and overseas approaches in mind, the following are some key areas that could be examined to increase the seismic resiliency of British Columbia's historic streetscapes:

ACTIVATE NETWORK

A BC-equivalent of a Seismic Safety Commission could be introduced to help spearhead some of these recommendations.

This would also provide a logical body to participate as a BC-representative in the Western States Seismic Policy Council (WSSPC), opening up a valuable networking opportunity for the province to tap into the wealth of knowledge and expertise in the region.

INCREASE KNOWLEDGE AND UNDERSTANDING

While there is an acceptance and acknowledgement among academics and professionals with regards to this region's concerning seismicity, greater awareness among the general public (including politicians) is needed with regards to the seismic risk being faced here and the possible mitigating strategies.

It is recommended to increase the awareness of the incentives already available in Vancouver and Victoria to ensure as many owners as possible consider such retrofit work, particularly with funding opportunities such as the Seismic Parapet Incentive Program.

Municipalities also need to be encouraged to compile publicly available lists of their vulnerable buildings.

o Such lists exist for some of the larger municipalities, such as Vancouver (Hoekstra 2016) and Victoria (Bebamzadeh et al. 2019), but unfortunately, they are not publicly accessible or searchable. These should be easily accessed and regularly updated to encourage awareness of at-risk buildings and to galvanise action to mitigate said risk.

Professionals of the built environment (such as architects and engineers) should be encouraged to find creative solutions to address the seismic upgrading requirements of heritage buildings, while respecting and protecting their heritage value and Character Defining Elements (CDEs) and avoiding causing unnecessary damage.

o CDEs should guide where interventions do not go; and

o There is no one-size-fits-all solution to addressing seismic upgrading, each building should be assessed and planned for based on its own inherent strengths and vulnerabilities.

ENCOURAGE ACTION

Even without introducing legislation mandating such action, owners of buildings with fall hazards (such as chimneys, cornices, hanging signage, ornamental features, parapets, etc.), should be actively encouraged to secure these life-safety threats, as soon as possible.

o As visible from the experience in California and New Zealand, however, mandatory requirements are far more successful than voluntary ones.

> Based on the review of California, it is concluded that mandatory programs are much more effective at mitigating URM seismic risk than are voluntary (or other passive) programs. However, there are a number of socioeconomic issues to be considered and it is essential that any ordinance must have substantial input from the stakeholders within the community. Based on the facts that Victoria does not have an inventory of URM buildings, does not have ordinances requiring parapet upgrades, and only requires comprehensive upgrades as part of a change of use/ occupancy, it is concluded that URM seismic risk mitigation measures in Victoria are lacking compared to other jurisdictions. The same may be said of Vancouver or southwestern BC in general.
>
> (Paxton 2015, p. 68)

EXPAND INCENTIVES

Part of the process for encouraging action must include expanding financial incentives and assistance for such work, from all levels of government.

There is a current petition to the Government of Canada (from February 2022) to establish a federal level tax credit for the conservation of heritage buildings, which would be a welcome and much needed incentive to encourage such rehabilitation work. Support of such a federal level tax credit should be encouraged.

While there is the much needed (and over-subscribed) provincial level funding offered through Heritage BC's Legacy Fund, the Heritage Conservation Program is a broader funding source, supporting all types of heritage conservation work, not solely seismic upgrading efforts.

o It is recommended that a separate Seismic Upgrading Fund be established, perhaps a very targeted programme similar to Victoria's Seismic Parapet Incentive Program, to encourage this important and urgently needed work, particularly securing fall hazards.

While the City of Victoria should be commended for its robust heritage incentive programme, it is only one municipality out of hundreds in the province providing such funding opportunities, despite the risk to these other areas as well.

o In fact, even within its immediate vicinity, the 12 other cities, district municipalities and towns of the Greater Victoria Region are not eligible for the various incentives offered by the City of Victoria (the House Grants, the Building Incentive Program, the Tax Incentive Program and the Seismic Parapet Incentive Program).

o Municipalities should be encouraged to develop their own seismic incentive programmes, similar to Vancouver and Victoria, in order to address and motivate this much-needed work ***before*** *a seismic event takes place.*

EXPLORE POLICY

Although a daunting task, it is highly recommended that there be an exploration into whether a Provincial level policy can be adopted to help mitigate the risk posed by existing buildings, including heritage buildings and especially unreinforced masonry (URM) buildings.

- *Whether in the vein of California's targeted URM Law or New Zealand's broader Earthquake-Prone Buildings Act or perhaps another.*

Even if not a formal policy or legislated requirement at the federal or provincial levels, municipalities should be encouraged to investigate what additional tools can be used to increase efforts in seismic rehabilitation, including risk assessment of individual buildings and support for appropriate mitigation.

> Seismic retrofitting of existing buildings remains a complex and often politically difficult area for governmental authorities. Issues of heritage, construction complexity, social upheaval and financial considerations including loss of rental income, can put the building owner to considerable disadvantage and threaten the commercial viability of any retrofit project. This disruption has to be balanced against the advantages of the nation's building stock becoming more resistant to earthquake damage, and hence providing a safer social environment for its citizens.
>
> (Murphy 2020, p. 1)

CONCLUDING REMARKS

While it is recognised that this is a complicated and expensive endeavour, the urgency with which action is required is abundantly clear when looking at the experience of these other jurisdictions; particularly the more recent experience of Christchurch, New Zealand. It is crucial that British Columbia take a more proactive approach, rather than a reactive one, to addressing the seismic risk of the area and the seismic rehabilitation needed for its existing buildings, including its numerous heritage buildings. The potential loss of lives, living quarters and livelihoods within and around these buildings is too high to not do more, while there is still time.

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