SEISMIC RISK AND BRITISH COLUMBIA'S HISTORIC STREETSCAPES

SUMMARY BRIEF

CUMMER HERITAGE CONSULTING

CHC

KATIE CUMMER, PHD CAHP

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.

BRITISH COLUMBIA | Heritage Branch

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INTRODUCTION

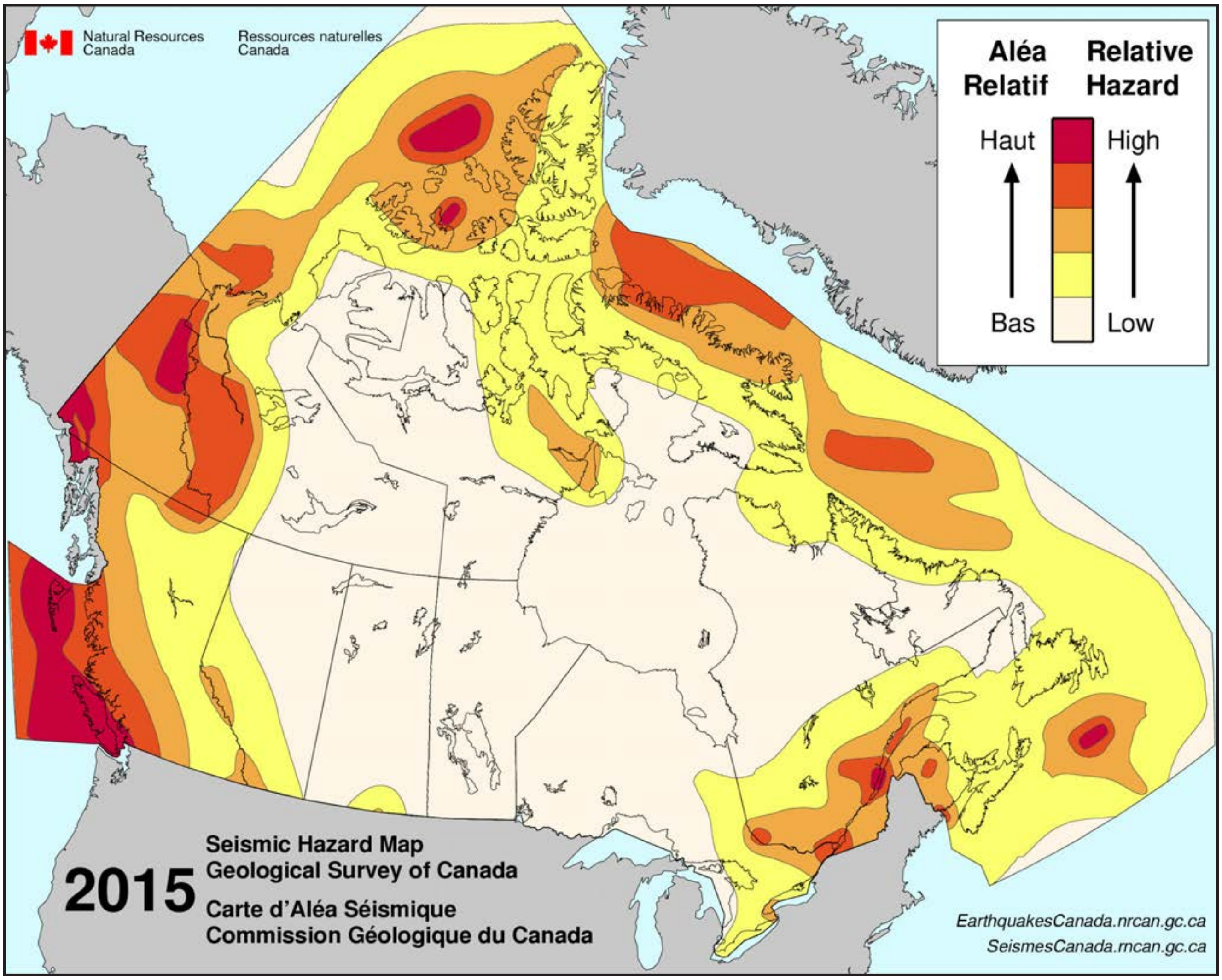


Fig. 1.1: Seismic Hazard Map of Canada, 2015. (Source: Natural Resources Canada)

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. Often distinctly designed using long-lasting materials, 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 particularly worrisome when considering the various and 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.

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, further highlighting the need for investment in seismic rehabilitation:

> - 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%.
>
> - 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, such as the various 19th and 20th century unreinforced masonry (URM) buildings distributed throughout the province, which are some of the most at risk. This is the case because they were built prior to our modern building code using materials and techniques that do not account for seismic vulnerability.

> 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)

There is a surprising lack of BC published materials outlining how best to approach the protection and 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 much more technical nature largely intended for academics and professionals, often engineers. To a non-professional, this content can be somewhat overwhelming and inaccessible.

This brief, based on a larger research 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. There is a need for greater focus and attention on this issue in British Columbia to protect the historic built environment and the lives within them.

The hope is, through anaylsis of the US and New Zealand, 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 retrofitting and seismic upgrading are used interchangeably in this document.

Fig. 1.2: Historic streetscpes such as this are distributed throughout BC and are at possible risk whenever the next large earthquake should strike. (Source: Ian Babbitt)

> 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)

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 and 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). The largest, most recent earthquakes for BC were in the 1940s. In 1946, there was a magnitude 7.3 earthquake at 10:15 am on Sunday, June 23rd and in 1949, there was a magnitude 8.1 earthquake on Monday, August 22nd. On March 28th, 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.

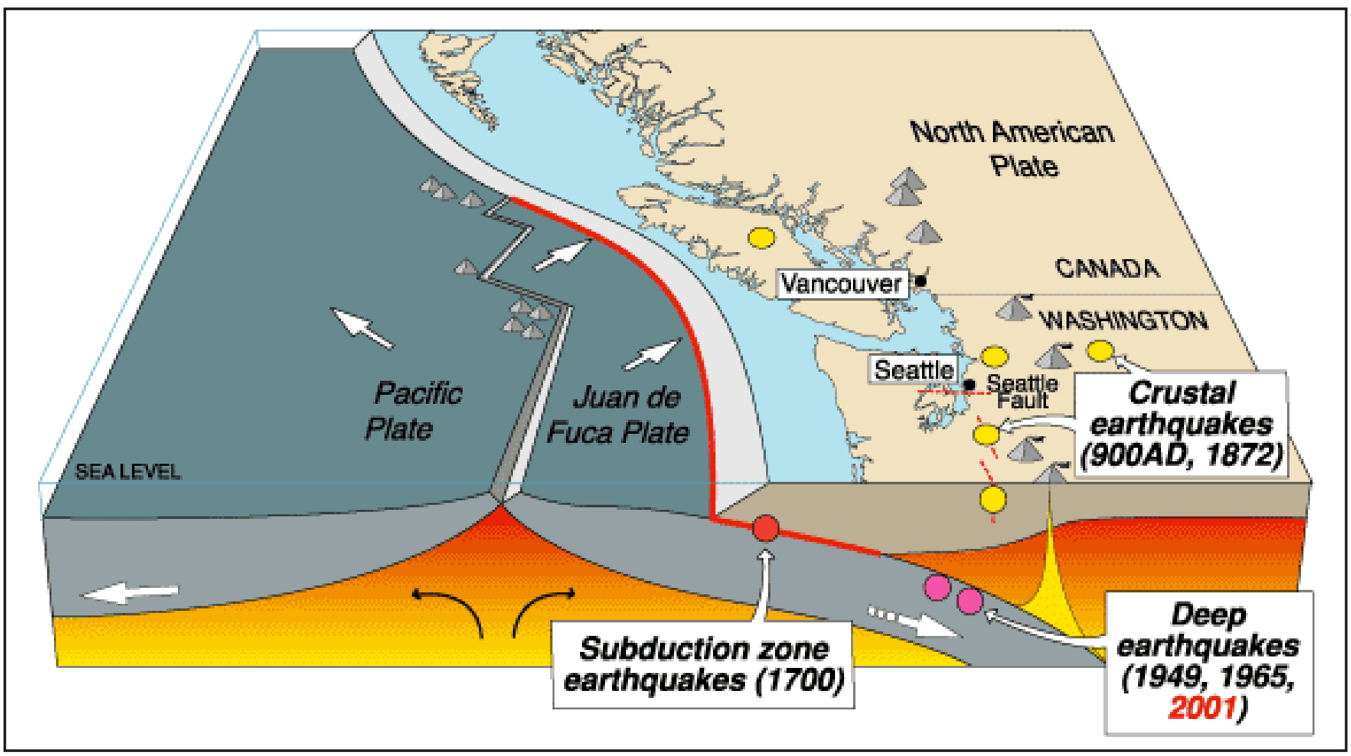


Fig. 2.1: Cascadia earthquake sources affecting British Columbia and the northwest coast of the USA. (Source: United States Geological Survey)

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.

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. 2.2 to 2.3). 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. 2.2: Port Alberni Chimney Damage, 1946, over 70 km away from the earthquake's epicenter. (Source: CDM)

Fig. 2.3: 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. 2.4 to 2.7).

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)

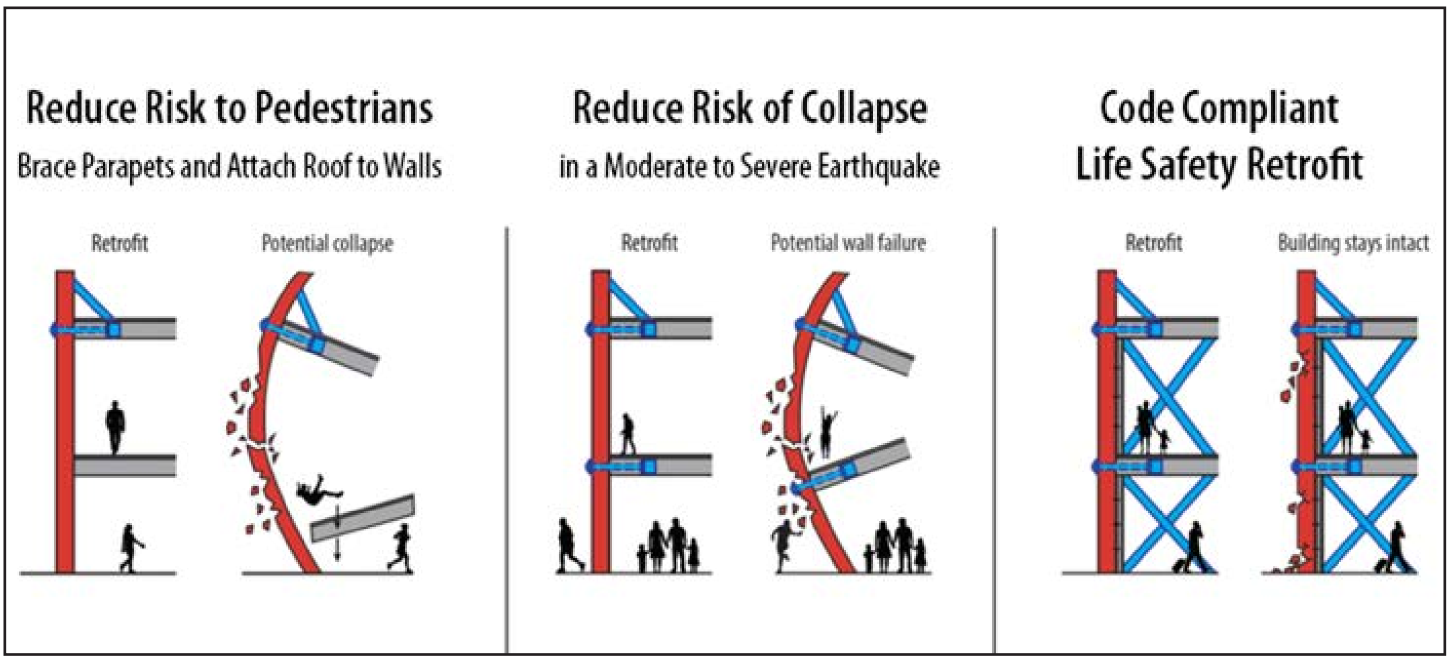


Fig. 2.4: Illustration of the risks posed by existing buildings, particularly Unreinforced Masonry (URM) buildings. (Source: Portland Government)

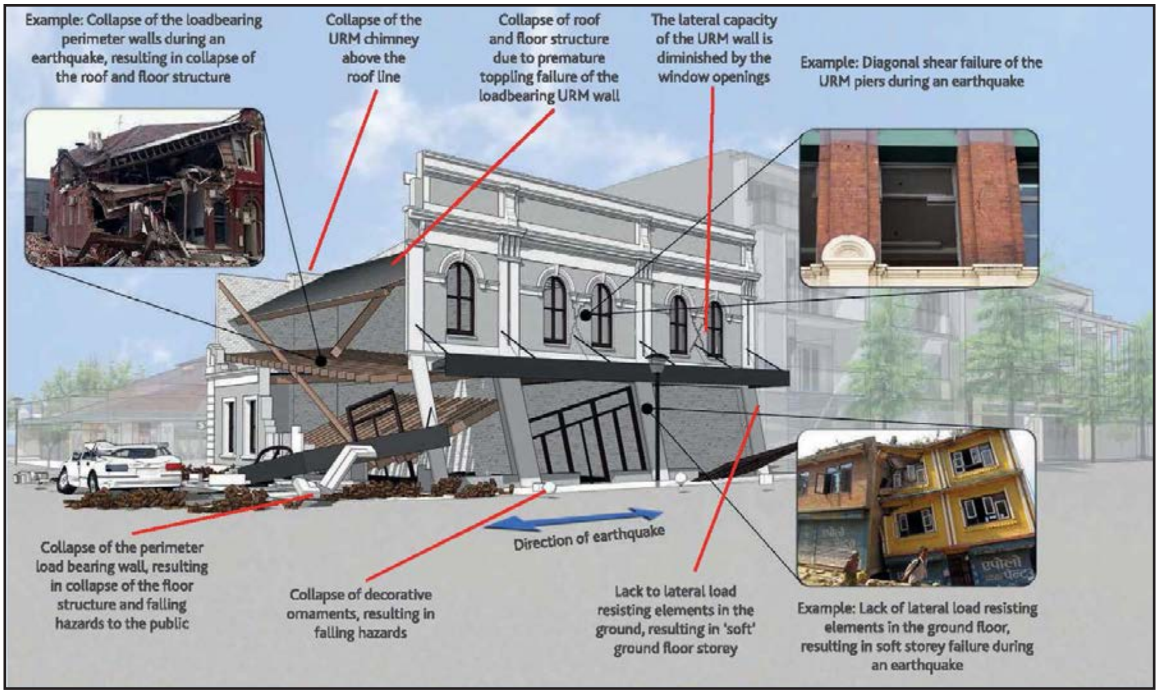


Fig. 2.5: Illustration showing one direction of earthquake forces acting on a building, with example damage. (Source: Auckland Council 2017, p. 24)

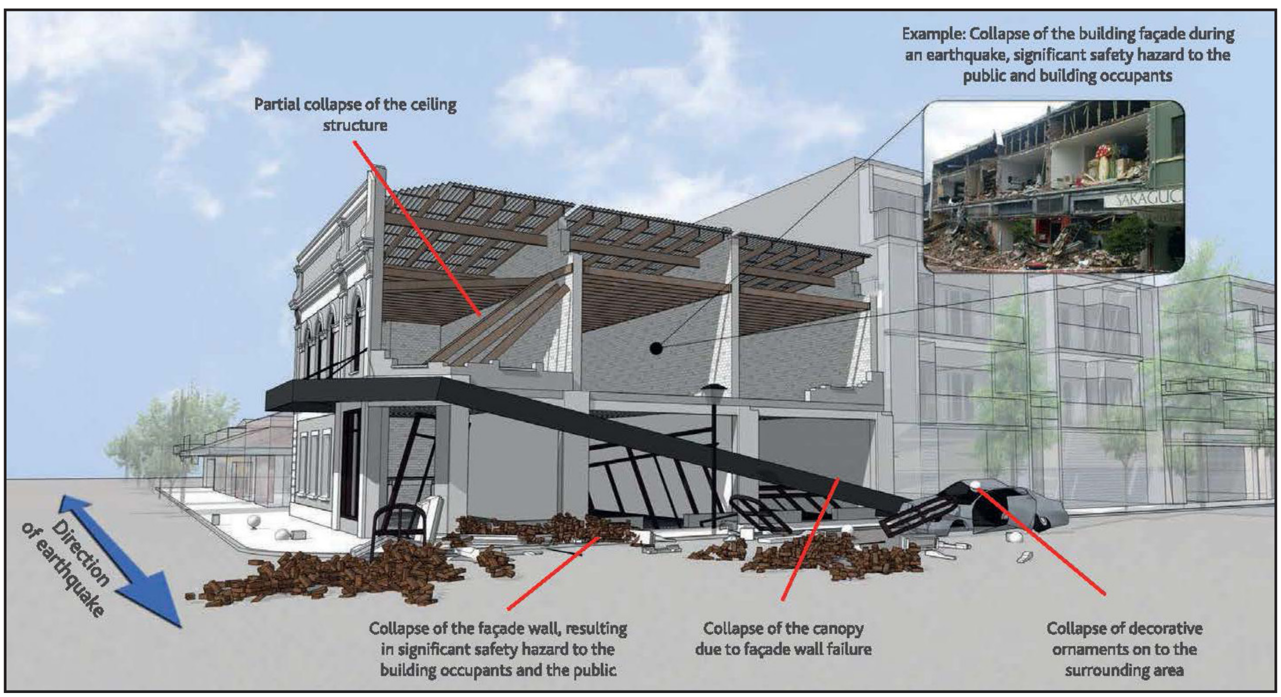


Fig. 2.6: Illustration showing the other direction of earthquake forces acting on a building, with additional example damage. (Source: Auckland Council 2017, p. 25)

Fig. 2.7: 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; 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)

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.

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)

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)

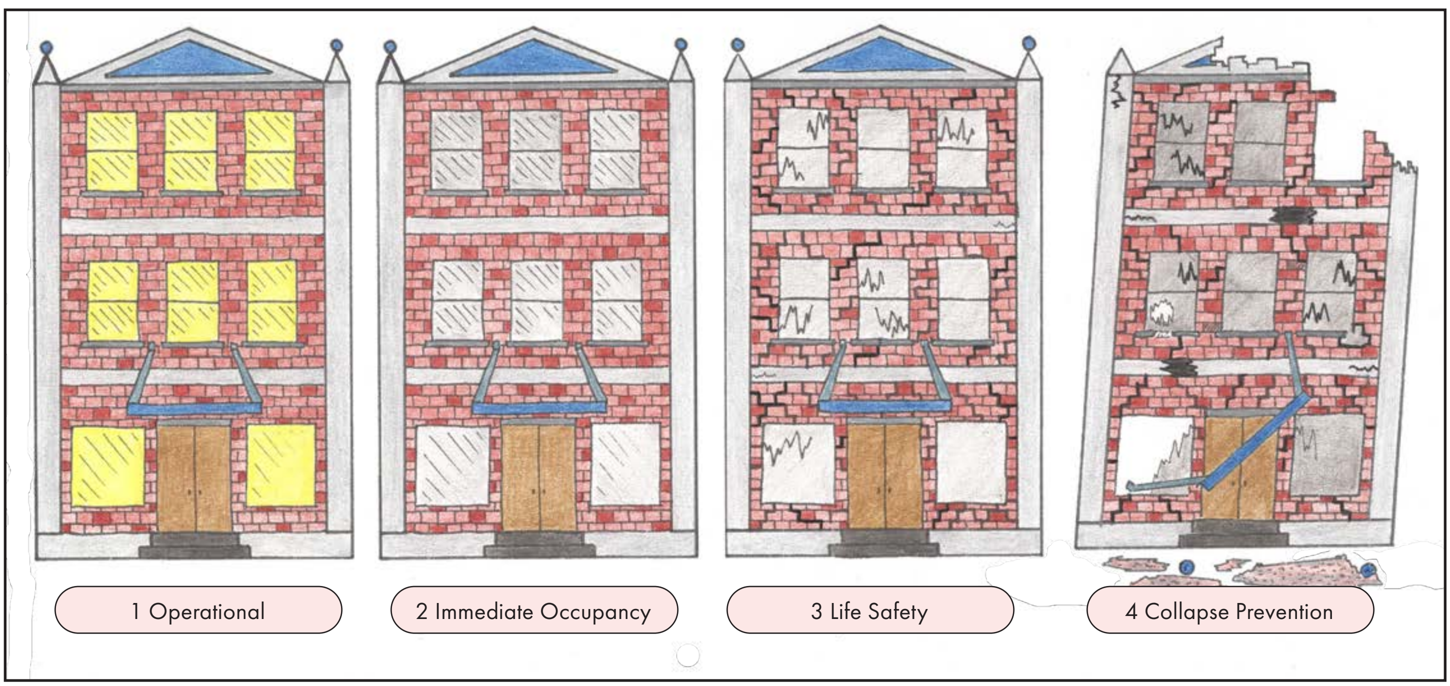


Fig. 3.2: Illustration of the different building performance levels that heritage buildings can be seismically upgraded to. (Source: Ian Babbitt, based on the American Society of Civil Engineers performance level illustration from ASCE 41)

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).

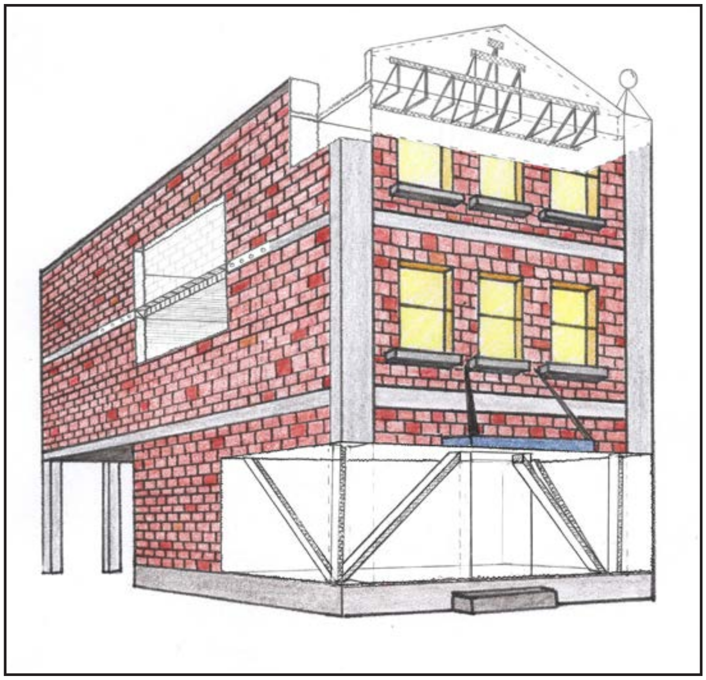
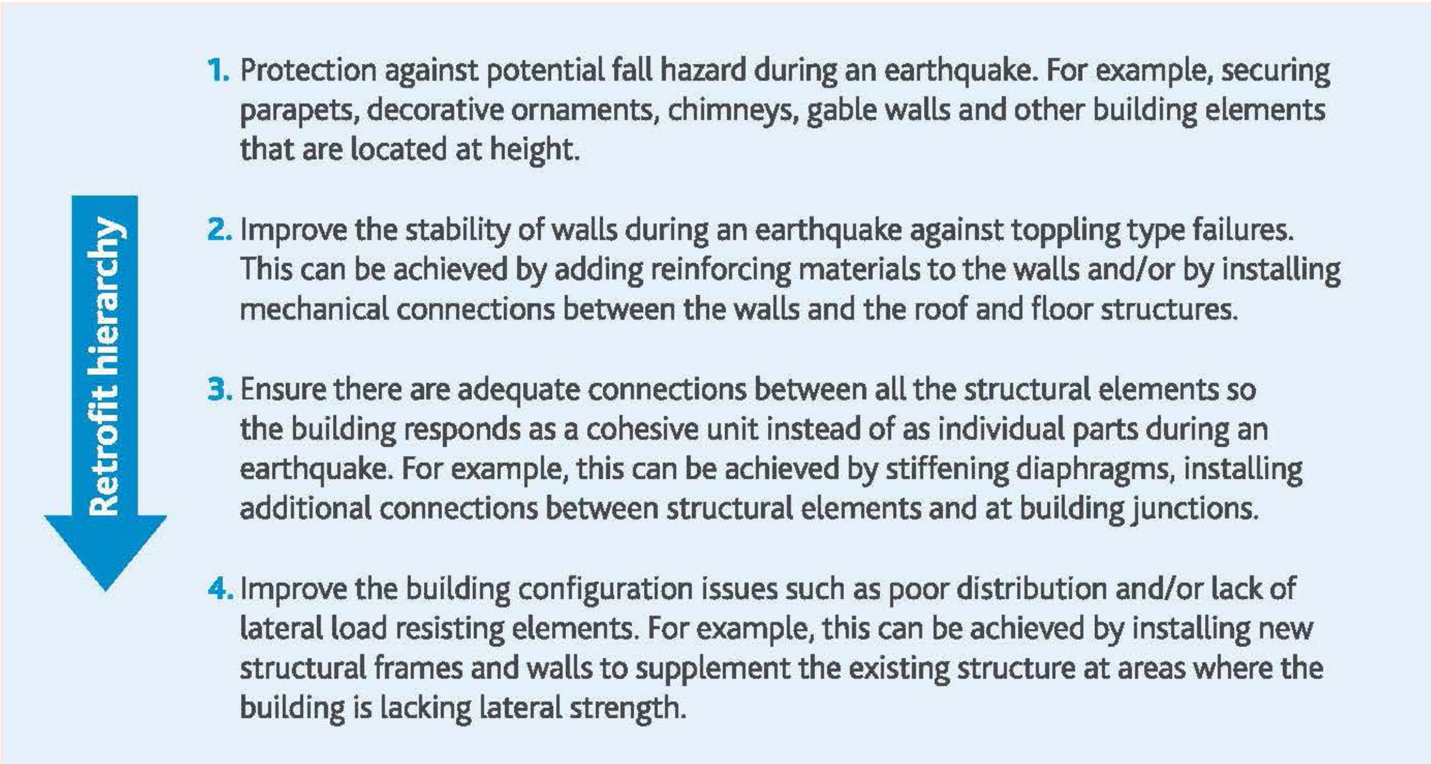


Fig. 3.3: Illustration of some of the different seismic upgrading options available. (Source: Ian Babbitt)

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, 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).



Retrofit hierarchy

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 hope is to encourage the seismic upgrading of existing buildings, especially heritage buildings, which are particularly vulnerable having often been built prior to any building code. Although the cost to seismically upgrade heritage buildings is high, it is desperately needed in this region to save lives and livelihoods.

Unfortunately, as a result of the high cost, 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 examined in detail in the larger research report, other jurisdictions use different financial, legislative and policy approaches to further encourage the seismic upgrading of their existing buildings, including heritage ones. The following section provides a summary of recommendations based on that larger research, as possible inspiration for BC going forward.

CONCLUSION

SUMMARY OF FINDINGS

The province of British Columbia is not alone in its seismic risk. 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, including 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. In examining the US West Coast States and New Zealand (as discussed in full in the larger research report), 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. 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.

> 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)

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.

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), which "develops seismic policies and shares information to promote programs intended to reduce earthquake related losses" (WSSPC 2022). The WSSPC technically includes both British Columbia and the Yukon (Fig. 4.1), but there is currently no BC representation in the WSSPC membership. This would open up a valuable networking opportunity for the province to tap into the wealth of knowledge and expertise in the region.

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 2022)

Fig. 4.1: Map of the Western States Seismic Policy Council. Note the inclusion of BC and the Yukon. (Source: WSSPC)

The mission of the Oregon Seismic Safety Policy Advisory Commission (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)

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 funding opportunities like the Seismic Parapet Incentive Program.

Municipalities also need to be encouraged to compile publicly available lists of their vulnerable buildings. This 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 risk reduction policy be enacted.

o Such lists exist for some of the larger BC 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.

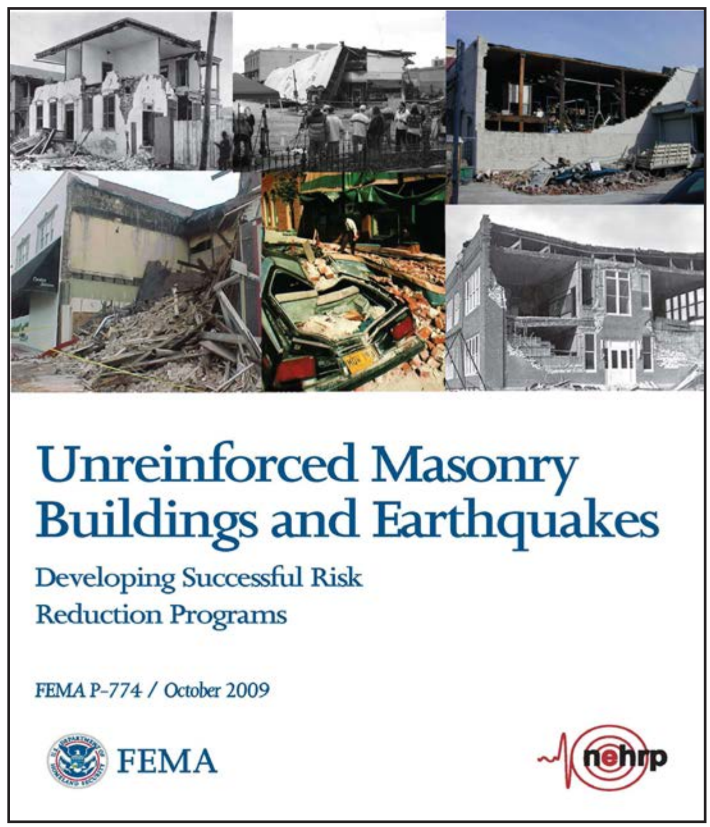


Fig. 4.2: One example of the numerous useful FEMA publications publicly available for reference and community use. (Source: FEMA)

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 That being said, as visible from the experience in California and New Zealand, mandatory requirements are far more successful than voluntary ones.

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.

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)

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)

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)

EXPAND INCENTIVES

Part of the process for encouraging action must include expanding financial incentives and assistance for such work, from all levels of government, to increase the seismic resiliency of British Columbia.

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. 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).*

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)

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.

o California's targeted URM Law or New Zealand's broader Earthquake-Prone Buildings Act (Building Performance 2018) are useful potential policy development references. Part of these policies include the placement of warning placards at the entrances of at-risk buildings that receive a revised sign once seismic retrofit has been undertaken (Fig. 4.3). They also recommend establishing seismic retrofit standards; adopting mandatory strengthening programmes; and enacting measures to reduce the number of occupants in URM buildings.

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.

o Seattle's URM Policy Committee document is an immensely useful reference for any municipality exploring the important, but complicated work of introducing a seismic retrofit policy (URM Policy Committee 2017).

Fig. 4.3: Example of a seismic hazard sign installed on URM buildings in California. (Source: Courtney Sherwood)

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)

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)

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 (Fig. 4.4). 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. "By February 2014, 43 percent of central Christchurch's heritage buildings listed with the New Zealand Historic Places Trust had been pulled down" (Anderson Lloyd 2014).

It is interesting to note the efforts and progress made in Oregon and Washington developing seismic risk reduction legislation and the delays caused by the COVID-19 pandemic. These regions are not alone in being derailed by the time, effort and resources going into managing that crisis. Unfortunately, it has resulted in time being lost preparing for the substantial risk continuously posed by the eventual megathrust earthquake that will rock this region. It is crucial that British Columbia take a more proactive approach, rather than a reactive one, to address 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.

Fig. 4.4: 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)

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KATIE CUMMER, PHD CAHP
KCUMMER@GMAIL.COM
(778) 678 1913