The 11th Canadian Conference on Earthquake Engineering
Canadian Association for Earthquake Engineering

SEISMIC UPGRADING OF HERITAGE BUILDINGS ON THE DOWNTOWN EASTSIDE OF VANCOUVER

Andy Metten, P.Eng.,Struct.Eng.
Partner, Bush, Bohlman & Partners LLP, Canada
ametten@bushbohlman.com

ABSTRACT: The Downtown Eastside of Vancouver is one of the oldest and most troubled parts of the city with many heritage buildings that are in poor condition and lacking in seismic resistance. Several of the buildings are four to eight-story; unreinforced brick with weak wood diaphragms and soft stories. The area is one of the poorest in Canada and has a significant demand for housing of the homeless. This paper discusses the philosophy and practice of a collapse prevention upgrade to these building both for functionality and for seismic resistance while reducing Vancouver's homeless numbers. Case studies of the seismic upgrading of five century-old, brick-walled, wood-floored Single Room Occupancy (SRO) hotels with significant structural deficiencies are discussed. The philosophical issues raised by seismic upgrading are also considered.

1. Introduction

The City of Vancouver has an active desire to maintain a stock of housing that is accessible to those that would otherwise be homeless. In an attempt to stop the demolition of SRO hotels the city bought several that were constructed in the early 1900's. These buildings had been poorly maintained and were in need of repair and renovation. This upgrading addressed livability and health issues as well as carrying out much needed maintenance and restoration of heritage aspects of the building. Under a Private-Public-Partnership (P3) project started in 2011 and funded in part by the Government of Canada thirteen Single Room Occupancy hotels were upgraded on the Downtown Eastside of Vancouver. The Code provisions for seismic upgrading a building that is not being expanded and does not have a change of use are limited. At the start of the project considerable work was undertaken to establish a level of seismic upgrading that would be performed on the buildings. A life safety upgrading approach was established as the benchmark level for all proponents in the P3 project.

1.1. Typical Heritage SRO Construction

During the early part of the twentieth century several multistory brick and timber hotels were constructed in Vancouver, in many cases built inexpensively for loggers who would spend at least part of the year on rest breaks in the city. The hotels had many small rooms designed for occupancy by only one individual often with a communal bathroom. These buildings had several similarities in their layout and construction that would have a significant effect on their seismic performance. The main seismic issues were:

- Heavy multi-wyeth load bearing brick walls. These walls would be between 2 and 4 wythes thick, adding considerable mass to the building. When unpunched with openings; they are quite stiff but lack strength for seismic resistance.
- A tall and slender building with little resistance in the transverse direction other than lath and plaster walls between the small rooms. The ground floor of the buildings is typically open to

create public areas and this coupled with the higher floor to floor in this level results in a soft and weak story at the ground level.

- Weakness in the longitudinal direction, particularly above the lobby level where setbacks eliminate the firewalls at the sides of the building where the only wall of consequence is the interior corridor wall made of lath and plaster.
- A wood floor often from solid laminated timber that provides good vertical load carry capacity but is a poor diaphragm. The connections between the diaphragm and the walls is also weak often consisting of a wood or steel ledger with minimal mechanical connection to the mass brick.

During the early part of 2015 a 2012 vintage hotel building on Granville Street in Vancouver was demolished, while this building was not part of the SRO renewal initiative its demolition was done in way that provides a cross section featuring the seismic issues of the of the five buildings that we will discuss. Figure 1 shows the Wyland building (former Old Continental Hotel at 1390 Granville St.) during its demolition and the issues that must be addressed in the seismic upgrading of similar buildings. The Old Continental Hotel was built in 1911-1912 the same period as the five hotels discussed in this paper.

Fig. 1 – Typical SRO Brick and Wood Construction and seismic issues

1.2. Upgrading Triggers and Code Mandated Upgrading

Building Codes typically cover new construction and are often completely silent when addressing the renovation of existing buildings. Traditionally the *Authority Having Jurisdiction* in this case the City of Vancouver did not require upgrading on a building that is not being expanded in size (horizontally or vertically) and is not undergoing a change of use. However, that philosophy is evolving and the City of Vancouver had a 2007 guideline that showed upgrading standards from S1 to S4 (see Table 1) which depended on the extent of renovation. The SRO upgrading P3 design and pursuit phase occurred with the 2007 edition of the Vancouver building bylaw in effect. Most of the buildings were to be upgraded to the level of S3, which as shown in “Acceptable Solution” column of Table 1, provides a “bolts-plus” approach to seismic upgrading but does not address the issues of overall lack of lateral capacity and brittleness in the structure and does not address the weak and soft story. A concern during this pursuit was that the City of Vancouver was due to release what would become the 2014 edition of the Vancouver building bylaw which would contain a complete Part 11 with requirements for the upgrading of existing buildings. The concern was that the SRO’s would go in for permit under the new Vancouver Building Bylaw and be subject to those rules with significant cost implications for the successful P3 proponent.

The upgrading requirements S1 through S4 that were required under the 2007 Vancouver Building Bylaw are shown in the table below. In addition to discrepancies between the objective statement and the acceptable solution (particularly for upgrading type S3) the triggers for these upgrading were often difficult to follow.

Category	Objective Statement	Acceptable Solution
S1	Proposed work must not have an adverse effect on the structural capacity of the existing structure.	Entire Building - Proposed work must not reduce the structural integrity of the existing building.
S2	Limited structural upgrade required in order to provide minimum protection to building occupants during a seismic event within the project area.	Project Area - Non-structural elements and falling hazards must be restrained to resist lateral loads due to earthquakes within the project area.
S3	The building structure shall be upgraded to an acceptable level in order to provide a minimum level of property and life safety to unreinforced masonry or other buildings having less than 30 percent of the current required seismic resistance. Falling hazards over exits and sidewalks must be addressed.	Entire Building - Bolting floor and roof structure to bearing walls and strengthening of floor and roof diaphragms as required to safely distribute lateral forces to bearing walls (i.e., Bolts Plus) All falling hazards such as cornices, parapets and awnings located above exits and sidewalks must be restrained to resist forces due to a seismic event.
S4	The entire building structure shall be brought up to an acceptable level in order to meet seismic requirements of the By-law.	Entire Building - Building to be upgraded to resist 75 percent of the current By-law specified lateral force levels, where the building is evaluated as having less than 60 percent of the current required seismic resistance.

Table 1 – Structural Upgrading Options under the 2007 Vancouver Building Bylaw

In December 2014, a new Vancouver Building Bylaw (VBBL) came into effect. The 2014 VBBL has Part 11 defining the triggers and extent for upgrading. Clear flow-charts are provided and if the buildings discussed in this paper were to apply for permits under the 2014 Code the need to upgrade the seismic capacity of the buildings would be mandatory.

1.3. The Need for Seismic Upgrading

The many philosophical arguments associated with seismic upgrading include:

- If there is no change in use and no increase in building area there is a perception that there is no change in risk to the occupants and costs of seismic upgrading should not be a barrier to upgrading the building. However, the extension of the duration of use of a building with significant seismic deficiencies increases the chance that a seismic event will occur in this extended duration of use and therefore increases the risk of loss of life in that building.
- On a statistical basis, seismic failures have not caused deaths in Vancouver while being homeless is a definite threat to life. Between 2006 and 2014, 280 homeless people died on the streets of Vancouver. From a historical life preservation standpoint, putting seismic upgrading funds into creating additional SRO's would be more effective.
- If there is limited funding to be spent on seismic upgrading should those seismic upgrading funds be spent on SRO's or buildings that are often deemed to be more "worthy" of these funds such as schools and hospitals.
- As structural engineers, are we doing seismic upgrading to limit our liability or to benefit those that live in the building? None of us wishes to work on a project that collapses in an earthquake,

killing many of the occupants inside. Protecting against this probable loss of life outcome is a natural, and ethically required, reaction for a structural engineer.

- If we are housing 800 homeless people in the upgraded buildings do we not have an ethical responsibility to at least provide collapse prevention to the building? The opinion of all engineers working on these buildings was that they would collapse in even a minor seismic shake. The collapse would result in loss of life inside both to building occupants and those on the street outside.
- The protection of heritage buildings must include the need for seismic upgrading. While heritage consultants and structural engineers can argue their cases for project funds, we do not protect the heritage if is vulnerable to collapse or risk mitigating demolition after even a minor seismic event.

1.4. Competition for Project Resources

As structural engineers who make at least part of our living from seismically upgrading buildings because we believe it is a necessary life safety measure we naturally want a significant portion of the project budget to go to seismic upgrading. However, other consultants or Code requirements are competing for the funds that would go to seismic upgrading. Figure 2 which shows how seismic upgrading can disappear in a series of demands that attempt to make the building more livable and Code compliant. Regarding seismic upgrading costs as the sole reason that we cannot retain or upgrade heritage buildings is not reasonable, as the seismic work is just one of a series of competing demands.

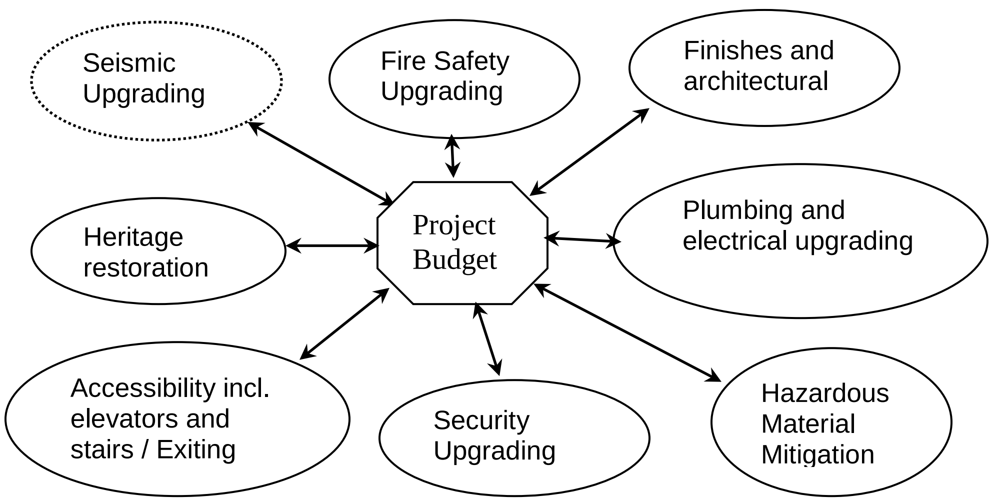


Fig. 2: Competing for Project Resources

1.5. The Influence of Heritage on the Upgrading Process

An important part of upgrading the SRO's on Vancouver's Downtown Eastside was the retention of heritage features of the building, including its appendages such as signage, exterior fire escapes and cornices. The seismic upgrade scheme must be sensitive to the heritage requirements by not placing appearance changing exterior frames or walls on the building or removing the brick facade of the building. A heritage upgrade must also address life safety issues including fire protection, exiting and seismic. The earthquake in Christchurch, New Zealand of February 2011 showed that demolition of even very significant heritage buildings would occur quickly after the event if the damage caused the building to become a hazard to recovery efforts. The project specifications for the SRO upgrading contained extensive heritage preservation requirements. Seismic upgrading to the buildings was all done on the interior of the building except for the fastening of brick veneer and the restraint of other "non-structural" items such as cornices, which was done in a way that was not visible.

1.6. The Need for Seismic Upgrading

Five of the hotels that were upgraded were of similar construction having wood floors and multi-Wyeth brick walls. The five hotels that match this description are shown in table form below.

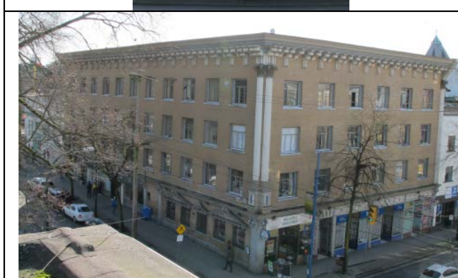
Hotel	Stories	Construction Type	Photo	Seismic Upgrade System
Marble Arch / Canada Hotel (518 Richards St.) (Built 1912)	7	Wood Floors often from solid laminated timber. Multi-Wyeth Brick walls, Interior load bearing stud walls with lath and plaster. Often a transfer floor above the main floor with steel beams. Spread concrete footings. All buildings had fundamental weakness and a Code force compliance in the range of 5%. All buildings had a weak and soft story.		Concrete walls & new concrete spread footings some with tie-downs. Diaphragm upgrades with plywood and steel straps. Steel connectors between walls and diaphragms, Connect brick veneer to mass brick.
Hazelwood Hotel (342 East Hastings St.) (Built 1912)	5			Concrete walls & new concrete spread footings. Diaphragm upgrades with plywood and steel straps. Steel connectors between walls and diaphragms, Connect brick veneer to mass brick.
Tamura House (396 Powell St.) (Built 1912)	4			Concrete walls & new concrete spread footings. Diaphragm upgrades with plywood and steel straps. Steel connectors between walls and diaphragms, Connect brick veneer to mass brick.
Sunrise Hotel (101 East Hastings St.) (Built 1906)	4			Plywood walls in upper floors, diaphragm upgrades with plywood, connecting walls to diaphragm, steel frames in ground floor & concrete walls and footings in basement.
Rice Block (404 Hawks Ave.) (Built 1912)	4			Plywood walls in upper floors, diaphragm upgrades with plywood, connecting walls to diaphragm, steel frames in ground floor & concrete walls and footings in basement.

Table 1 – Five brick and timber SRO hotels upgraded

1.7. Upgrading Requirements

Once the decision is made to upgrade the building's seismic capacity the problem becomes one of addressing the various deficiencies in the building in the most cost-effective manner. The project proponents for both firms competing in the P3 design were instructed to use design loads that were less than that required for a new building but would provide the building with the seismic system it lacked. Both proponents used a life safety approach to seismic upgrading. Drift control was fundamental for the successful seismic upgrade and drifts under the loads were limited to 1% to prevent failure of the load bearing brick. The use of a Code permitted drift of 2.5% is too large for an existing brick building and will not protect the brick vertical load carrying system from failure. For the most part the drift control was the governing seismic design criteria. In addition to the necessity of a seismic system in the form of walls and braces there was also a need to provide diaphragms that could transmit the loads to the seismic elements and restraint of objects that could fall from the building. The project contained the upgrading of several buildings and from the design standpoint this allowed efficiency from the reuse of typical details and from the construction standpoint it allowed for lessons and innovations in one building to be applied to subsequent buildings.

1.8. Options for a Seismic System

The added seismic system must address both the need for strength and stiffness. While the use of plywood on the walls of the SRO rooms was advocated as a seismic upgrade method this had significant structural issues due to the difficulty in providing sufficient drift control with plywood walls and the desire to keep the ground floor reasonably free of obstructions for use as retail space. The Marble Arch, Tamura House and the Hazelwood Hotel used concrete walls throughout their full height. The Rice Block and the Sunrise Hotel had a seismic system consisting of plywood walls in the upper floors and steel bracing added in the main floor with concrete walls and foundations below the braces in the basement level. Use of plywood walls in seismic upgrading a heavy brick building requires covering almost all walls above the main floor in plywood and extensive work is necessary to at the main floor ceiling level to transfer both the overturning forces from the plywood walls and transfer the shear forces from the terminated plywood walls to the braces below. Providing a seismic system using concrete walls throughout proved to be most cost effective solution. In doing the concrete walls some of the buildings used one-sided forms with gunnite concrete walls while others used traditional two sided concrete forms. Sometimes wood-slat formworks was used to match the heritage look of the building.

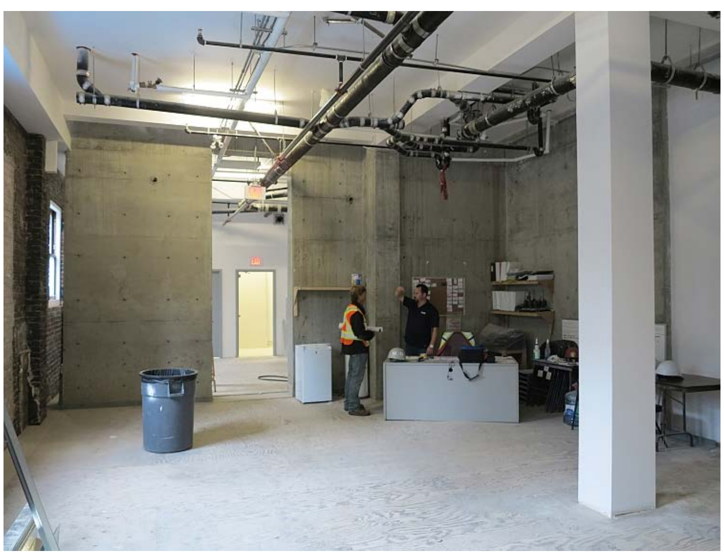



Fig. 2a (Left): Completed Concrete walls in the ground level of Marble Arch Hotel

Fig. 2b (Right):Steel brace bay / moment frame frames in the ground level of the Sunrise Hotel

1.9. Diaphragm Upgrading

A second significant requirement of seismically upgrading the buildings is providing a diaphragm that can transfer the forces from the walls to the seismic resisting elements. The five buildings in this paper all had wood diaphragms that had significant issues with carrying the seismic loads. Improvements in diaphragm shear capacity was achieved by adding plywood to the floors, steel strapping for drag struts and angles for diaphragm chords. The heavy brick walls that were only loosely connected to the diaphragm were tied firmly to the floor by adding connectors to the diaphragm attached to the brick through with threaded rods in cored holes fastened with epoxy. Only coring was used on the brick to prevent the disruption of the century old mortar with hammer drilling. The straps to the diaphragm were designed using a yielding neck that provided a ductile fuse and helped reduce the number of screws required to the diaphragm.

Fig. 3: Diaphragm Upgrading with the addition of Plywood, angles for diaphragm chords and Steel Straps. The steel straps have a potential yielding region to reduce the amount of connection required at the diaphragm side.

1.10. Providing footings for the New Seismic system

The new seismic system requires footings to transfer the loads to the foundation. Concrete footings were added to carry the seismic loads. Footings for the Marble Arch used tie-down anchors to carry some of the overturning moment and reduce the size of the footing for other buildings the footing size was increased to pick up dead load of the structure and resist overturning moments. With the exception of Tamura House all the buildings in this study had a basement and the top of the footings became the new basement floor. Excavation for the footings was carried out with a mix of small excavating equipment and by hand. Footings for existing columns were incorporated in the new footings. All the sites were located on firm ground, classified as Site Class C and bearing under ultimate loads ranged up to 450 kPa. Under some circumstances, the footings were constructed in segments to assist with underpinning existing walls, in these cases couplers were used to connect the reinforcing steel from one section to the next.

Fig. 4a & 4b:Footing construction in the Marble Arch (Left) and the Hazelwood (Right) .

1.11. Parts and Portions Upgrading – Avoiding Falling Hazards

All of the buildings in this study are immediately adjacent to sidewalks, streets, and alleys on at least two sides of the building and objects falling from the building present a risk to those outside. To mitigate this it is necessary to fasten potentially falling objects to the building in a way that provides a load-path for these objects. Of particular concern are cornices, parapets, brick chimneys and signage. While the brick chimneys were removed this was not possible with heritage items such as the parapets and cornices. The parapets are of particular concern as they are of brick construction and may be quite tall to accommodate roof slopes. Structural steel frames provided the mitigation of falling of parapets particularly for those portions of the parapet that extend above the top diaphragm. In some cases plywood diaphragms were added both at the top of the roof level and the ceiling level. Figure 2 shows the upgrading of the parapet in the Marble Arch hotel where plywood is added at both the roof and ceiling level and steel supports are added to the tall parapet.

Fig. 5a (left) – Upgrading of Front Parapet on Marble Arch Hotel the angle to connect the brick to the diaphragm at the bottom of the parapet can be seen, plywood and connection at the top of parapet has not been performed at the time of the photograph.

Fig. 5b(Right) – Installing angle bracket support and reworking brick where the mortar had turned to sand on the Sunrise Hotel

2. Construction Process – Putting the Design in Place

The construction process posed new challenges with the removal of finishes exposing new challenges as the damage from time and neglect. Most of the century old wood in the building was sound; however, removal of finishes exposed some areas of rot that required repair. Hazardous materials with both chemical and biological hazards needed addressing before the reconstruction could start. Some of the hotels, such as the Marble Arch, were partly occupied during the construction with residents vacating two floors at a time as the construction progressed. Later hotels were fully vacated which was a considerable assistance in the sequencing of the construction. The conceptual design and P3 pursuit process started in 2010, the first hotels were completed in 2014 and it is expected that all thirteen hotels will be completed and occupied by the end of 2016.

Fig. 6a and 6b: Pre-Renovation Marble Arch Hotel and Completed Canada Hotel.

3. Conclusions

a) The seismic upgrading of the five SRO hotels discussed in this paper show that it is possible to upgrade the seismic resistance of heritage buildings in a cost effective way that mitigates their life safety hazards while respecting the heritage appearance of the building. Restoration of only heritage aspects with no seismic upgrading does not mitigate the life safety aspects of the building and will result in demolition of the building following only a minor seismic event.

b) The seismic upgrading must produce a sufficiently stiff system so that the brittle load bearing brick elements will not shatter resulting in collapse of the building. The upgrading system requirements must include both lateral load capacity and drift control and the drift control limit for brittle brick buildings should be less than the code limit of 2.5%.

c) A life safety level upgrading addresses the most significant seismic issue of a soft story along with the bolting of objects such as parapets that can fall from the building. This upgrading substantially improves the seismic resistance of the building and the risk to life for both those in the building and on the sidewalk outside. Buildings with essentially no seismic system were provided with a competent load path.

d) The provisions of Part 11 of the 2014 Vancouver Building Bylaw (VBBL) provides better guidance on the seismic upgrading requirements and triggers than does either the previous version of the VBBL or the National Building Code of Canada 2015 edition. Building Codes need to address the requirements for existing buildings.

f) Upgrading of heritage buildings under a Public-Private-Partnership is a challenging as the condition of the buildings is difficult to fully appreciate until the site work commences. However, this project successfully upgraded thirteen heritage buildings and improved over 800 SRO units. There is an advantage from both a design and construction standpoint to group this type of work together such the same team is doing several projects and typical details can be reused.

4. Acknowledgment

1) Vancouver BThe upgrading work discussed in this paper was performed as part of a $143 Million Public-Private-Partnership (P3) project funded in part by the Government of Canada. Habitat Housing Initiative (HHI) was the successful proponent, Ameresco provided project management under the direction of Chris Jackson.

The architect on the project is Merrick Architecture Borowski, Sakumoto, Fligg under the diligent direction of Mitch Sakumoto MAIBC.

The author is the engineer of record on all five buildings discussed in this paper and this paper relies on the experience gained during the design and construction of those upgrades. The following project engineers made the project possible by producing innovative solutions to many challenging problems.

Marble Arch Hotel – Jim Mandelli P.Eng. of Mandelli Engineering, Davor Ajdukovic, P.Eng.

Tamura House – Trevor Whitney, P.Eng.

Rice Block – Frank Nadalini, P.Eng., and Payman Hosseini, EIT.

Hazelwood Hotel – Adrian Colombo, EIT

Sunrise Hotel – Frank Nadalini, P.Eng. and Payman Hosseini, EIT.

Geotechnical solutions for the new footings were provided by Karen E. Savage, P.Eng. of Horizon Engineering Inc.

Contractor on the renovations was Darwin Construction, the innovative and diligent site superintendents on each of the projects were without exception the difference between success and failure.

5. References

1) City Of Vancouver, *Vancouver Building Bylaw* (VBBL) 2007, Vancouver December 2007.

2) City Of Vancouver, *Vancouver Building Bylaw* (VBBL) 2014, Vancouver December 2014

3) McGinn, Barry Architect, McGinn Engineering and Preservation; Unpublished building heritage summaries

4) Additional information on the SRO P3 can be found at:

http://www.partnershipsbc.ca/projects/projects-under-construction/sro-renewal-initiative/