Structural Engineers Association of B.C.

British Columbia Earthquake Fact Sheet

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1. Overview of BC Seismicity

Each year, seismologists with the Geological Survey of Canada record and locate more than 2500 earthquakes in western Canada. The Pacific Coast is the most earthquake-prone region of Canada. In the offshore region to the west of Vancouver Island, more than 100 earthquakes of magnitude 5 or greater (large enough to cause damage had they been closer to land) have occurred during the past 70 years. Part of the Pacific Ring of Fire, the concentration of earthquakes along the west coast is related to the presence of active faults, or breaks in the earth's crust. The surface of the earth is always changing, as the earth's crust is made up of "plates" (like pieces of a jigsaw puzzle) that are constantly moving relative to one another at speed's of about 2-10 cm/year (about how fast your fingernails grow). The plates can either slide past one another, or they can collide, or they can diverge (move apart).

The west coast of Canada is one of the few areas in the world where all three of these types of plate movements take place, resulting in significant earthquake activity. Earthquakes in this region occur along the faults in the offshore region (e.g., the M=8.1 Queen Charlotte Island earthquake of 1949); within the subducting ocean plate (e.g., a magnitude 6.8 earthquake beneath the Seattle-Tacoma region in 2001); and within the continental crust (e.g., a magnitude 7.3 earthquake on central Vancouver Island in 1946). Moving inland from the coast (and the active plate boundaries), the frequency and size of the earthquakes decreases. Saskatchewan and Manitoba are the least earthquake-prone areas in Canada.

Offshore Region

From northern Vancouver Island, to Haida Gwaii, the oceanic Pacific plate is sliding to the northwest at about 6 cm/year relative to North America. The boundary between these two giant plates is the Queen Charlotte fault - Canada's equivalent of the San Andreas fault. Canada's largest historical earthquake- a magnitude 8.1, occurred along this fault on August 22, 1949. This earthquake, larger than the 1906 San Francisco earthquake, caused nearly a 500-km-long segment of the Queen Charlotte fault to break.

Cascadia Subduction Zone

West of Vancouver Island, and extending from northern Vancouver Island to northern California, the oceanic Juan de Fuca plate is moving towards North America at about 4-5 cm/year. This region is called the Cascadia subduction zone. Here, the much smaller Juan de Fuca plate is sliding (subducting) beneath the continent (it is about 45 km beneath Victoria, and about 70 km beneath Vancouver). The ocean plate is not always moving though. There is evidence that the Juan de Fuca and North America plates are currently locked together, causing strain to build up in the earth's crust. It is this squeezing of the crust that causes the 500 or so small earthquakes that are located in southwestern British Columbia each year, and the less-frequent (once per decade, on average, damaging crustal earthquakes (e.g., a magnitude 7.3 earthquake on central Vancouver Island in 1946). At some time in the future, these plates will snap loose, generating a huge offshore "subduction" earthquake - one similar to the 1964 M=9.2 Alaska earthquake, or the 1960 M=9.5 Chile earthquake. Current crustal deformation measurements in this area provide evidence for this model. Geological evidence also indicates that huge (magnitude 9) subduction earthquakes have struck this coast every 200-850 years. The most recent one occurred on January 26, 1700.

The St. Elias Region, the Southwestern Yukon Territory, and Northwest BC

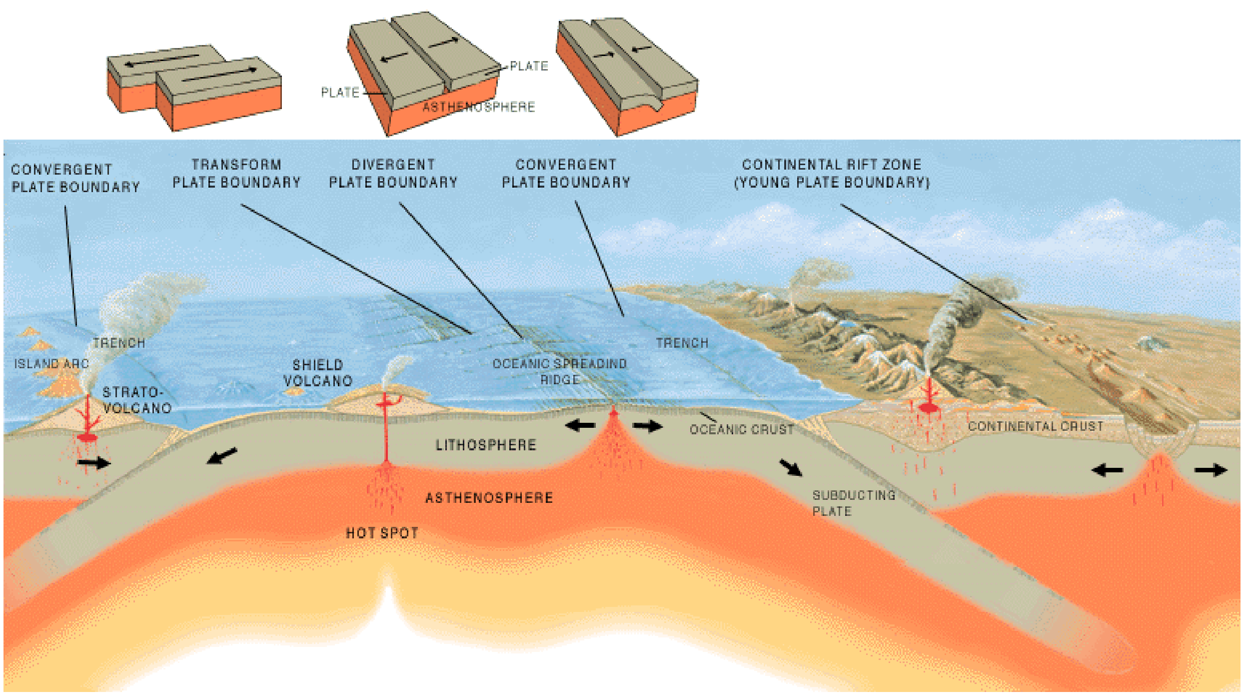
The St. Elias region of the southwest Yukon Territory, northwest British Columbia, and southeast Alaska is one of the most seismically active areas in Canada. Here, the plate boundary between the giant Pacific and North American plates is changing from one of transform (sliding past one another), to subduction (where the Pacific plate is being forced beneath the Aleutian Islands to the northwest). This results in very rapid uplift rates (mountain building) of up to 30 mm/year. The area of the plate margin has experienced many large earthquakes, including a sequence of three earthquakes of magnitude 7.4 to 8.0 in the year 1899. In 1958 a magnitude 7.9 earthquake occurred along the Fairweather fault (the northern extension of the Queen Charlotte transform fault). The most significant inland zone of seismicity follows the Dalton and Duke River segments of the Denali fault zone through the southwest Yukon. Farther inland, there is minor seismicity between the Denalli and Tintina fault systems. The rate of seismic activity increases at the eastern edge of the cordillera (see below).

Northern Cordillera

The northern Rocky Mountain region (north of 60N) is one of the most seismically active areas of Canada. The largest earthquake recorded in this area, to date, is the magnitude 6.9 earthquake of December 23, 1985 in the Mackenzie mountains of the Northwest Territories. Magnitude 6-plus earthquakes have occurred in the Richardson Mountains of the Yukon Territory (M=6.2 in May, 1940; M=6.5 in June, 1940, and M=6.6 in March, 1955).

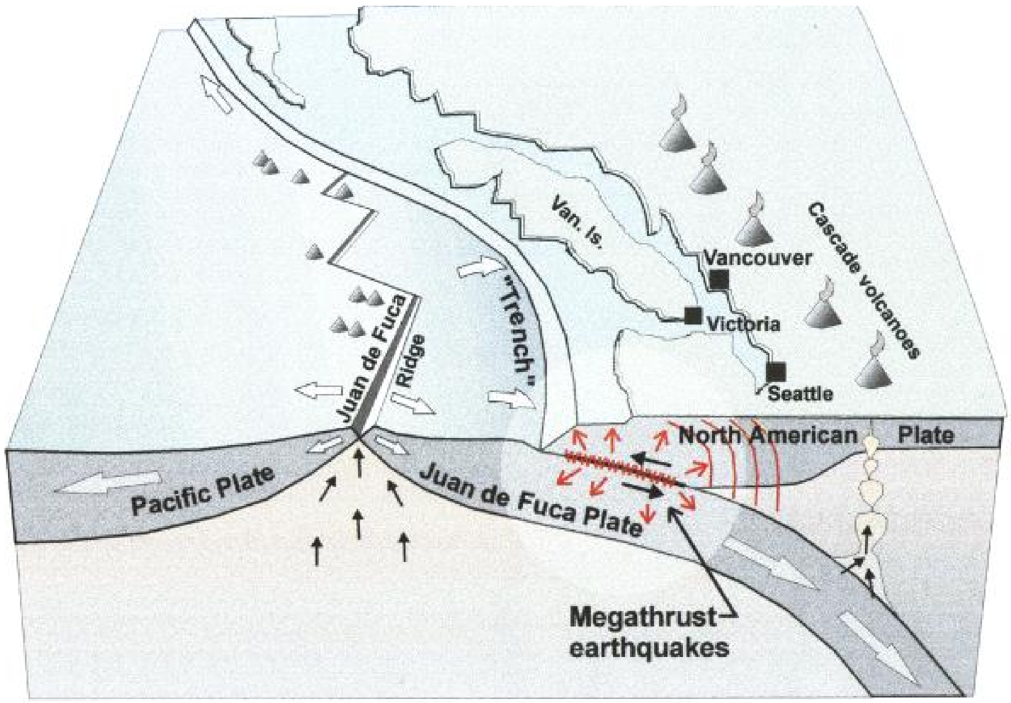
Southern Cordillera

South of 60 N, seismicity in the interior and Rocky Mountain areas drops off rapidly. The largest earthquake recorded in the southern Cordillera was a magnitude 6.0 in 1918 that struck the Valemount area of the Rocky Mountain trench. In 1986 a magnitude 5.5 earthquake occurred near Prince George, causing some minor damage.



Sectional View of the Pacific Offshore

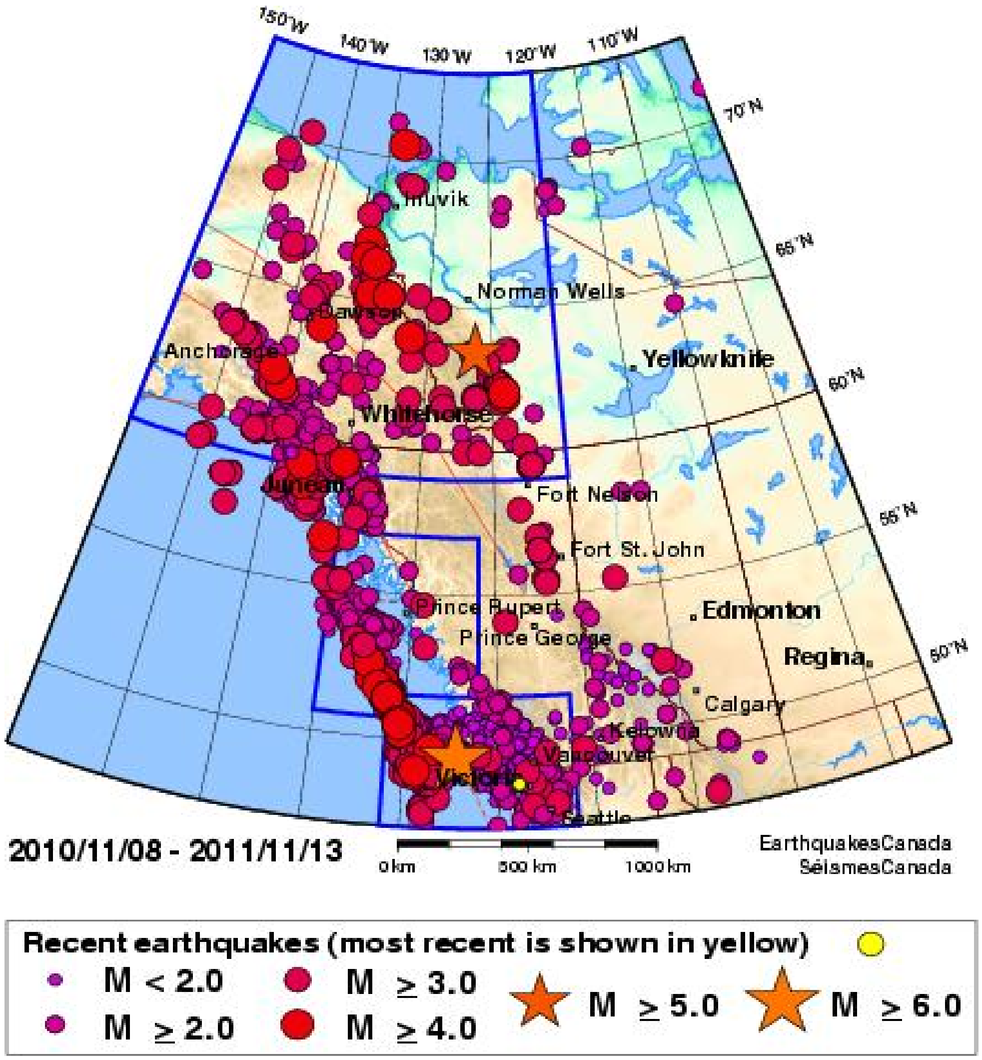
Source: Natural Resources Canada, Earth Sciences Sector, Earthquakes Canada



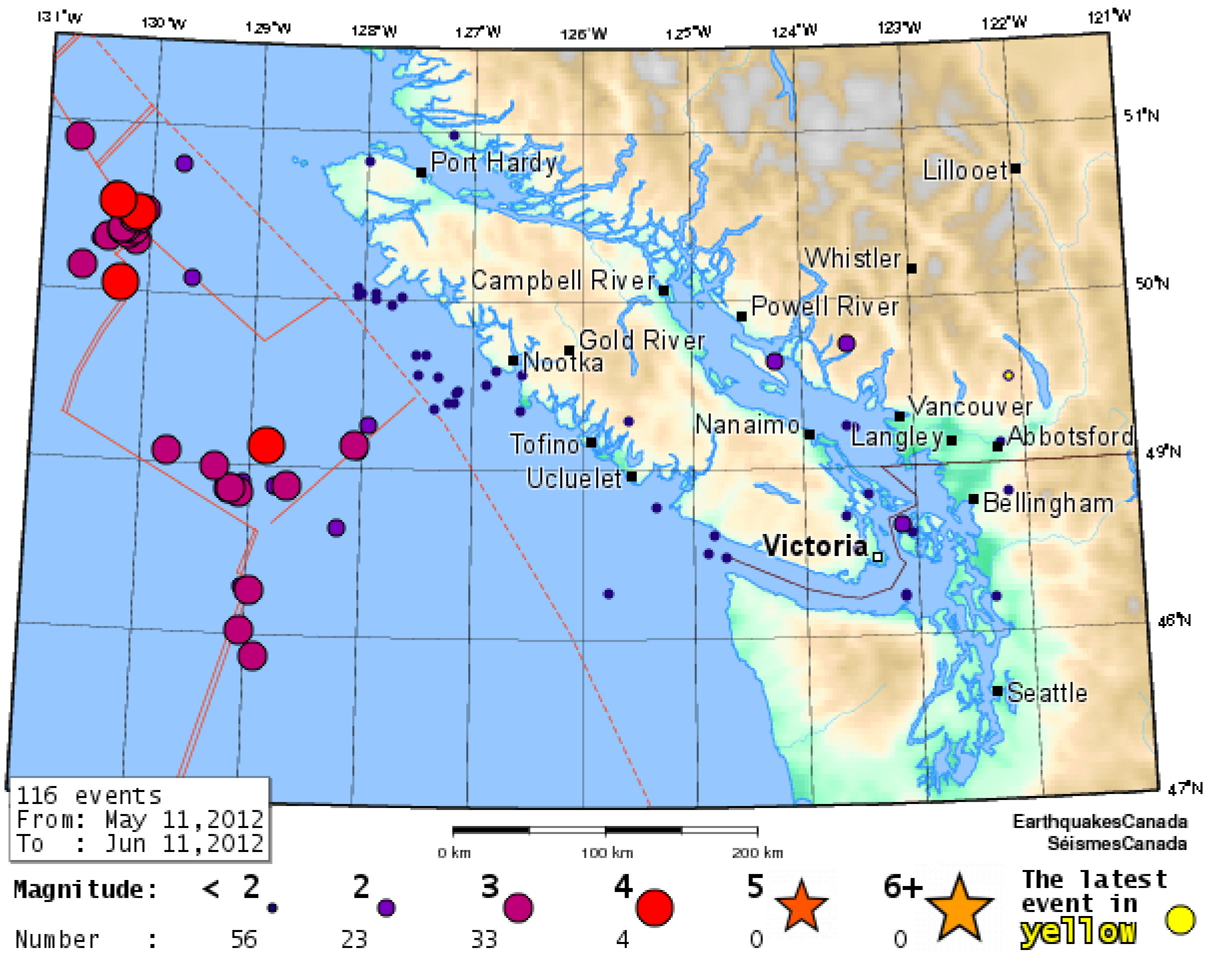
Close up view of the southern half of BC - offshore

Source: Natural Resources Canada, Earth Sciences Sector, Earthquakes Canada

The populated areas of the province including the Lower Mainland and southern Vancouver Island have, in recent history, escaped significant earthquakes leading us to be somewhat complacent about the potential danger from a major event. There is ample evidence that to suggest that we should be seriously concerned. The following charts, extracted from NRCan's website (earthquakescanada.ca) indicate the locations and magnitudes of recent earthquakes in BC.



Source: Natural Resources Canada, Earth Sciences Sector, Earthquakes Canada



Lower Mainland, Vancouver Island & the Pacific Offshore: Recent Seismicity

Source: Natural Resources Canada, Earth Sciences Sector, Earthquakes Canada

2. Earthquake Effects on Buildings

It is well known that the west coast of Canada has a high likelihood of earthquakes. The type of seismic ground motion at a building site depends on a number of factors, including:

- Distance of the building from the earthquake rupture zone
- Magnitude of the earthquake
- Depth of the earthquake rupture, and
- Soil conditions at the building site

Earthquakes affect buildings differently depending on the type of ground motions and characteristics of the building structure. Seismic ground motion is typified by both vertical and horizontal shaking. Generally the horizontal shaking is larger, and causes damage. Large distant earthquakes contain long-period energy that can impact large (taller) structures, whereas smaller nearby earthquakes generally contain more high-frequency energy that can damage smaller (shorter) structures.

If the ground motion is strong enough, it will move a building's foundation. However, inertia tends to keep the upper stories in their original position, causing the building to distort. Since inertial forces are greater when objects are heavier, earthquake forces are greater in heavier buildings. Higher ground accelerations also create more stress in a structure.

Because buildings shake with different natural frequencies, it is possible for shaking of one building to be out of phase with its neighbour. If the two buildings are close to each other, "pounding" of the two buildings into each other may occur, causing damage to both.

Loss of external façade layers of a building is also possible. Failure of secondary structural masonry and brick items such as chimneys and parapets is also common, especially on older buildings when the attachment of these materials to the main structure is poor. These falling items can be a serious hazard.

6.3 quake strikes New Zealand city. February 22, 2011 4:02 PM

Source: cbsnewscom

3. Performance Criteria for Buildings

Brittle structures such as those constructed of unreinforced brick or poorly reinforced masonry generally do not perform well under this shaking motion, whereas more ductile structures such as those constructed of wood, reinforced concrete or structural steel will usually perform much better. As a result, structural engineers aim to make their building designs as ductile as possible, using not only ductile materials but paying attention to the ductility of the joints as well. Research into the ductility of building connections such as at beam-to-column joints is ongoing and improving steadily.

Buildings designed prior to the 1970's were not explicitly required to have ductility incorporated in them. In the early 1980s, the design standards for reinforced concrete were revised significantly to ensure non-brittle behaviour under design-level earthquake loadings.

More recently structural design has incorporated a "strong column, weak beam" philosophy. The purpose of this philosophy is to ensure that the building columns will not collapse under seismic motion while the ductility "demand" is concentrated in the beams, which are better able to carry load even after their capacity has been exceeded.

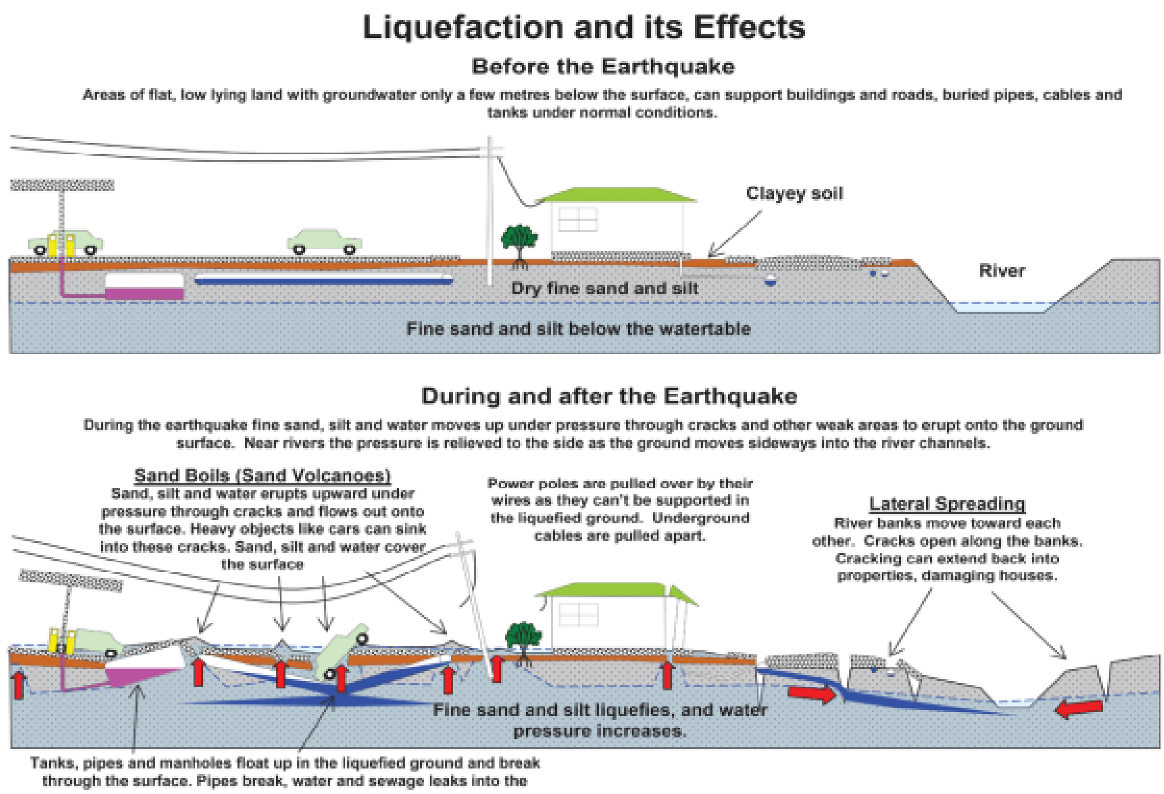
The current philosophy of the British Columbia Building Code (2006) provides that most buildings be designed to a minimum level for life safety. That is, if a "design event" earthquake were to be experienced the building would not collapse and it would be possible to escape. That does not mean that the building would not be damaged, in fact major repairs might be required to rehabilitate it. Some buildings, such as hospitals, fire halls, and schools are assigned higher safety factors to ensure that they can respond to the design event earthquake with minimal damage (and so remain operational).

The "design event" earthquake has a 2% probability of exceedance in 50 years (1/2475 year return period). In other words, there is a 98% probability that a building will not experience this design event (I suggest trying to stay away from "magnitude" if you can… what the probabilistic maps provide are ground motions at the 2% in 50 year level… these are then turned into a "design event" – correct?) in a design life of 50 years. The design ground motions for "firm ground" conditions (e.g. dense glaciated soils or rock) are specified in the climatic data for each city and town in the province, based on proximity to known earthquake sites.

Foundation soil conditions can have a significant impact on a building and are taken into account in the structural design. Sites located on river deltas with a high water table and underlying deep silt and sand strata (such as some areas in Richmond and Delta) are highly susceptible to liquefaction (for silts or sands below the water table) and may require special design treatment from the geotechnical and structural engineer. Ground improvement using a variety of soil densification techniques is often required to mitigate liquefaction hazard. Liquefaction caused significant damage in the 2011 Christchurch, New Zealand, earthquake. The effects of liquefaction are shown in the photos and sketch below.

Vehicle buried in Liquefied Soil
Source: dailytelegraph.com.au

Liquefaction immediately following the Tohoku earthquake left this house with a permanent lean.
Source: japanpropertycentral.com



Source: Fact sheets compiled and distributed by the Institution of Professional Engineers of New Zealand

4. Performance of non-structural elements

In buildings of all ages, ceiling systems, and in-ceiling services such as light fittings and air conditioning supply systems, plumbing and electrical services, book cases and filing cabinets may suffer significant damage during an earthquake. These are referred to as “non-structural components”.

Greater effort is being directed to providing suitable seismic restraint for these components as it has been found that the repair costs can be very large despite the fact that a buildings performed well structurally. It is not unusual for the building structure to survive an earthquake relatively intact, but the non-structural components are so badly damaged that the building is rendered un-usable.

The requirement for lateral restraint of non-structural components is included in the BC Building Code, but it is an area that is frequently neglected as, to owners, it appears to be an additional expense with no obvious benefits. Often there is more than one engineer involved in the design of the seismic restraints for non-structural components. Coordination between the contactors, the structural engineer of record, and the professionals responsible for the design and implementation of the restraint systems for non-structural components is vital to minimize the damage to the building in a seismic event.

Non-structural damage: Japan earthquake March 2011

5. What should you do?

a. As a homeowner:

Valuable information on how to prepare your home and family for a major earthquake can be found at the web-sites below:

http://www.earthquakescanada.nrcan.gc.ca/info-gen/prepare-preparer/eqresist-eng.php

http://www.seismic.ca.gov/pub/CSSC_2005-01_HOG.pd

http://vancouver.ca/emerg/prepyourself/earthquaketips.htm

b. As a current owner/occupier of an existing building not built to the current building code:

Building codes are updated on a regular basis and there is currently no requirement for owners to strengthen their buildings to meet the design event specified for new buildings (e.g., the current codes). As a result, for buildings that have not been retrofitted, age is the primary indicator of expected seismic performance. Other factors, such as the type of construction, structural concept, relative strength of the strong and weak axes of the building, ground conditions, irregularities in the shape and proximity to adjacent buildings (pounding effect) all come into play.

Some prudent owners voluntarily undertake strengthening of their buildings. The Province of BC has undertaken extensive seismic retrofitting of many schools.

If in doubt about the seismic stability of your building, consult with a qualified structural engineer.

c. As a future developer/owner of a new building:

Potential owners of new buildings should be fully aware that meeting current BC Building Code minimum requirements does not guarantee that a building will be serviceable after a design event earthquake. The code simply specifies the level of structural performance necessary for life safety.

Serviceability is another issue. Only 15-25% of original construction costs are for the structure, and the prudent owner would be wise to work with his design team to assess the economic risk associated with loss of use of his new building vs. the cost of specifying a higher level of performance for both the structure and the non-structural components.

Acknowledgements:

1. Natural Resources Canada www.earthquakescanada.nrcan.gc.ca
2. IPENZ Engineers New Zealand
3. Woodworks USA