PACIFIC NORTHWEST EARTHQUAKE RISK PRIMER

MRP Engineering Newsletter **February 2013**

The Pacific Northwest region has a history of significant seismic activity, which directly affects local communities and business operations. Moderate earthquake events in Washington State (1949, 1965, and 2001) and in Oregon (1993) have served as reminders of regional hazards. In addition, the world recently experienced several major earthquakes and tsunamis, which caused severe local impacts with significant worldwide repercussions. Cumulative losses from the 2010 and 2011 earthquakes in Haiti, Chile, New Zealand, and Japan may exceed US$300 billion. MRP Engineering investigations of these earthquakes indicate that rebuilding and the economic recovery of the affected regions could well span a generation. Furthermore, preparedness and mitigation actions are very effective in limiting potential impacts.

The awareness of earthquake hazards and associated risks has led to limitations on available insurance coverage, prompting many organizations toward better understanding and management of their exposures. This newsletter summarizes Pacific Northwest earthquake hazard and risk considerations.

PACIFIC NORTHWEST SEISMIC SOURCES

The Pacific Northwest (including British Columbia) is located along the boundary of two tectonic plates, which can cause destructive earthquakes as they come into contact with one another. As shown in Figure 1, one of the tectonic plates, the Juan De Fuca plate, forms the ocean floor, slides beneath (subducts) the North American plate, and is slowly driven into the earth's mantle. The principal sources of potential future earthquakes are discussed below:

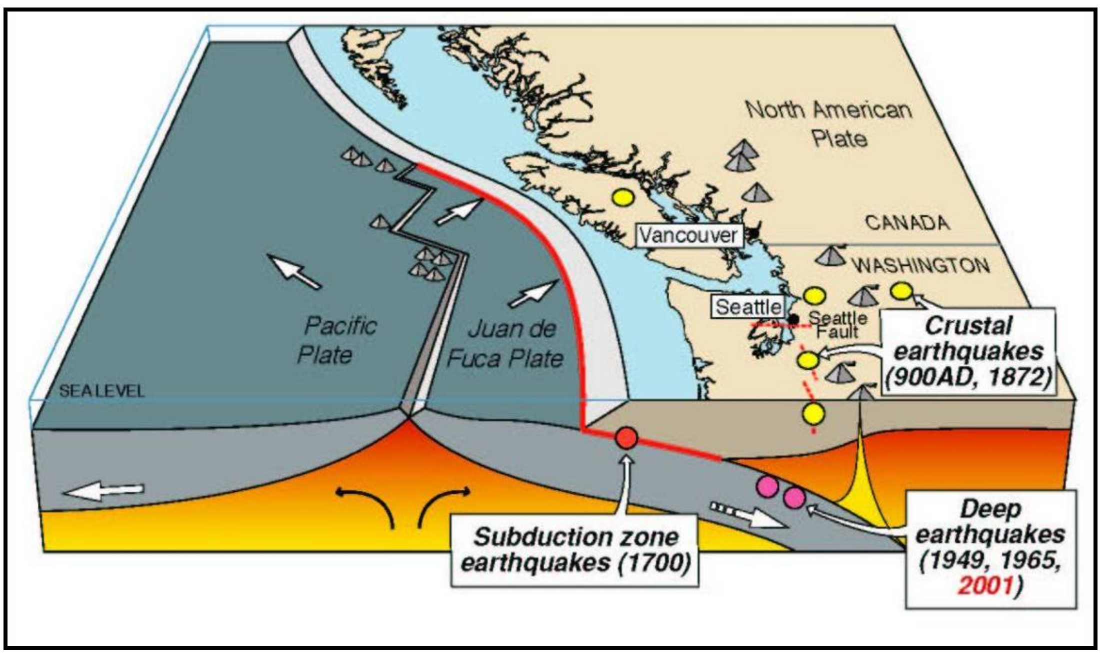


Figure 1: Pacific Northwest Tectonic Setting (Source: USGS)

- Offshore Cascadia subduction zone is capable of M8 to M9 earthquakes about every 300 to 500 years. The last such event occurred on January 26, 1700.

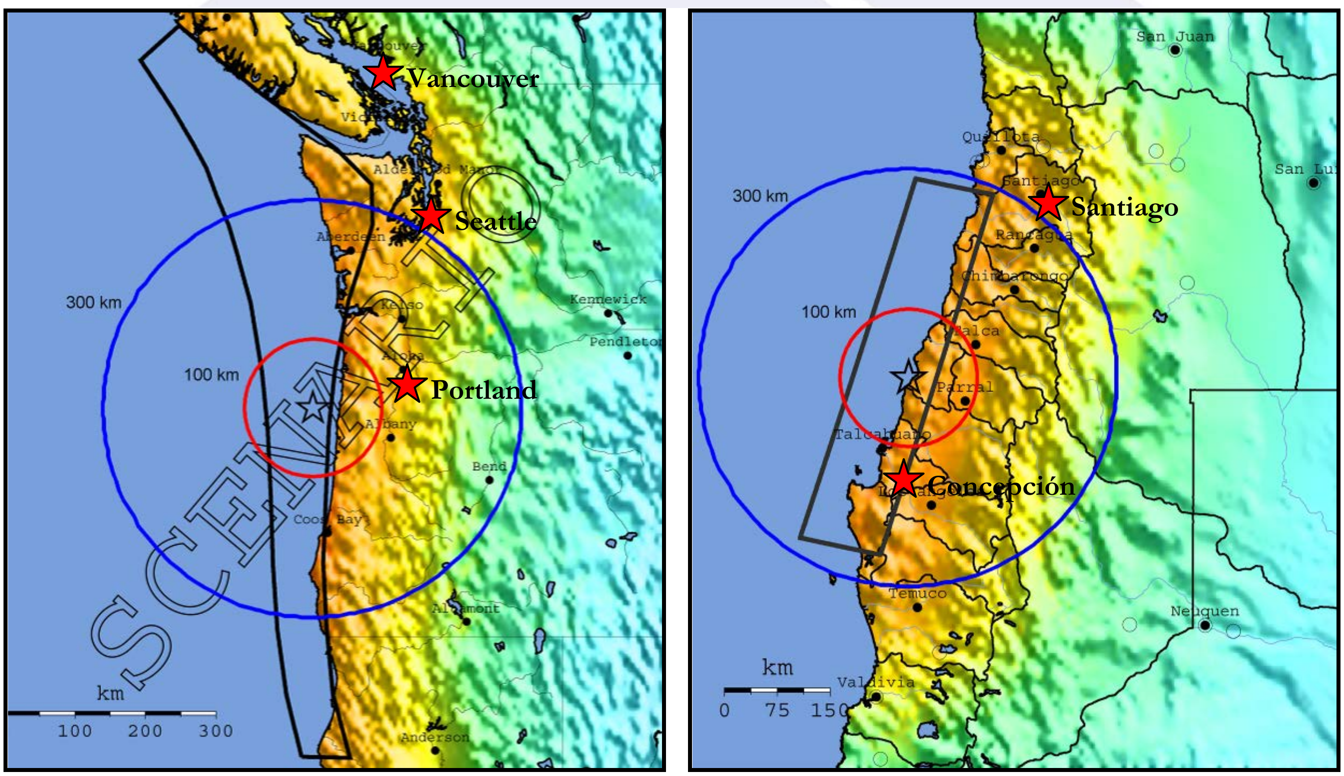
  Subduction zone earthquakes occur at the convergence between the Juan de Fuca and North American plates as described above. The contact area of the plates extends to a depth of about 40 kilometers. The plates remain locked in frictional contact until the resistance to sliding is overcome.

The plates then slide against each other up to several meters in a very short time, releasing tremendous energy. Resulting subduction zone earthquakes may have a great magnitude (M > 8). Vertical displacement of the sea floor may result in a tsunami along coastal areas, as experienced following the 2010 M8.8 Chile earthquake, and the 2011 M9.0 Great East Japan events. Elevation changes may occur along the coastline. Significant aftershocks (M > 7) may follow.

- Crustal earthquakes are shallow events (within a depth of ten kilometers) that could occur along local faults. These faults, such as the Seattle fault and Portland Hills fault, have relatively long recurrence periods, but are capable of M7+ events and associated aftershocks. The largest known crustal event occurred in 1872 near Lake Chelan in central Washington State (M7+).
- Benioff (deep) zone earthquakes occur as the subducted Juan De Fuca plate breaks apart at depths of 40 to 60 kilometers below the surface. In Washington State this mechanism was responsible for the M6.8 Olympia earthquake in 1949, the M6.5 SeaTac event in 1965, and the M6.8 Nisqually earthquake in 2001. A M7 earthquake in 1946 affected central Vancouver Island.

SUBDUCTION ZONE EARTHQUAKES COMPARED

The 2010 M8.8 earthquake that impacted central Chile has significant relevance for the Pacific Northwest region. Chile is also located along the boundary of two tectonic plates with many similarities to the Cascadia Subduction Zone. As shown in Figure 2, in addition to affecting Pacific Northwest coastal communities, a M9 subduction zone earthquake would impact relatively distant metropolitan areas of Portland and Seattle, as well as Vancouver in British Columbia.



M9.0 Cascadia Subduction Zone scenario

M8.8 Offshore Maule, Chile earthquake

Stronger shaking →

Figure 2: Subduction Zone Earthquakes Compared (Source: USGS)

SEISMIC HAZARDS

In general, most earthquake damage occurs due to strong ground shaking. The Modified Mercalli Intensity scale (MMI) is often used to measure ground-shaking intensity at the site of interest. While an earthquake has only one magnitude, it can have many intensities that are influenced by the distance from the epicenter as well as local soil conditions. The MMI scale has twelve discrete levels. At MMI VI and below, damage is slight. Weak structures can be damaged in MMI VII level shaking. Engineered structures can be damaged at MMI VIII. Duration and frequency of shaking are also important in projecting the potential for damage.

Earthquake magnitude is an estimate of the earthquake size, or strength at its source. It is the most familiar earthquake descriptor to engineers, geologists, and the general public. Richter magnitude scale is logarithmic, meaning that each whole number increase represents a ten times increase in the recorded amplitude. Each whole number increase also represents a 32-fold increase in the energy released. Thus, a M7 earthquake releases 1,000 times the energy compared to a M5 earthquake.

In addition to ground shaking, site-specific soil failures (fault ground rupture, landsliding, differential settlement of foundations, soil liquefaction) can cause excessive movements of structures leading to damage. Soil liquefaction represents reduction in soil strength and stiffness by earthquake shaking or other rapid loading. Liquefaction occurs in saturated soils. Significant damage from liquefaction can occur to supported structures, buried utilities, and waterfront structures. Maps of soil liquefaction prone areas, such as that shown in Figure 3, are available for many communities in Washington, Oregon, and British Columbia.

Figure 3: Example Liquefaction Susceptibility Map

BUILDING CODES

Until recently, the most widely accepted code regulations in the western United States for seismic design of structures and nonstructural components were those found in the Uniform Building Code (UBC). The basic design philosophy of the UBC, including the 1997 edition, was that structures should be able to resist earthquake ground motions as follows:

Ground Motion Level	Damage Level
Minor	None
Moderate	No structural damage, some nonstructural damage
Major	No collapse, but possible structural and nonstructural damage

To implement this approach, the UBC specified ground motion criteria, equivalent static force equations, analysis procedures, load combinations and factors, structural detailing requirements, and acceptance criteria. The International Building Code (IBC) is the basis for the current generation of building codes used in the United States and represents a substantial update of seismic design for new construction. The 2009 IBC has been adopted throughout the U.S.

SEISMICALLY VULNERABLE BUILDING TYPES

Some existing structures may not meet the seismic performance criteria intended by modern building codes for new construction. The following are examples of structures that can be vulnerable to damage in major earthquakes.

Unreinforced masonry bearing walls

Concern: Inadequate wall anchorage, unstable walls and parapets, and soft stories

Solution: Wall anchorage, strongbacks, diaphragm upgrades, braced frames

Pre-1980s residential wood frames with tuck-under parking or soft story

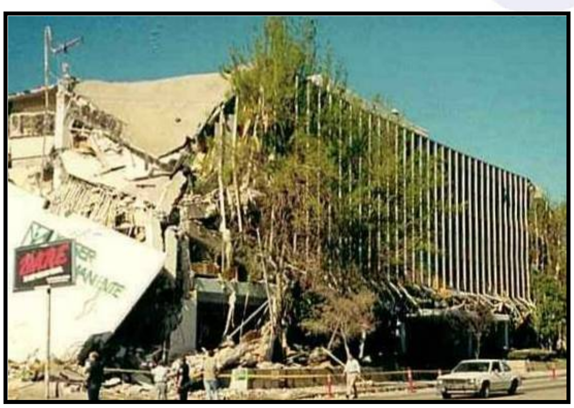
Concern: Collapse or partial collapse due to inadequate first-story strength

Solution: Steel moment-resisting frames or shear panels at grade level

Pre-1970 reinforced concrete frames

Concern: Collapse due to inadequate steel reinforcing to confine concrete elements

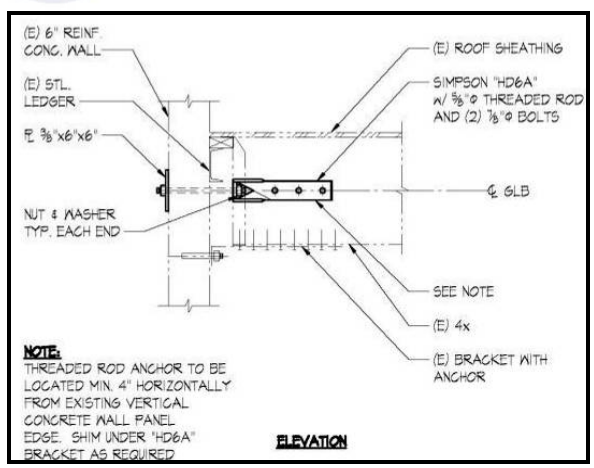
Solution: Reinforced concrete shear walls or energy dissipation devices



Pre-1974 reinforced concrete tilt-up and masonry block buildings

Concern: Wall separation or collapse due to weak roof-to-wall anchorage and diaphragms

Solution: Wall anchorage and roof diaphragm connections



BUILDING CONTENTS AND INFRASTRUCTURE

As reported by MRP Engineering following recent major earthquakes, damage to inadequately restrained equipment and contents can dominate earthquake losses and affect re-occupancy timeframe. Gas-fired equipment damage can lead to fire following an earthquake. Fallen components near exits can block building egress.

Understanding of important on-site and off-site lifelines, such as electricity, water supply, and communications is also important. Electrical power in particular is key to enable post-event inspections, testing, and eventual startup or re-occupancy.

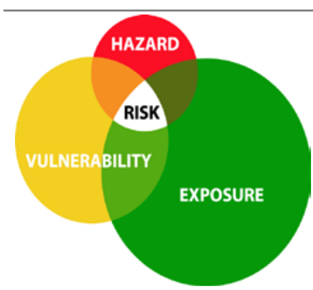
DETERMINATION OF EARTHQUAKE LOSSES

A seismic risk evaluation is an effective first step in understanding potential earthquake exposures. A risk evaluation report also provides a “loss summary” (see Table 1 below) based on the technical review of a property. The risk can be expressed as a probable maximum loss (PML), or cost to restore the structure or facility to pre-earthquake condition, represented in terms of percentage of its replacement value. When coupled with financial values at risk, a loss summary for the existing facility can be used in making property insurance procurement or risk-management decisions. The table below also illustrates potential reduced losses for a “retrofitted” case (in blue), assuming that loss-control recommendations are implemented. This information is very useful in assessing the benefits of seismic risk mitigation.

Table 1: Example Loss Summary

Item	Value	Existing		Retrofitted	
Buildings	$100M	30%	$30M	15%	$15M
Equipment	$100M	20%	$20M	10%	$10M
Time element	$200M	6 months	$100M	3 months	$50M
Total	**$400M**	**$150M**		**$75M**	

SUMMARY



The Pacific Northwest is earthquake country. Understanding of potential earthquake exposures and losses represents the first step in managing risk and making insurance procurement decisions. MRP Engineering is ready to assist you with all facets of your earthquake risk-management program, from initial facility risk screening all the way to finalizing design and construction documents for upgrades.

MRP ENGINEERING

MRP Engineering is a structural engineering and risk analysis firm specializing in earthquake engineering. We assist our clients in protecting their business operations from risks to physical assets resulting from extreme events such as earthquakes and hurricanes. Our philosophy is to listen to your needs and then provide you with practical and cost-effective structural engineering-based risk reduction solutions. Our technical staff actively contributes to the advancement of earthquake engineering standards and routinely investigates performance of structures and systems following actual earthquake events. For further information, please contact us at info@mrpengineering.com.