Downtown Portland Earthquake Preparedness Tour

April 18, 2012, 2 p.m.

Text by Yumei Wang, Edward C. Wolf, Randall Toma, Jon Henrichsen, David O'Longaigh, Devon Lumbard and Allison Pyrch

Introduction and Purpose

Yumei Wang, DOGAMI and Edward C. Wolf, Writer

The sun had not yet risen in San Francisco 106 years ago today when a 300-mile segment of the San Andreas Fault lurched and shook the young city for nearly one minute. The magnitude 7.9 temblor came to be known as the Great San Francisco Earthquake.

San Francisco became a different city on April 18, 1906; that much is beyond dispute. Shaking and fire destroyed more than 28,000 buildings and displaced nearly three-quarters of the city's population. A world-class city emerged from the ashes, but living well in that lively seismic zone remains a work in progress.

Over the last 25 years, Portland has slowly come to terms with its own precarious seismic circumstance. A fault called the Cascadia Subduction Zone runs the length of Oregon's coast, and when that fault slips all of Western Oregon will be shaken by a temblor longer and stronger than San Francisco's great earthquake. For lessons, Portland must turn not just to California but also to subduction zone peers including Chile and Japan, where residents plan and build with earth's fury in mind.

Today's tour, hosted by the City of Portland and Multnomah County, examines four threads of Portland's urban fabric from the standpoint of preparedness for a great earthquake (or for the local earthquake that faults almost literally underfoot could unleash):

1. **Buildings:** *Mercy Corps Headquarters*, including the historic Parker-Scott Building, an unreinforced masonry (URM) structure originally designed and built without regard for earthquakes that has been retrofit for modern use;
2. **Bridges**: The *Burnside Bridge*, emblematic of the eleven Willamette River crossings that enable the private and commercial circulation that is Portland's lifeblood;
3. **Infrastructure**: The *Willamette harbor wall*, public infrastructure that protects downtown Portland from flooding and maintains a navigable river channel; and
4. **Responders:** *Portland Fire Station #1*, a fully retrofitted example of the thirty-one fire and rescue stations from which the city will stage emergency response when an earthquake strikes.

Japan's tragic triple disaster in March 2011 showed how problems cascade through interconnections. Japan's remarkable resilience showed how steps to protect lives and keep commerce flowing also propagate through well-planned interconnections. On today's tour, we will seek connections where Portland's resilience can be strengthened. We will look for the forest, not the trees.

We hope that you enjoy today's downtown Portland tour. We look forward to sharing information by earthquake experts, together building a preparedness culture and discussing your ideas and questions.

Hosted by the City and County and Sponsored by the Portland Earthquake Project Organizers

Mike Pullen, Multnomah County Communications Office, 503-209-4111, mike.j.pullen@multco.us
Randy Neves, Portland Bureau of Emergency Management, 503-823-4614, randy.neves@portlandoregon.gov

Tour Leader and Speakers:

Yumei Wang, Oregon Dept. of Geology & Mineral Industries (DOGAMI), Geohazards Engineer, yumei.wang@dogami.state.or.us
Stop 1: Mercy Corps, Randall Toma, ABHT Structural Engineers
Stop 2: Burnside Bridge, Jon Henrichsen, Multnomah County Bridge Section
Stop 3: Harbor Wall, David O'Longaigh, City of Portland Bridge Engineer
Stop 4: Portland Fire Station, Devon Lumbard, Degenkolb Engineers

TOUR AGENDA

2:00 - 3:30

2:00-2:10 Meet at Skidmore Foundation, S.W. First & S.W. Ankeny
Purpose of tour, Yumei Wang, DOGAMI

STOP 1

2:10-2:25 Mercy Corps, 43 S.W. Naito Parkway, URM seismic upgrade
Speaker: Randall Toma, ABHT Structural Engineers, Principal Engineer, Randall Toma, randall@abht-structural.com

STOP 2

2:30-2:45 Tour Burnside Bridge phase 1 seismic upgrade
Speaker: Jon Henrichsen, Multnomah County, Bridge Engineer, 503-988-3757, Ext. 228

STOP 3

2:50-3:05 Tour Portland Harbor Wall, no study
Speaker: David O'Longaigh, Supervising Bridge Engineer for the City of Portland, David.OLongaigh@portlandoregon.gov

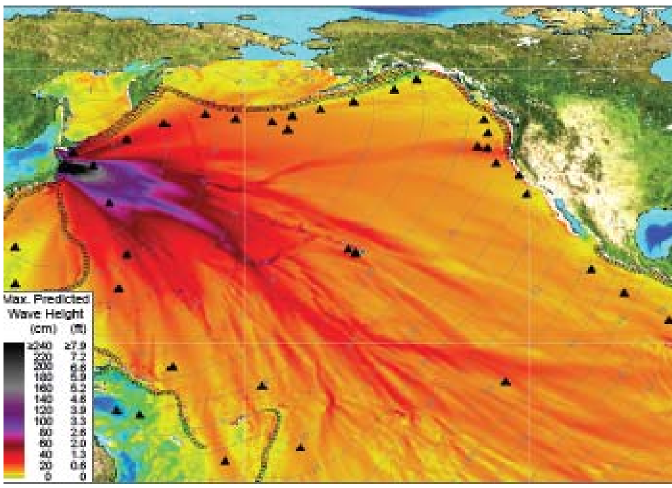
STOP 4

3:10-3:25 Tour Portland Fire Station, Degenkolb Engineers
Speakers: Devon Lumbard, Project Engineer, 503-536-5434 and Kent Yu, Degenkolb Engineers, Principal Engineer, 503-702-2065

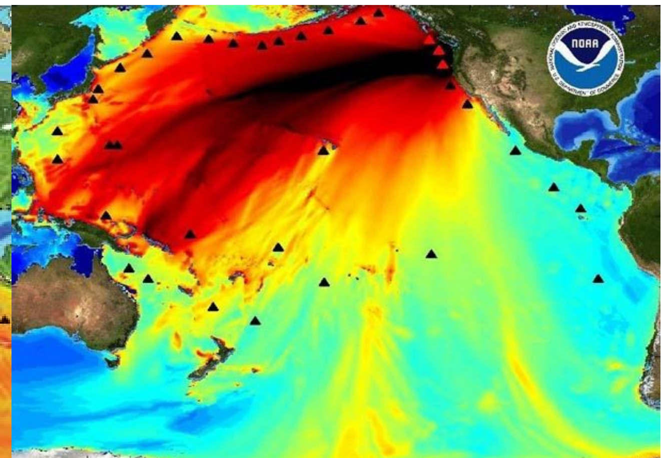
3:25-3:30 Questions for all speakers

Background

The March 11, 2011 Tohoku Japan disaster is considered to be a mirror image of the Cascadia fault. Japan's tsunami hit Japan's coastline, and traveled across the Pacific Ocean to the west coast of the US. The Cascadia fault produced a similar magnitude 9 earthquake on January 26, 1700 and a Cascadia tsunami crossed the Pacific Ocean and damaged coastal harbors in Japan. The Cascadia fault is due to strike again, and Portland must take action to become better prepared.



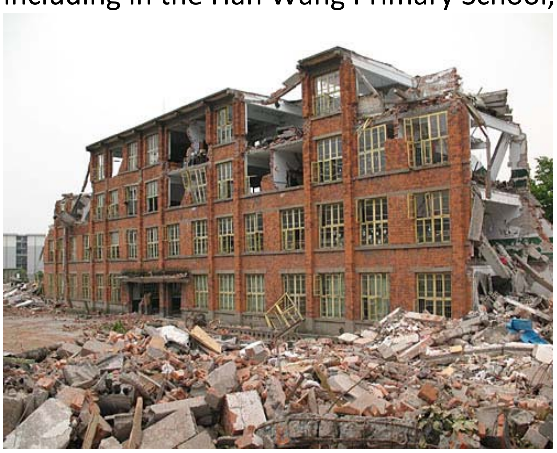
March 11, 2011 Japan Tsunami (Source NOAA)



Hypothetical Cascadia Tsunami (Source NOAA)

Stop 1: Mercy Corps

Unreinforced Masonry (URM) buildings can collapse during earthquakes, killing and injuring its occupants. About 19,000 students died in schools in the 2008 Wenchuan China earthquake, including in the Han Wang Primary School, which was a URM.



Han Wang Primary School, China 2008 earthquake damage URM (Source: Kit Miyamoto)

Mercy Corps, a URM building, was seismically upgraded to protect its occupants. Randall Toma, Principal at ABHT Structural Engineers, provides an overview.

History of Structure

- The existing building portion of the Mercy Corps Headquarters is the historic Skidmore Fountain building (aka Packer-Scott Building or Reed Building) which was constructed in the 1890's (1890-1892) for use as a wholesale warehouse.

- The Skidmore Fountain Building was originally constructed with exterior unreinforced masonry (URM) walls along with one main interior URM wall which supported the wood floor and roof framing.

Picture 1: Mercy Corps south side

New Structure

- The new Mercy Corps Headquarters is an approximate total 80,000-sf building which consists of a new four-story 37,500-sf steel frame building constructed adjacent to and integrally with the existing four-story approximate 42,500-sf Skidmore Fountain Building. **See Picture 1**.

Picture 2: East side of existing building during construction

Seismic Vulnerability

- The unreinforced masonry (URM) walls originally used to construct the existing building are particularly vulnerable in a seismic event (earthquake) due to the brittle nature of the URM. The URM could start to crack and fall from the building in a large earthquake creating life safety issues for people inside and outside the building. Large portions of URM could also eventually collapse in an earthquake leading to loss of portions of the building.

Picture 3: Inside of existing building during construction with added steel

Seismic Upgrade

The Skidmore Fountain Building was seismically strengthened with some of the following elements:

- Added concrete walls to the existing building to provide more seismic support. **See Picture 2**.
- Added foundations and piles were added to support the building.
- Steel framing along the URM walls. The steel framing helps to provide a backup gravity support for the wood and floor framing the URM walls are supporting as well as to strengthen the URM walls from falling off the

building in an earthquake. **See Picture 3**.

- The existing building was connected to the new building with steel beams.

Expected Performance in an Earthquake

- In an extremely large Cascadia event, the building will remain standing. While the building may not be able to be occupied, all occupants should be able to get out of the building safely.

Stop 2: Burnside Bridge

Some bridges are designated emergency routes and should be reliable after disasters, including a Cascadia earthquake. Bridge decks can become dislodged from their supports during earthquake shaking, such as this bridge in the 2010 magnitude 8.8 Chile earthquake.

2010 Chile earthquake, bridge damage (Source: ASCE TCLEE)

Jon Henrichsen, Multnomah County bridge engineer provides an overview of the Burnside Bridge.

The Burnside Bridge was built in 1926 and is among the oldest bridges over the Willamette. However, among Multnomah County's inventory of bridges the only bridge newer within the downtown Portland area is the Morrison Bridge. The Burnside carries more than 30,000 cars a day connecting the east side of Portland with the downtown area.

Bridge structures built during this period did not adequately account for the possible forces that can be imposed on a bridge during a seismic event. With increased understanding of how earthquakes can effect bridges efforts have been made to improve these older structures to better withstand seismic forces. When considering the most efficient use of limited funds to improve these bridges several factors are taken into consideration. These include the importance of the bridge and how vulnerable the bridge is. Another important factor is whether the bridge is improved to provide better life safety or serviceability.

When considering the relative importance of a bridge, an individual bridge is ranked against all of the structures within the state system. There are over 6000 bridges considered within the state inventory. Each bridge is ranked based on how critical the structure is and how vulnerable it is to a given theoretical earthquake event. The most critical bridges include those that serve the main highway system through the state. Next are those that are considered important local lifeline routes within given cities. The Burnside Bridge is classified as a critical lifeline bridge for the Portland area.

The vulnerability of a structure considers how much impact an earthquake would have given the specific location of the bridge. How close a bridge's supports are to bedrock vs. how much soil it is sitting on will determine just how much of the earthquake's forces are transmitted into the structure and how much damage those forces can do.

The priority or importance factor is calculated based on these two values. The current scale for this factor goes up to 42. The higher the number, the more need there is to address the seismic capacity of the bridge. Burnside Bridge scored a 7 on this scale. Although this is rather low on the list it was determined by Multnomah County and the State that as a lifeline for the Portland area some retrofit work needed to be done.

Types of Seismic Upgrades

There are two levels of phases for seismic retrofit of bridges: Phase I and Phase II. A Phase I retrofit looks at the superstructure of the bridge and designs the bridge to hold together in the event of an earthquake. The main purpose is to prevent the deck of the bridge from falling of its supports. This level of retrofit serves the main purpose of protecting lives. As long as the bridge stays intact during an earthquake we can minimize the loss of life due to catastrophic collapse of the bridge. The bridge will most likely sustain significant damage during such an event to where it will no longer be useable after the event and will need to be replaced.

A Phase II retrofit is an attempt to strengthen the structure such that it will be strong enough to remain in service after a significant seismic event. This level of retrofit looks at strengthening and improving the capacity of the substructure including the foundation. This is much more costly and in some cases too costly to consider vs. just replacing the bridge.

For the Burnside Bridge, a 1995 seismic retrofit study identified four improvements that could be done in a Phase I retrofit and eight improvements for a Phase II retrofit.

Phase I

1. Longitudinal restrainers at each abutment
2. Longitudinal restrainers at Piers 1 and 4
3. Strengthening approach span end diaphragm
4. Strengthen fixed span connection to pier wall

Phase II

1. Strengthen approach span bracing
2. Approach span base isolation
3. Counterweight restrainer
4. Bascule pier collar beam
5. Bascule leaf strengthening
6. Post-tension Bascule Pier
7. Soil Densification at abutments
8. Restore bar through trunnion

A computer model testing of these improvements showed that a Phase I retrofit would significantly improve the structures' capacity to stay intact during a seismic event, greatly improving the bridge's capacity to protect lives by not collapsing. However computer models revealed that the Phase II retrofit would do little to improve the chances of the bridge remaining in service after an earthquake.

In 2002 Multnomah County did a Phase I retrofit to the bridge. The design was based on a seismic force of 0.2g which is based on a 500-year return event. This retrofit included longitudinal restraints at each of the bents and piers that were subject to pull-off in a seismic event. This included a total of 18 bents. Also at piers 1 and 4 bearing wedges were added to reduce the risk of bearing failure in a seismic event.

A 2002 Phase I seismic upgrade of the Burnside Bridge included restraining rods to prevent girders from being pulled off piers during an earthquake.

Although there are no plans at this time to do further seismic improvements to the Burnside Bridge, the County will be soon updating the 20-year capital plan for bridges.

Stop 3: Harbor Wall

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David O'Longaigh, Supervising Bridge Engineer for the City of Portland provides an overview of the Harbor Wall.

The Portland Harbor Wall was constructed in the 1930s and runs along the west side of the river beginning at the Steel Bridge and continuing to just past the Hawthorne Bridge. The wall was built to provide flood protection to Downtown Portland as well as providing a terminal for ships to dock, a function it still serves during the annual Rose Festival. The wall was built around the then existing bridge abutments for the Burnside, Steel & Hawthorne bridges, and as such does not directly support any of the bridges along the Waterfront. The Morrison Bridge, which was built after the Harbor Wall, is also structurally independent of the Harbor Wall. A photo taken during construction is shown below.

Fig. 43 View showing forms in place for first pour of tremie concrete dragline distributing fill.

Source: Oregon Historical Society

The bulk of the mile-long wall was constructed using large timber cribs which were sunk onto the river bed using rock as ballast. The cribs are supported on loosely compacted soils placed on the river bed. It should be noted that the wall at the Burnside Bridge was constructed on piling, both vertical and battered, which was built between the existing bridge abutments at that time. A recent underwater sonar inspection showed the entire Harbor Wall to be in good physical condition.

At the time the wall was constructed, seismic concerns were not a factor considered by its designers. According to local geotechnical expertise there is therefore a potential for the wall to be vulnerable to liquefaction and lateral spreading, although no formal study for the harbor wall has been performed. Liquefaction occurs when seismic shaking causes loosely compacted saturated soils to liquefy and loose strength. Lateral spreading happens when liquefied soils near a waterway or slope flow downslope. Based on local known information, lateral spreading may be anticipated along Waterfront Park in this area.

Whereas the extent of the potential for lateral spreading has not been fully studied, there is a possibility it could extend to Naito Parkway, which is designated as a seismic lifeline for response during a major earthquake. It is further possible that a lateral spreading wall could also induce additional lateral forces to the existing bridge abutments along the Waterfront, causing some damage to their foundations. Further study would be needed to confirm this.

Stop 4: Portland Fire Station

Fires are common after major earthquakes, including the 1906 San Francisco earthquake. Having reliable fire stations to help respond to fires and other problems is important for saving lives and damage control.

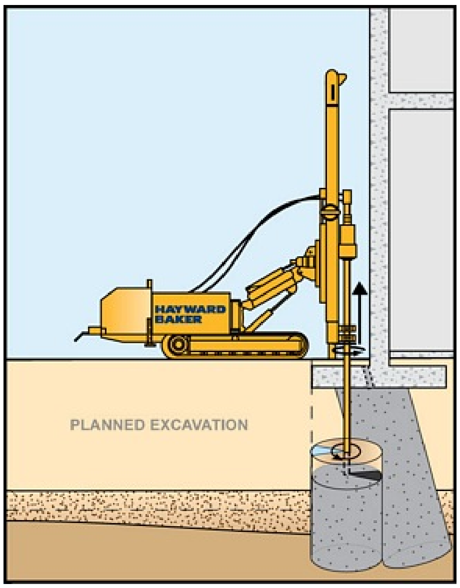
1906 San Francisco earthquake, fire damage
http://cms.westport.k12.ct.us/cmslmc/Grade6/Disasters/pages/earthquake.htm

Devon Lumbard, a project engineer at Degenkolb Engineers, provides an overview of the Fire Station #1 seismic upgrade.

Built in 1952, Portland's Fire Station #1 is the largest fire station in Portland and houses more than a dozen personnel responding to over 6,000 emergencies per year. While it looks like a brick building, the fire station is actually constructed out of concrete with concrete walls hidden behind the brick around the outside of the building and concrete floors and columns on the inside. The main building is three stories tall and has a 5-story drill tower for firefighter training in the back.

The building was evaluated and it was determined that even in a moderate earthquake; the building would sway from side to side enough to potentially jam the apparatus bay doors and prevent them from opening. This would mean that the firefighters would first have to cut their way out of their own building before being able to respond to the emergencies in the surrounding communities. Even worse, the building was prone to collapse in a large earthquake such as the Cascadia earthquake due to several hazards. The tall and slender drill tower would pull away from the shorter main building, swing around, and impact into the main building. The concrete columns would crack and begin to crumble, causing the floors to collapse. The ground under the building could liquefy and experience lateral spreading, causing the columns to sink into the ground and cracking the concrete beams.

To prevent all of this from happening, the building was retrofitted so that the firefighters could focus all of their attention on the public instead of rescuing themselves after an earthquake. To accomplish this, new concrete walls were added behind the existing exterior walls to prevent the building from excessively swaying. The connection of the drill tower to the main building was strengthened and a structural "fuse" was installed to control the swaying interaction of the two. All of the columns were wrapped with carbon fiber to prevent them from collapsing. Finally, concrete was pumped into the ground under the columns to prevent them from sinking into the ground due to liquefaction of the soil. All of these retrofits were completed in 2009, and the building is now safe and ready to support the Portland firefighters after the next earthquake.



Liquefaction vulnerability was mitigated by installing jet grouted columns (Source: Hayward Baker)

Allison Pyrch, senior geotechnical engineer at Shannon and Wilson, and Yumei Wang provide information on liquefaction and lateral spreading.

Recent earthquakes have shown that severe liquefaction damage can be widespread and under-engineered waterfront walls commonly fail in major earthquakes. Liquefaction, lateral spreading and a harbor wall failure along this section of the Willamette River would likely induce additional pressures to the bridge foundations, would likely compromise the shipping channel, potentially hinder emergency response and recovery after a major earthquake, and potentially affect other structures.

Allison Pyrch and Yumei Wang took part in an international engineering investigation team that observed numerous waterfront structures that failed in the 2010 magnitude 8.8 Chile earthquake due to liquefaction and lateral spreading. As an example, this sea wall (below) failed due to liquefaction of the foundation soils under the wall, which lost strength such that it could no longer support the weight of the concrete wall, as well as the increase of pressure exerted by the liquefied soils behind the wall. Lateral spreading damage in the form of cracks behind the wall can be seen in the photo.

Source: Allison Pyrch and Yumei Wang as part of engineering investigation team for the 2010 magnitude 8.8 Chile earthquake.

For More Information

- Oregon Dept. of Geology & Mineral Industries, www.oregongeology.org
- Portland Liquefaction Susceptibility Map, www.oregongeology.com/sub/publications/GMS/gms079_1.pdf
- Portland Bureau of Emergency Management, www.portlandonline.com/oem/
- Multnomah County Bridges, www.multco.us/bridges
- Mercy Corps and the Portland Earthquake Project, www.mercycorps.org/events/2012/04/09/26758