Buildings and earthquakes—Which stands? Which falls?

This document* was produced to accompany the **Teachable Moment resources for Haiti** produced by IRIS and the University of Portland

Introduction

The two most important variables affecting earthquake damage are (1) the intensity of ground shaking caused by the quake coupled with (2) the quality of the engineering of structures in the region. The level of shaking, in turn, is controlled by the proximity of the earthquake source to the affected region and the types of rocks that seismic waves pass through en route (particularly those at or near the ground surface).

Generally, the bigger, closer, and shallower the earthquake, the stronger the shaking. But there have been large earthquakes with very little damage either because they caused little shaking in populated areas, or because the buildings were built to withstand that kind of shaking. In other cases, moderate earthquakes have caused significant damage either because the shaking was locally amplified, or more likely because the structures were poorly engineered.

Damage during an earthquake results from several factors

Strength of shaking. The strong shaking produced by a magnitude 7 earthquake becomes half as strong at a distance of 8 miles, a quarter as strong at a distance of 17 miles, an eighth as strong at a distance of 30 miles, and a sixteenth as strong at a distance of 50 miles.

Length of shaking. Length depends on how the fault breaks during the earthquake. The maximum shaking during the Loma Prieta earthquake lasted only 10 to 15 seconds. During other magnitude 7 earthquakes in the Bay Area, the shaking may last 30 to 40 seconds. The longer buildings shake, the greater the damage.

Type of soil. Shaking is increased in soft, thick, wet soils. In certain soils the ground surface may settle or slide.

Type of building. Certain types of buildings, discussed in the reducing earthquake damage section, are not resistant enough to the side-to-side shaking common during earthquakes.

Resonant frequency of building. See page 3.

From USGS http://quake.usgs.gov/prepare/future/

Haiti Devastation Exposes Shoddy Construction

see next page for text and link to video!!!!

Haiti's Buildings Weren't Fit To Withstand Quakes

Listen to NPR's Interview of Haiti's only earthquake engineer

Haiti's magnitude 7.0 earthquake struck a country whose buildings were barely built to engineering standards and were hopelessly fragile in the grip of such a strong quake.

Watch: **DEMO_Build A Better Wall_Butler.mov**

Robert Butler demonstrates the value of structural elements on earthquake hazard mitigation.

Also available on Internet: **http://www.iris.edu/hq/programs/education_and_outreach/videos#M**

*Information gathered from:

Haiti devastation exposes shoddy construction

By Ayesha Bhatty, BBC News, London

Experts say it is no surprise that shoddy construction contributed to the level of destruction in Haiti following Tuesday's earthquake. But the scale of the disaster has shed new light on the problem in the impoverished Caribbean nation. Tens of thousands are feared dead after being crushed by buildings that collapsed. Scores more remain trapped under the rubble. "It's sub-standard construction," says London-based architect John McAslan, who has been working on a project linked to the Clinton Global Initiative in the country. "There aren't any building codes as we would recognise them," he added. Mr McAslan says most buildings are made of masonry - bricks or construction blocks - which tend to perform badly in an earthquake.

Cheap concrete

There are also significant problems with the quality of building materials used, says Peter Haas, head of the Appropriate Infrastructure Development Group, a US-based non-profit group that has been working in Haiti since 2006. "People are skimping on cement to try to cut costs, putting a lot of water in, building too thin, and you end up with a structure that's innately weaker," said Mr Haas, who was on his way to Haiti to help assess the safety of damaged buildings. "Concrete blocks are being made in people's backyards and dried out in the sun," he said. Mr Haas said there were also "serious problems" with the enforcement of building codes in Haiti. He said the government did not function at all in several parts of the country, and many communities lacked basic services such as electricity, sanitation services or access to clean water. "So the problem of code enforcement is low down on the list," he said.

Poor record

Even before the quake, Haiti's building safety record was poor. Almost 100 people - mostly children - died when two schools collapsed within days of each other in November 2008. At the time, Haitian authorities blamed poor construction for the accidents. Roger Musson, head of seismic hazard at the British Geological Survey, said he was "not at all" surprised at the level of destruction in Haiti. He said Haiti, the poorest country in the western hemisphere, was not used to dealing with earthquakes of this magnitude. Tuesday's quake was the worst in two centuries. The country is more used to dealing with hurricanes, which have been getting more frequent in recent years, according to Mr Musson. "Most buildings are like a house of cards," he said. "They can stand up to the forces of gravity, but if you have a sideways movement, it all comes tumbling down." Ironically, people living in the shanty towns might have had a better chance of survival than those trapped under concrete buildings, many of which "pancaked". "A simple shack's collapse is likely to cause less damage to human safety than a multi-floor building that collapses," Mr McAslan said.

"...the loss of life from earthquakes is typically 10 times higher in developing countries than the West and the damage can be up to 100 times worse."

Narrated animations from USGS showing why poorly constructed buildings collapse during an earthquakes:

http://www.youtube.com/watch?v=K-y1R_3tZTE

and how reinforcement works:

http://www.youtube.com/watch?v=3X1ZnlkVjY0

Aftershocks

Mr McAslan says it is more complex and expensive to earthquake-proof a building than equip it for hurricane damage. "The priorities have inevitably been elsewhere, but I'm absolutely certain that the attention of the government will be to build back better." He said the main task for the authorities now was to save as many lives as possible, then to stabilise damaged buildings so they could withstand any aftershocks, and finally, to assess how to create buildings that could reasonably withstand another earthquake. According to Mr McAslan, the extent of deforestation in Haiti also contributed to devastation. He said that on the hillsides of Petionville, a suburb east of Port-au-Prince, buildings simply "collapsed and collapsed and collapsed" on to each other as there was no forest to protect them. According to the US Geological Survey, the loss of life from earthquakes is typically 10 times higher in developing countries than the West and the damage can be up to 100 times worse.

Resonance

In the case of Haiti, building design is the key point, not resonance. There probably will turn out to be some effects of resonant soft soils, but right now all that is certain is that the buildings were poorly constructed. But understanding resonant effects on different buildings helps students understand why building codes are so important.

Tall or Small? Which is Safer? It depends on resonance!!

During an earthquake buildings oscillate, but not all buildings respond to an earthquake equally. If the frequency of oscillation of the ground is close to the natural frequency of the building, resonance (high amplitude continued oscillation) may cause severe damage.

Small Buildings:

Small building are more affected, or shaken, by high-frequency waves (short and frequent). For example, a small boat sailing in the ocean will not be greatly affected by a low-frequency swell where the waves are far apart. On the other hand several small waves in quick succession can overturn, or capsize, the boat. In much the same way, a small building experiences more shaking by high-frequency earthquake waves.

Tall High Rises:

Large structures or high rise buildings are more affected by low-frequency, or slow shaking. For instance, an ocean liner will experience little disturbance by short waves in quick succession. However, a low-frequency swell will significantly affect the ship. Similarly, a skyscraper will sustain greater shaking by long-period earthquake waves than by the shorter waves.

Resonance video lecture demonstration:
John Lahr demonstrates the simplest and most spontaneous way to demonstrate the concept of resonance and building height uses spaghetti and small weights (raisins or marshmallows.
This and the other two resonance demonstrations are on the IRIS "Video's" webpages:
www.iris.edu/hq/programs/education_and_outreach/videos

Tall and Short Buildings Stood—Middle-size Buildings Fell

1985 Mexico City quake kills 10,000

On September 19, 1985, a magnitude 8.1 earthquake occurred off the Pacific coast of Mexico. 350 km (217 miles) from the epicenter damage was concentrated in a 25 km^2 (9mi^2) area of Mexico City. The underlying geology contributed to this unusual concentration of damage at a distance from the epicenter. An estimated 10,000 people were killed, and 50,000 were injured. In addition, 250,000 people lost their homes. The set of slides (link below), shows different types of damaged buildings and the major kinds of structural failure that occurred in this earthquake including collapse of top, middle and bottom floors and total building failure.
Interestingly, the short and tall buildings remained standing. Medium-height buildings were the most vulnerable structures in the September 19 earthquake. Of the buildings that either collapsed or incurred serious damage, about 60% were in the 6-15 story range. The resonance frequency of such buildings coincided with the frequency range amplified most frequently in the subsoils.

To see slide show go to the NOAA website:
Earthquake Damage in Mexico City

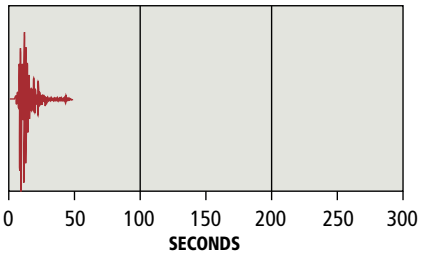
Quake Scenarios

The two scenarios below are Seattle-area earthquake scenarios show the possible effects on buildings of different structural integrity of a shallow, magnitude 7 (**M7**) earthquake and a **M9** subduction-zone earthquake. These scenarios could apply to any cities on the coast or inland valleys of Washington and Oregon (as well as Chile, Alaska, British Columbia, Japan, N.Zealand).

M7 shallow earthquake

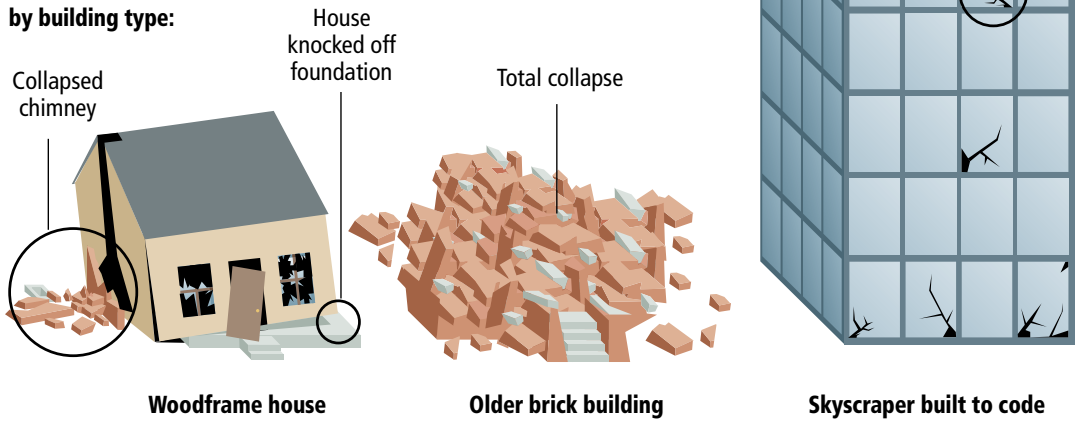
UPDATE: This can be equated to the Magnitude 7 earthquake in Haiti on Jan. 12, 2010

DURATION, INTENSITY AND STRUCTURAL DAMAGE



Duration: Roughly 20 to 60 seconds
Intensity: Violent ground shaking
Damage: Taller, newer structures built to flex would likely handle the shaking best. Brick or other unreinforced masonry buildings would do poorly, as would woodframe structures that aren't tied to their foundations

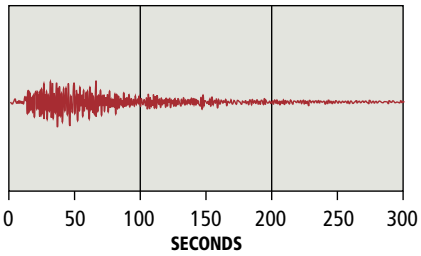
How damage varies by building type:



M9 subduction earthquake

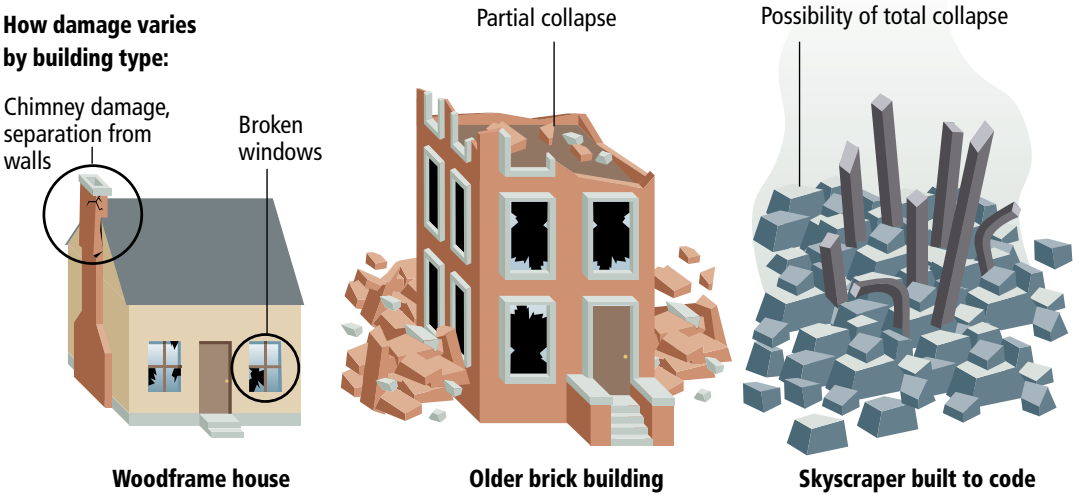
UPDATE: This can be equated to the Magnitude 7 earthquake in Haiti on Jan. 12, 2010

DURATION, INTENSITY AND STRUCTURAL DAMAGE



Duration: Roughly 1 to 5 minutes
Intensity: Moderate ground shaking
Damage: This is the scenario scientists know least about. Some say the long duration of shaking could start modern skyscrapers and bridges swaying back and forth until they collapse because many structures have only been engineered to withstand shaking for seconds rather than minutes. Others think the damage might not be as severe because the shaking is not as violent as a shallow quake.

How damage varies by building type:



Activities

Web links to interactive activities

INTERACTIVE Game: You have 25 min. to select retrofits to <u>Stop a Disaster and save a town</u>!!!

You can reduce human, physical, and financial catastrophe by making quick choices to plan and construct a safer environment, but you have limited funding. Expect good and bad advice along the way.

1) Go to **www.stopdisastersgame.org/en/home.html** and touch
   PLAY GAME > Launch game > Play game (again)
2) **Select a Scenario**: Type: **<u>Earthquake</u>** / Select **SELECT DIFFICULTY LEVEL** (start "EASY" to learn)
3) Roll over each buildings to decide to get Info, Demolish, or provide Upgrades (each has a cost)

WARNING: 25 minutes goes by quickly. Fix big older buildings first.

INTERACTIVE Design a bridge; add structural elements; then set off an earthquake!!

Fun interactive program allows you to design the Bay Bridge...and then destroy it with an earthquake. Select bridge types, seismic safety features and earthquake type:

http://eduweb.com/portfolio/bridgetoclassroom/engineeringfor.html

Relevant Web links

IRIS Seismic Monitor **http://www.iris.edu/dms/seismon.htm**

IRIS Teachable Moments **http://www.iris.edu/hq/programs/education_and_outreach/moments**

MCEER—Earthquake Engineering to Extreme Events .
Haiti Earthquake 2010: Facts, Engineering, Images & Maps
http://mceer.buffalo.edu/infoservice/disasters/Haiti-Earthquake-2010.asp

IRIS Animations and Video Lectures