

# 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/>

**Activities [pages 4-5](#) (touch to go there)**

**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.*

**Touch  
image to  
go to Video  
page**

**["Build a Better Wall" Video Demo Lecture](#)**

*Robert Butler demonstrates the value of structural elements on earthquake hazard mitigation. Instructions begin on Page 8*

# Construction

## Haiti devastation exposes shoddy construction

By Ayesha Bhatti  
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

*"...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."*

[Link to narrated QuickTime & Scroll to "Animated Building Collapse"](#)

Narrated animation from USGS showing why poorly constructed buildings collapse during an earthquake. Scroll down to: [Animated building collapse](#)

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.

### 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.

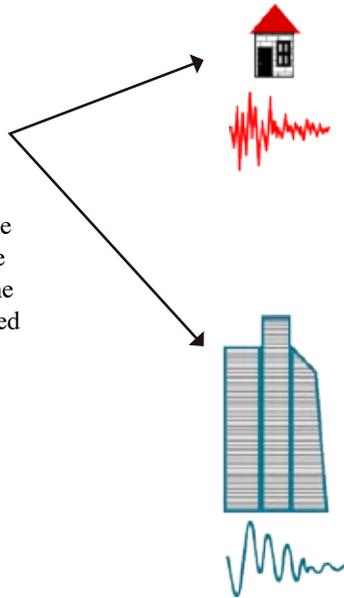
**What is the future? See:**  
[Haiti Quake: A Plan for Reconstruction](#)

# 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 buildings 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.

### **Below: [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). See*

## Tall and Short Buildings Stood— Medium 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<sup>2</sup> (9mi<sup>2</sup>) 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.

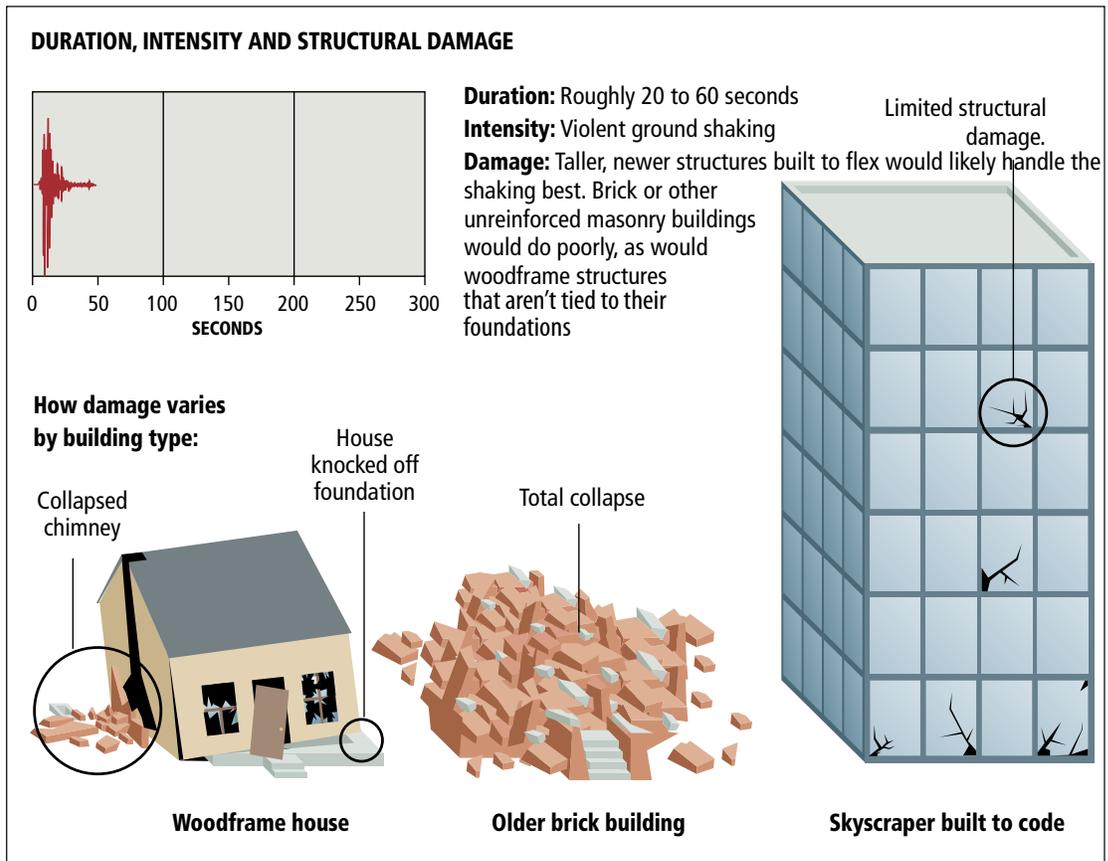
To see slide show go to the NOAA website:  
[Earthquake Damage in Mexico City](#)

# Quake Scenarios

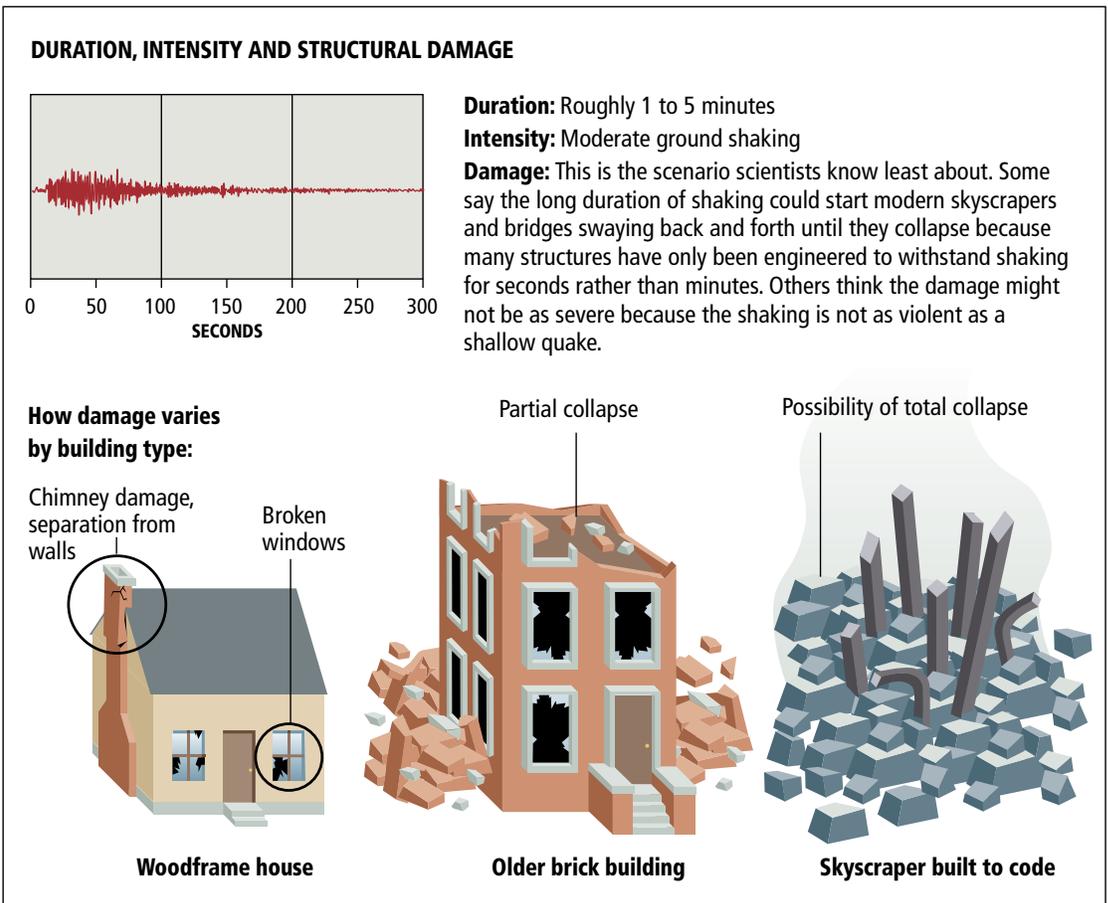
The two scenarios below are Seattle-area earthquake scenarios show the possible effects on buildings of different structural integrity of a shallow, magnitude 7 (M7) earthquake and a M9 subduction-zone earthquake. These scenarios could apply to any cities on the coast or inland valleys of Washington 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



## M9 subduction earthquake



## Activities

- 1) **Build a Better Wall—Structural Reinforcement; the Better Building** from FEMA is shown on page 1 of this document. It is in its entirety on [pages 8-18](#) of this PDF document.
- 2) **A shake table** can be used to test the resistance of structures to seismic shaking. It can also be used to demonstrate the sensitivity of structures of different heights to the frequency of the ground motion. Visit Larry Braile's [Earthquake Shaking – Building Contest and Shake Table Testing Activity](#) and look at his Damage Slides: <http://web.ics.purdue.edu/~braile/edumod/eqphotos/eqphotos1.htm>  
<http://web.ics.purdue.edu/~braile/edumod/eqphotos/eqphotos2.htm>
- 3) **Resonance Activities:** See “Building Stability during Earthquakes” on [page 7](#)
- 4) **Liquefaction:** learn how soft sediment can affect how a building stands  
[www.exploratorium.edu/faultline/activezone/liquefaction.html](http://www.exploratorium.edu/faultline/activezone/liquefaction.html)
- 5) **INTERACTIVE Game: You have 25 min. to select retrofits to Stop a Disaster and save a town!!!**  
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](http://www.stopdisastersgame.org/en/home.html) and touch **PLAY GAME > Launch game > Play game** (again)
  - 2) **Select a Scenario:** Type: **Earthquake** / 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.*
- 6) **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>
- 7) **HOW BIG WAS IT? How do you get across the idea of magnitude? M5 vs M7?**  
See “Pasta Quake” on [page 19](#) of this document.

## 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](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>

**Reducing Earthquake Losses Throughout the United States —Building Safer Structures**

<http://quake.usgs.gov/prepare/factsheets/SaferStructures/>

IRIS [Animations](#) and [Video Lectures](#)

## Activity

# Building Stability during Earthquakes\*\*

The three highly effective activities address earthquake resonance on buildings.

We offer different styles and levels of the same basic processes using a variety of materials.

**Time:** 5-30 Minutes

**Target:** Grade Level: 6-12

**Content Objective:** Students will predict how a structure will react to vibrations (oscillations) of different frequencies, and describe the phenomenon of resonance.

### Introduction

*Why do buildings of different heights respond differently in an earthquake?* These activities show that how seismic waves travel through the layers of the Earth can effect how a building might wobble. Aside from architectural constraints, i.e., how well built the structure is, the particular resonance of the ground during an earthquake can knock down a small building and spare the skyscraper. The resonance is the continued oscillation (up-and-down or back-and-forth motion). During an earthquake, buildings oscillate. If the frequency of this oscillation is close to the natural frequency of the building, resonance may cause severe damage. These models allow students to observe the phenomenon of resonance.

### Teacher Preparation—Choice of Models

*First*, decide which oscillation model fits your class time, as well as preparation time. FEMA’s Seismic Sleuth’s BOSS model has much background material. With all models, practice before using in class!!

- 1) The spaghetti-and-marshmallow (or raisin) model is the quickest to assemble and is described in the movie, Modeling Resonance using Spaghetti.
- 2) The [BossLite model](#) (Movie-Manilla Folder; instructions on BossLite link) has the advantage of looking more like buildings; you could even draw windows on them. Because of the different weight of manilla folders, we found we had to experiment with doubling up the files as they were too floppy.
- 3) The **BOSS model** (Movie Boss Model) is the most elegant, and will be a permanent tool for the classroom. But it does take some assembly time and must be stored. The activity is in the PDF file: [FEMA’s Seismic Sleuths](#) (Unit 4, page 248)

*Second*, find out what students already know about the concepts of amplitude, frequency, and resonance. If they are not familiar with these terms, introduce them by building on what students already know from other areas. They may know, for example, that resonance and

### Materials:

Watch the 3 videos on resonance to determine how elaborate an activity you want.

[Video clips of the Resonance Demonstrations](#) introduce the concept of resonance in these three demonstrations:

[Modeling Resonance using Spaghetti Noodles \(easiest\)](#)

[Modeling Resonance using Manilla Folder](#)

[Modeling Resonance using BOSS Model \(most effective\)](#)

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frequency are used in describing the tone of musical instruments and the quality of sound produced by different recording techniques and players. The phenomenon of resonance also accounts for laser light.

*Third*, review the terms and concepts introduced in this lesson. Explain that seismic waves caused by earthquakes produce oscillations, or vibrations, in materials with many different frequencies. Every object has a natural rate of vibration that scientists call its natural frequency. The natural frequency of a building depends on its physical characteristics, including the design and the building material. Resonance is a buildup of amplitude in a physical system that occurs when the frequency of an applied oscillatory force is close to the natural frequency of the system. In the case of an earthquake, the ground shaking may be at the same frequency as the natural frequency of a building. Each vibration in the ground may come at or dangerously close to the natural frequency of the structure.

*Fourth*, ask the class to hypothesize what would happen when buildings of two different heights, standing next to each other, resonate from an earthquake. (Remember to practice a lot before demonstrating. The BOSS model, though most time consuming to construct, works best!) Students invariably select the tallest building. Wiggle the model so that the shorter building vibrates the greatest. If you have some images of this effect from actual earthquakes, show them now. The Mexico City quake described on page 27 is a good example of mid-size buildings falling preferentially.

*Fifth*, entice students to further investigation by leaving them with the question: “**How could you add structural elements to reduce resonance in a building?**” Adding sheer structure keeps things from falling. Watch the video [Building Strength Demo](#) on the IRIS “Videos” page.

# Structural Reinforcement:

## The Better Building



The activity is from  
[FEMA's Seismic Sleuths](#)

### RATIONALE

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Students will learn how diagonal braces, shear walls, and rigid connections strengthen a structure to carry forces resulting from earthquake shaking.

### FOCUS QUESTIONS

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How may the structure of a building be reinforced to make it better able to withstand earthquake shaking?

### OBJECTIVES

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#### Students will:

1. Recognize some of the structural elements of a building.
2. Describe how the horizontal and vertical structural elements carry the horizontal and vertical loads of a building.
3. Describe how diagonal braces, shear walls, and rigid connections provide paths for the horizontal load resulting from an earthquake.
4. Observe how added structural elements strengthen a model wall to withstand shaking.

### MATERIALS

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#### TEACHING CLUES AND CUES

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Jumbo craft sticks are available at craft and hobby stores. They are larger than ice cream sticks, about the size of tongue depressors.



You may want to build this model and the one in Lesson 4.3 at the same time, and introduce them both in the same class period. This would allow two groups to be actively engaged with the models of the same time.

### MATERIALS

#### Teacher: for one model wall

- 21 jumbo craft sticks, about 15 cm x 2 cm x 2 mm thick sticks, about the size of tongue depressors.
- Electric drill with 3/16" bit
- Goggles for eye protection
- 1 piece of thin wood (about 2 mm thick) 45 cm x 6 cm (about 18 in. x 2 in.)
- 1 piece of sturdy wood (2 x 6) for a base, about 45 cm (18 in.) long
- 16 machine bolts, 10 x 24, about 2 cm long (.75 in.)
- 16 machine screw nuts, 10 x 24
- 32 washers, #8
- 7 small wood screws  2 pieces of string, each approximately 25 cm (10 in.) long

#### Reinforcing elements for one wall:

- 1 piece of thin wood (about as thick as the craft sticks) 20 cm x 2 cm
- 1 piece of lightweight cardboard, about 15 cm x 15 cm (a little less than 6 in. square)
- 8 small paper clamps to fasten wood and cardboard

#### For each small group

- One set of the above supplies if they are each building a model wall
- One copy of Master 4.2b, Load Paths Worksheet
- Pens and pencils

### **“Build a Better Wall” Video Demo Lecture**

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

## **PROCEDURE**

### **Teacher Preparation**

Assemble the model wall, following the diagram on Master 4.2a, Building a Model Wall, and try it out before class. Be sure the bolts are just tight enough to hold the structure upright when no force is applied.

#### **A. Introduction**

Tell students that this lesson is designed to demonstrate how the structural elements of a wall carry forces. The activity deals with three structural elements that carry the lateral shear forces caused by ground shaking during an earthquake: diagonal bracing, shear walls, and rigid connections. It is designed around an apparatus called the model wall. Remind the students that this is a model, designed to demonstrate only certain characteristics of real walls.

#### **B. Lesson Development**

1. Show students the model and tell them that it represents part of the frame of a building. Describe the components of the wall, and ask them, “What holds this wall up?” The answer is in the interaction of the vertical and horizontal elements, but try to keep the students focused on discovery, since in this activity they will see the architectural principles demonstrated. Explain to students that what they refer to as weight will be called the force of gravity in this lesson.
2. Now ask students to predict what would happen if you quickly pushed the base of the wall, simulating an earthquake. Remind them that an earthquake may cause ground shaking in many directions, but for now we are modeling shaking in one direction only.
3. Divide the class into the same seismic engineering teams (SETs) as for Lesson 1 and give each group one copy of Master 4.2b, Load Paths Worksheet. Invite students to take turns investigating the model’s response in their small groups.

## **VOCABULARY**



### **Braces or Bracing:**

structural elements built into a wall to add strength. These may be made of various materials and connected to the building and each other in various ways. Their ability to withstand stress depends on the characteristics of the materials and how they are connected.

**Load:** the sum of vertical forces (gravity) and horizontal forces (shear forces) acting on the mass of a structure. The overall load is further broken down into the loads of the various parts of the building. Different parts of a building are designed and constructed to carry different loads.

**Load path:** the path a load or force takes through the structural elements of a building.

**Rigid connections:** connections that do not permit any motion of the structural elements relative to each other.

**Shear force:** force that acts horizontally (laterally) on a wall. These forces can be caused by earthquakes and by wind, among other things. Different parts of a wall experience different shear forces.

**Shear walls:** walls added to a structure to carry horizontal (shear) forces. These are usually solid elements, and are not necessarily designed to carry the structure’s vertical load.

**Structural elements or structural features:** a general term for all the essential, non-decorative parts of a building that contribute structural strength. These include the walls, vertical column supports, horizontal beams, connectors, and braces.

- a. Instruct one student in each group to push at the bottom of the model from the lower right or left side. (When pushed just fast enough, the model should collapse at the first floor only.) Ask students why the other floors didn't collapse. (The first floor collapsed because it was too weak to transfer enough horizontal force to move the upper stories. It could not transfer the shaking to the upper stories.)
  - b. Direct students' attention to the load path diagrams on Master 4.2b and explain that pushing the base of the building is equivalent to applying force horizontally to the upper stories. A force applied horizontally to any floor of a building is called the shear force on that floor. Shear forces can be caused by the ground shaking of an earthquake as well as by high winds. Invite students to carefully apply horizontal forces at different points on the model to simulate earthquake shaking. (Earthquakes affect buildings at ground level.)
4. Ask students how they could add structural elements to create a path for the load to follow to the ground when strong forces act upon the structure. Help the students discover the effect of adding a shear wall, diagonal bracing, and rigid connections, using string, cardboard, extra wood, and clamps, as in the diagrams on the master. On each of the three diagrams provided, have students draw a force arrow (a vector) and trace the path the force takes to the ground.
  5. Challenge students to design and build three different arrangements of the six structural elements depicted on the worksheet. Each time they modify the design they must modify the diagram to show the new load path. Check each structure and diagram until you are sure that students understand the concepts. When a structure is well reinforced, you should be able to push on the upper story and slide the whole structure without any of the walls failing.
  6. Either have the groups discuss the questions on the master, with one student recording each group's response, or ask individual students to write responses to specific questions. After all the groups finish the questions, have a reporter for each SET present its response to one of the questions. Allow the class to come to some consensus on their responses to that question, then proceed to another group until all the questions have been discussed.

### C. Conclusion

As a closing activity, challenge a volunteer to remove an element (a craft stick) that, according to the load path diagram, is not carrying any load. Have the student unbolt one end of that element and push the reinforced structure to see if it holds. It will, if the load path is correct.

Finally, help the students connect the behavior of their model walls to their mental images of real buildings during an earthquake. Emphasize that the back and forth, horizontal component (or shearing) of ground shaking is the force most damaging to buildings. Buildings are primarily designed to carry the downward pull of

## TEACHING CLUES AND CUES



This activity is designed as a demonstration or as a group activity. If you decide to have each

group build a model wall you will need more materials.



Encourage students to choose roles within their SETs and later report their results by role, with

the technician reporting the data, the engineer describing the calculations, the scientist explaining the relationships, and the coordinator facilitating.



Students may try both pushing the structure directly and moving the table. Shaking the table

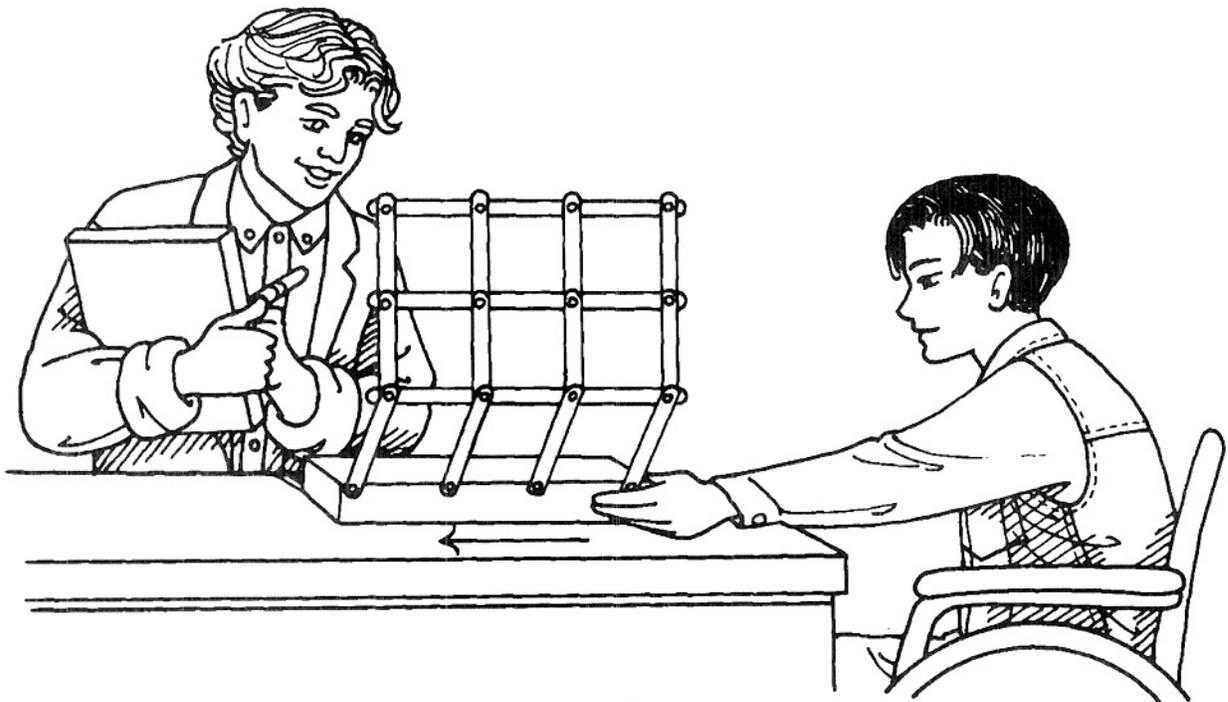
on which the structure rests would simulate the transfer of energy from the ground to the building.

gravity, but to withstand earthquake shaking they need to be able to withstand sideways, or horizontal, pushes and pulls.

## **ADAPTATIONS AND EXTENSIONS**

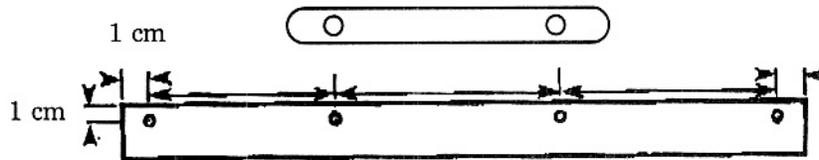
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1. Challenge students to find the minimum number of diagonal braces, shear walls, or rigid connections that will ensure horizontal stability in their models.
2. Invite students to design, construct, and test other structural elements that could make buildings earthquake-resistant, such as square rigid connections. Some might try putting wheels or sleds on the bottom of their buildings.
3. If you have some very interested students, you may give them access to all your building supplies and challenge them to design and construct larger structures. Ask students to consider how they could design a building so that the ground shaking does not transfer to the building. There are new technologies that allow the ground to move, but not the building. One of these is called base isolation. Have students research this topic in periodicals. (See Unit Resources.) ▲

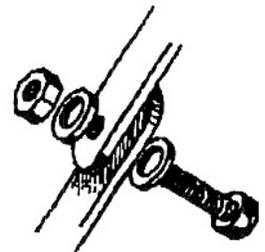
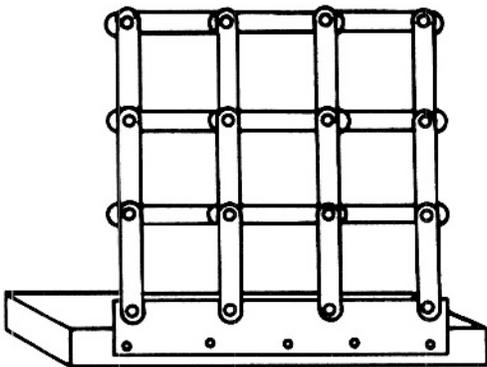


# Building a Model Wall

1. Stack 21 craft sticks one on top of the other. Wrap a rubber band around the center to hold them together. Using a 3/16 in. bit, carefully drill a hole through all the sticks at once, 1 cm from the end of the stack. Drill slowly to avoid cracking the wood.
2. Select the thinner of the two large pieces of wood (45 cm x 6 cm). Drill a 3/16 in. hole 1 cm from one end and 1 cm from the edge. Measure the distance between the holes drilled in the craft sticks and space three more 3/16 in. holes at that distance 1 cm from the edge so that a total of four holes are drilled (see illustration).
3. Use the small wood screws to mount this piece of wood on the base (the 2 x 6), fastening at the bottom and in the center. Leave the pre-drilled holes sticking up far enough above the top to accept the drilled craft sticks.



4. Using the bolts, washers, and nuts, assemble the craft sticks to build a model wall.
5. Experiment with tightening bolts and washers until they are just tight enough for the wall to stand on its own.





Name \_\_\_\_\_

Date \_\_\_\_\_

### A. Failing Wall

Observe and explain how the wall fails when its base is shaken rapidly back and forth, simulating the motion of a building hit by S waves during an earthquake. Tighten all the nuts just enough to allow the joints to move. Sharply push the base a few centimeters horizontally (right or left).

1. What part of the wall fails first?

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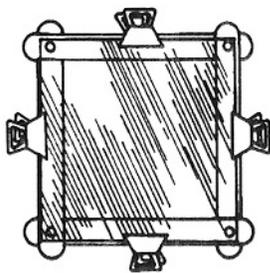
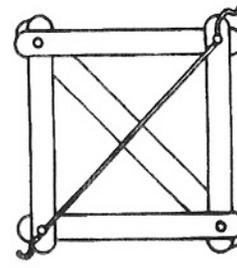
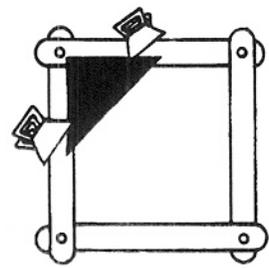
2. Imagine how the horizontal force you applied to the base travels to the upper parts of the wall. What caused the first structural failure?

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\_\_\_\_\_

### B. Load Paths with Additional Structural Elements

1. Pick up the two rigid connections, one shear wall (cardboard), one solid diagonal brace, and two pieces of string. Add structural elements to your wall to provide paths for the horizontal forces, or loads, to travel through the wall. Study the diagrams below to see how these structural elements provide load paths.



Use arrows to show the load path on each diagram.

**C. Summary**

1. What is a load path?

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2. Why must additional structural elements be added to a wall before it can carry horizontal forces?

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3. How many additional elements did you need to add?

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4. Why doesn't the force take some path other than the one you diagrammed?

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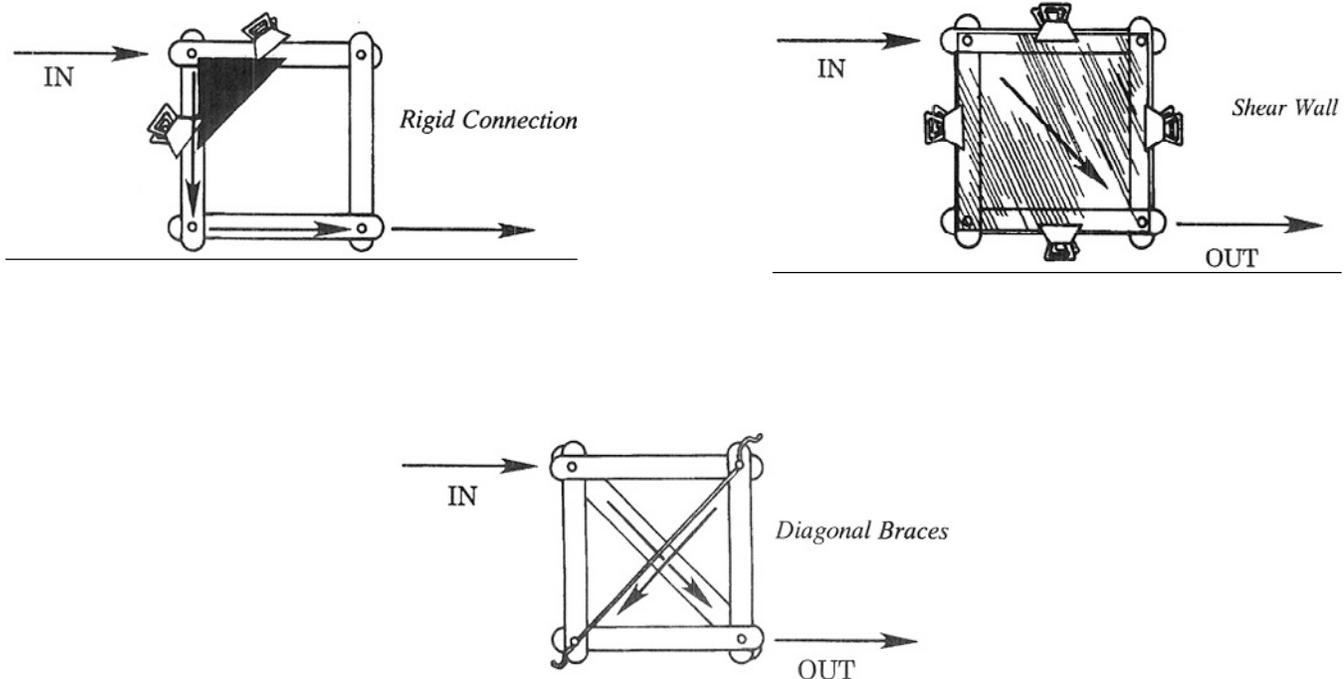
**A. Failing Wall**

Observe and explain how the wall fails when its base is shaken rapidly back and forth, simulating the motion of a building hit by S waves during an earthquake. Tighten all the nuts just enough to allow the joints to move. Sharply push the base a few centimeters horizontally (right or left).

1. What part of the wall fails first? *The first floor*
2. Imagine how the horizontal force you applied to the base travels to the upper parts of the wall. What caused the first structural failure? *The first floor has to carry all the load to the upper stories. It transfers forces to move the upper stories.*

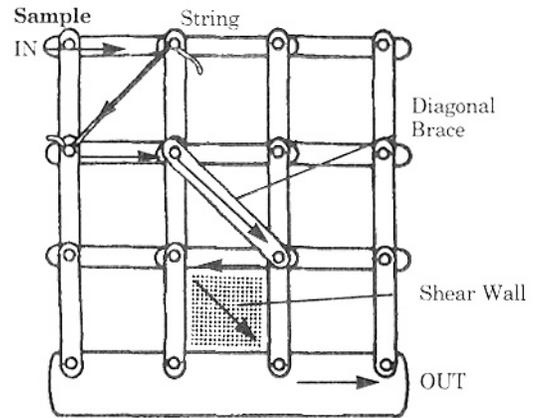
**B. Load Paths with Additional Structural Elements**

1. Pick up the two rigid connections, one shear wall (cardboard), one solid diagonal brace, and two pieces of string. Add structural elements to your wall to provide paths for the horizontal forces, or loads, to travel through the wall. Study the diagrams below to see how these structural elements provide load paths.

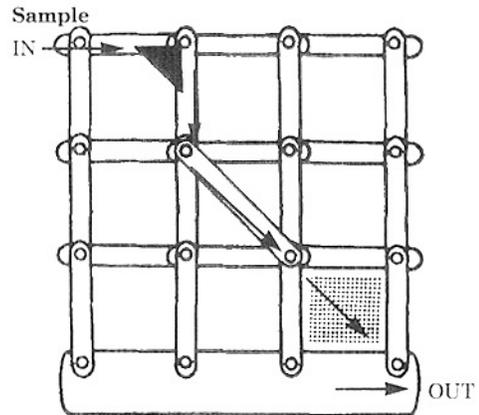


Use arrows to show the load path on each diagram.

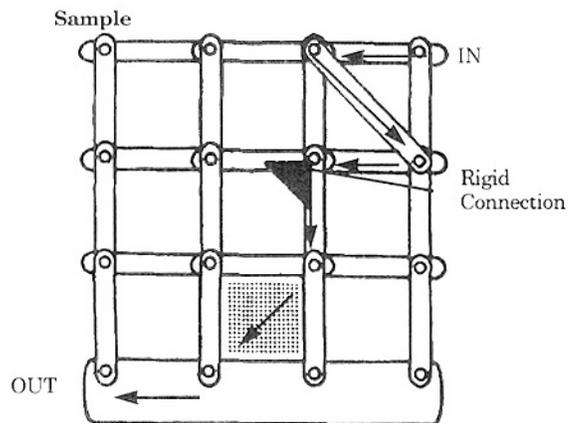
2. Put additional structural elements on your wall and push the third level. If the elements you added provided a load path to the base, the base of the wall should move. If they do not, the wall will fail somewhere. When you discover a setup that works, diagram it and sketch the load paths with arrows. Have your instructor look it over before you continue.



3. Design and build another set of additional structural elements. Sketch the load path here and have your instructor check it. Be sure each member of the team designs a set. The base of the model wall should move when lateral force is applied to the top elements.



4. Design and build a third set of additional structural elements. Use as few additional elements as possible. Sketch the load path and have your instructor check it. Be sure each member of the team designs a set. Test your load paths by removing elements not in the path to see if the building will stand up to a force.



### C. Summary

1. What is a load path?

*The path that the load (or force) follows through the structural elements of a building.*

2. Why must additional structural elements be added to a wall before it can carry horizontal forces?

*Normally, buildings only have to support vertical force (gravity). When horizontal forces are applied, as in an earthquake, additional elements are needed to carry them.*

3. How many additional elements did you need to add?

*Each joint needs only one additional structural element. Only one joint on each floor needs to carry the horizontal force, in this model.*

4. Why doesn't the force take some path other than the one you diagrammed?

*The diagram shows the places that are strong enough to carry the load. If there were more than one place, the load (or force) would travel through both.*

# Magnitude: Pasta Quake—The San Francisco Treat

Demonstration to learn the concept of magnitude & log scale

This activity is used with permission from Paul Doherty <http://www.exo.net/~pauld/index.html>

**Time:** 5-10 Minutes

**Target Grade Level:** 4th grade and up

**Content Objective:** Students will learn the earthquake magnitude scale by breaking different amounts of spaghetti. Visual scale of the pasta emphasizes the relative differences between magnitudes; each whole step in magnitude

## Background

The severity of an earthquake can be expressed in terms of both intensity and magnitude. However, the two terms are quite different, and they are often confused.

*Intensity* is based on the observed effects of ground shaking on people, buildings, and natural features. It varies from place to place within the disturbed region depending on the location of the observer with respect to the earthquake epicenter.

*Magnitude* is related to the amount of seismic energy released at the hypocenter of the earthquake. It is based on the amplitude of the earthquake waves recorded on instruments which have a common calibration. The magnitude of an earthquake is thus represented by a single, instrumentally determined value.

## To Do and Notice

Hold up one piece of spaghetti. Bend the piece between your hands until it breaks. Notice the work it takes to break the spaghetti. Call this a **5** on the Pasta Magnitude scale.

Hold up a bundle of 30 pieces of spaghetti. Bend the bundle until it breaks. Notice the work it takes to break the bundle. If the pasta magnitude scale were like the earthquake magnitude scale this would be a Pasta Magnitude **6** break.

Hold up 900 pieces of pasta, the remainder of the package. Bend the bundle until it breaks. Notice the work it takes to break the bundle. This is a Pasta Magnitude **7** break.

## What's Going On?

The magnitude scales for earthquakes are logarithmic scales. In particular for the Richter scale, each increase of 1 unit on the scale, say from 6 to 7, represented an increase of one order of magnitude, i.e. times 10, in the amount of motion recorded on a particular type of seismograph.

The now-common *Moment Magnitude* scale was defined because the Richter scale does not adequately differentiate between the largest earthquakes. The new “moment magnitude” scale is a new technique of using the Richter scale.

## Materials

1# package of thin spaghetti *or*  
2# package of regular spaghetti.

Haiti, 01/12/10

M 5  
(1)

M 6  
(30)

M 7  
(900)



In the moment-magnitude scale a magnitude increase of one unit corresponds to a factor of 30 increase in the energy released by the breaking of the fault in an earthquake. That's why we increased the number of spaghetti noodles from 1 to 30 to 900 ( $900 = 30 \times 30$ ).

## So What?

In order to release the energy of one M 7 earthquake you would have to have 30 M 6 quakes or 900 magnitude 5's. Notice also all the little “quakes” before and after the big-quake break.