

## Activity Overview

In this activity students investigate factors that make buildings stable or unstable. Using models, they investigate building design and modification. They interpret photos to gain insights into damage caused by real earthquakes. The students use a model to understand how wave frequency influences vibrations of structures.

At the conclusion of **Activity 6**, students should be able to outline the factors that can influence a building's response to shaking and ways of increasing earthquake resistance. They should be able to describe the geologic factors that influence stability, such as wave size and frequency and underlying material. Each student group should be able to describe how safer structures built on safe geologic materials increases safety of individuals and the community in their **Chapter Challenge** project. Content reading takes an in-depth look at how duration of ground shaking, direction of ground motion, underlying earth materials, resonance, and building materials all determine the extent of damage caused by an earthquake.

### Preparation and Materials Needed

Little preparation, besides gathering materials, is needed for **Steps 1 – 5** as students design and test and redesign and retest their models of buildings. Constructing the model for **Part B** takes only about one hour, but the model is excellent.

You will need a  $2 \times 4$  piece of wood about 45 cm long, 4 wooden dowel rods, a piece of wood about  $60 \times 2 \times 6$  cm, and a drill. Assemble the model. Drill holes 3 cm deep in the base at the spacing shown in the figure. Cut the dowel rods to the following lengths: 1 = 76.7 cm, 2 = 46.2 cm, 3 = 61 cm, and 4 = 23.3 cm. Cut the 60-cm-long board into four pieces 15 cm long each. Drill a hole 3 cm deep in the base of each of these blocks. Assemble the model. Number each block.

#### Materials

##### Part A

- Wooden dowels
- Large sheets of heavy-gauge mat board or corrugated cardboard
- Map pins
- Other materials of your own to test some of the building models you develop (like pushpins, string, tape, and paper binders)

##### Part B

- Two square pieces of wood (nailed together to make an “L”-shaped wooden base)
- 30 cm thin metal strip (A hacksaw blade is ideal for this exercise. Be extremely careful if a blade is used, taping the serrated edge to protect students from getting cut.)
- Small C-clamp (to hold metal strip to wood)
- Lump of modeling clay (about half the size of a large fist)
- Stopwatch

#### Assessment Tool

##### Think about It Evaluation Sheet

The **Think about It Evaluation Sheet** will help students to understand and internalize basic expectations for the warm-up activity.

## Think about It

### Student Conceptions

Students are likely to think that the size and height of a building, as well as the materials used to construct it will influence the extent of damages. If students have reviewed school earthquake drills and community building codes, they will likely have some conceptions about the safest places to be during an earthquake.

### Answers for the Teacher Only

The extent of damage to a building during in an earthquake can be influenced by the size of the earthquake, building design, underlying geologic material, frequency of earthquake waves, or resonant response of structures.

The safest place to be in a building during an earthquake is under a desk or table, in a doorway, away from glass, or outdoors.

## Investigate

### Teaching Tip

If you do not have access to a table that can be easily shaken, you can have the students build their models on lunch trays.

### Part A: Modeling the Response of Buildings to Shaking

Circulate from group to group asking questions that help the students better understand how structures respond to earthquakes.

3. a) Which variables do you want to explore?  
Some guiding questions for you to pose to students include the following:
  - Does the height of the building matter?
  - Does the size (area) of each individual floor matter?
  - Does the number or design of the supports matter?
  - How resistant do you think your building will be to vibration?
  - Was your building more or less resistant than you thought?
  
5. b) Answers will vary.
  - c) In general, more stable buildings will withstand more violent motion that has a longer duration.
  - d) Answers will vary. Probably not for buildings with square bases. Probably yes for buildings with rectangular bases. (Some guiding questions: Under what conditions does your building collapse quickly? Under what conditions does it stay up longer?)
  
6. b) Probably not, because the “floors” are not pinned together.
  - c) In general, wide structures are more stable, but that depends on the number and design of the supports.

### Assessment Tool

#### Investigate Notebook Entry-Evaluation Sheet

The **Investigate Notebook Entry-Evaluation Sheet** is designed to help students get a sense of the expectations for *EarthComm* notebook entries.

#### *EarthComm* Notebook Entry-Checklist

Refer students to the *EarthComm* **Notebook Entry-Checklist** to remind them of the criteria against which they will be assessed. The checklist also provides a quick guide for student self-assessment and provides you with an opportunity to quickly score student work.

7. Some guiding questions: What happens if you pin the floors together? What happens if you secure the building to the table? What happens if you add more pins?
8.
  - a) Some guiding questions: What do you think made the buildings collapse? Is the cause the same in each case? Note: In one case the building is intact but toppled (soil liquefaction); in another case the highway columns shifted, and the other ground floor of the building collapsed.
  - b) Some guiding questions: How do you think the waves were moving? It is difficult to say without having more information on how the building was designed or information about the earthquake. The bridge and building collapse may have been caused by surface waves moving from side to side as they passed.
  - c) In general, no, except in the toppled buildings. The buildings held together but the earth moved out from under the building. This is an example of damage caused by soil liquefaction.

### Teaching Tip

The *EarthComm* web site [www.agiweb.org/earthcomm](http://www.agiweb.org/earthcomm) contains multiple links which have excellent color photographs of earthquake damage around the world. These images can be used to supplement the photos in the student text and can be used to show the range of damage that can result from an earthquake.

## Part B: Modeling the Response of Buildings of Various Heights to Shaking

- 1–3. It should be easy for students to set up this model. The L-shaped wooden block can be clamped to a tabletop (no such clamp is shown in the drawing on page 170 in the Student Book), or it can be held firmly by one of the students.
4. The amplitude of the oscillation need not be large.
  - b) A smooth, regular curve should be obtained.
  - d) The oscillation period decreases as the height of the ball decreases.
5. In this part of the investigation, the students vary the period of the forcing oscillation (the moving of the apparatus back and forth on the tabletop). Be sure that they vary the period over a sufficiently wide range so that it includes the natural period of oscillation of the apparatus. Note: An oscillation can be described by its period (how long it takes for one complete oscillation) or its frequency (how many oscillations take place per unit of time). The period and the frequency are the inverse of each other. The oscillation can be described equally well by either the period or the frequency.

- d) The curve should have a peak in the middle, and a lower position to each side of the peak.
  - e) The period of the peak in the curve should correspond to the natural period of oscillation of the apparatus.
6. a) No.
- b) A tall building could be damaged by a less-than-major earthquake if its natural period of oscillation closely matches the vibration period of the earthquake waves.
  - c) In a typical large earthquake, the seismic waves have a range of frequencies, but the dominant frequencies are likely to fall into a fairly narrow range. The students should appreciate that if they are to design an earthquake-resistant building they should make sure that the natural frequency of oscillation of the building lies far away from the dominant frequency of the earthquake waves.

### Reflecting on the Activity and the Challenge

Students are adding to their knowledge about how earthquakes cause damage and what factors influence the severity of damage. They now know that building design, the natural frequency of the building, and characteristics of the earthquake waves (amplitude, duration, frequency) are important in addition to the underlying geology (Activity 5).

## Digging Deeper

Assign the reading for homework. The questions in **Check Your Understanding** on page 173 can be provided as a homework assignment.

### Assessment Opportunity

Use (or rephrase) the questions in **Check Your Understanding** for a brief quiz to check comprehension of key ideas and skills. Use the quiz (or a class discussion about the questions in the textbook) to assess your students' understanding of the main ideas in the reading and the activity.

## Check Your Understanding

1. Rupture of water, gas, and electric lines; damage to roads and railroad lines; failures of dams; landslides and other large-scale downslope movements of earth materials; tsunamis.
2. Presence of structures that might be damaged in the first place; earthquake magnitude; location relative to epicenter; nature of underlying earth materials; relationship between frequency of the earthquake waves and the natural frequencies of structures; inherent strength of structures; susceptibility of the area to landslides and other large-scale movements of earth materials.
3. Because structures that had been damaged in earlier earthquakes with strong horizontal motions were rebuilt to withstand that kind of motion, but the 1994 earthquake involved mainly vertical motions instead.
4. Because it is built on loose underlying materials, which are conducive to amplification of the earthquake waves.
5. Because earthquake wave energy is transmitted more rapidly, with lesser wave amplitude, in solid bedrock but more slowly, with greater wave amplitude, in loose earth materials.
6. Because some of the buildings had natural vibration frequencies that were close to the characteristic frequency of the earthquake waves, leading to resonance and amplified oscillation of the buildings, whereas other buildings had different natural vibration frequencies, which were different from the resonant frequency.

## Understanding and Applying What You Have Learned

1. Answers will vary.
2. Cross-braces are useful in adding strength to a building and make the building far more resistant to earthquakes.
3. Geoscientists (especially geophysicists and seismologists); civil and mechanical engineers who specialize in structural design; civil engineers who specialize in soil mechanics; urban planners; hospitals; firefighters; police; other emergency workers; insurance specialists; lawyers.
4. Answers will vary. Some possibilities: areas known to be located very near major active faults; areas underlain by cohesionless and water-rich earth materials like clay or silt sediment; areas with steep slopes that are susceptible to large-scale downslope movements of earth materials.
5. Answers will vary. Check geologic maps or soil maps for faults or weak geologic materials. Check with county officials.

## Preparing for the Chapter Challenge

Have the students write their list of recommendations about how the design for new structures in your community and changes to older structures may be made to minimize damage in your community if a major earthquake were to strike. The list will be incorporated into their brochure. Be sure to include suggestions for new building developers, homeowners, and local government and businesses.

## Inquiring Further

Students may tend to place less importance on this section unless they know that the suggested activities are keyed to the objectives, assessment, and **Chapter Challenge**. Take time to discuss additional questions posed by students and stress how they present an opportunity to extend the depth of understanding of the objectives and provide important information that can improve the quality of their **Chapter Challenge** report.

### 1. Earthquake engineering

Direct students to the *EarthComm* web site.

The inquiry at the NEIC web site will add depth to the students' understanding of the stability and instability of buildings. After viewing the pages the students should have new ideas on how to make buildings more earthquake resistant and recognize factors that caused damage to buildings.