Earthquakes and Buildings Don't Mix

***Putting Down Roots*, p. 18, "Response of Buildings to Earthquakes"**

Idaho State Standards:

8th/9th Earth Science 1.2.1, 1.2.2, 1.2.3, 1.6.3, 1.6.4 5.1, 5.2.1, 5.2.2, 5.2.3

Objectives:

Students will:

1. Explore earthquake hazards and damage to buildings by constructing model buildings and subjecting the buildings to ground vibration on a small shake table.

2. Compare the results of the building contest with photographs of earthquake damage to reinforce concepts of building design and earthquake risk.

RATIONALE

Students enjoy building the "best." This activity is designed for groups of 2-3 students working cooperatively to construct a model poster board building. The students must take into consideration the forces that act upon buildings during an earthquake. Most of the buildings constructed will withstand vertical or static loads. However, with horizontal motion most buildings will not survive shaking without the installation of diagonal bracing. Showing images of buildings that have collapsed from earthquake shaking will emphasize design weaknesses (see the PowerPoint "eqdamage" located on the CD-ROM).

Earthquake ground shaking and damage are related to the size (magnitude) of the earthquake, the distance from the epicenter, the local geological conditions, and the characteristics of buildings. Assessment of earthquake effects involves evaluating the hazard and the risk.

FOCUS QUESTION(S):

- What is the difference between an earthquake hazard and an earthquake risk?
- Can the risk of damage to buildings and the number of people that are expected to be hurt or killed from an earthquake be mitigated?
- How can buildings be made "earthquake proof?"

TEACHING CLUES AND CUES

The USGS definitions for earthquake hazard and earthquake risk can be found at http://earthquake.usgs.gov/image_glossary/. Inform students that earthquake hazard maps are used by structural engineers and government agencies to revise building codes. Show PowerPoint images of building and structural damage. The Discovery Channel has two good short video segments (1:40 min.) that discuss structural reinforcement techniques: "Engineering the Impossible: Arches vs. Beams" at http://science.discovery.com/videos/engineering-the-impossible-clips-arches-vs-beams.html and "Engineering the Impossible: Earthquake Proof" at http://science.discovery.com/videos/engineering-the-impossible-earthquake-proof.html. There is also a six slide presentation on "5 Reasons Buildings Fail in Quakes" at http://news.discovery.com/tech/five-reasons-buildings-fail-quakes.html.

Construct the simple shake table and either use the accelerometer set up or manually move the table (see instructions for Shake Table, p. 93).

Make sure that the materials for each group are measured and pre-cut. Measure the mass (g) of the different washers you will be using for weights in this activity. Write the mass on the washers with a permanent marker. Different-sized washers can be purchased at hardware stores. Time requirements for this activity are 3-4 class periods.

- Day 1, discuss the activity and show the videos and images. Show the students the materials that they will be using. Explain the activity and how the materials will be used. Give students time to collaborate with their team.
- Day 2, construction of building.
- Day 3, testing of their building.
- Day 4, discussion and wrap up.

Testing. Buildings are tested on the horizontal motion shake table. The base of the building is taped to the base plate of the shake table. The way you orient the building on the shake table will affect the integrity of the building. Most buildings will be able to survive the shaking using small masses (30-50 g). However, few buildings with these materials will withstand strong (about 1 g, 1 g = acceleration of gravity which is 980 cm/s^2 or 9.8 m/s^2), shaking with larger masses (50-80 g). If the shake table is large enough (16 x 50 cm), you can attach and test two or three buildings at the same time to provide a comparison of building responses. Just be sure you have enough washers of the same mass to place on each of the buildings. The use of tape or spring clips may be needed to keep the washers on the building.

MATERIALS:
for teacher

- Computer with internet access and projection system (images can be put on view graph and displayed on overhead projector is needed.

- Poster board, cut into the following dimensions /group:
  - 4 – 8 x 8 cm squares (floors)
  - 12 – 2 x 10 cm strips (uprights)
  - 12 – 1.5 x 15 cm strips (reinforcing)
  - 1 – 30 x 8 cm (cut and use as you wish)

  Note: There is a difference in quality and strength of lightweight poster board; the best poster board has one smooth, almost glossy side and one dull side
- Scotch Tape (2 cm or ¾" wide) 100 cm length/ group
- Scissors
- 30 cm. ruler
- Shake table with optional accelerometer (see instructions)
- Washers of different weight (g): Ten each of 3/4", 5/8", 1/2"

for student groups

- Pre-cut poster board
  - 4 – 8 x 8 cm squares (floors)
  - 12 – 2 x 10 cm strips (uprights)
  - 12 – 1.5 x 15 cm strips (reinforcing)
  - 1 – 30 x 8 cm (cut and use as you wish)
- Scotch Tape (3/4" wide)100 cm lengthm more or less may be needed
- Scissors
- 30 cm ruler

Figure 1. A completed lightweight poster board model building.

PROCEDURE:

Teacher Preparation

Cut up the poster board into the dimensions given. Inform students that the building 1) must be at least 30 cm high, 2) with at least 3 stories, 3) that there can be no central post or uprights (weights must be able to be placed on floors), and 4) that materials are limited to what is given to them. Inform students of the amount of time allotted to teams for construction. Be sure to allow a realistic amount of time for this activity.

A. Introduction

The design of the building will be up to students. Simple, rectangular building designs are effective. Many design options, particularly for the bracing, are possible. When it is time to test the design, the base will be taped to the base of the shake table. Masses (washers) will be placed on the floors and roof of the building and held in place by tape or bull clips.

B. Lesson Development

1. Discuss the difference between hazards and risk. Show images of structural damage from earthquakes. Show video segments on engineering techniques for building design.

2. Tell students they will be in teams of 2-3 and that they will be constructing a 3-story building at least 30 cm tall using the materials provided.

3. Give students time to discuss, collaborate, design, and construct their building.

4. Set up the shake table and test the buildings.

5. After the initial testing, discuss the specific design issue/ problem with the model buildings

C. Conclusion

Some design problems may be poor quality construction, weak joints or uprights, too much rigidity or flexibility, lack of reinforcement or diagonal bracing, etc.

Adaptations and Extensions

Have students construct water towers instead of buildings. Use paper cups held up with poster board strips as the water container. While testing, weigh the paper cup down with washers. You decide on height, materials, quantity, etc.

Model Building and Shake Table Construction

Simple, rectangular building designs are effective (Figure 1). Many design options, particularly for the bracing, are possible.

Testing:

- Buildings are tested on the horizontal motion shake table (Figure 1). Tape the base of the building to the base plate of the shake table. Choose the direction in which you wish to orient the building.

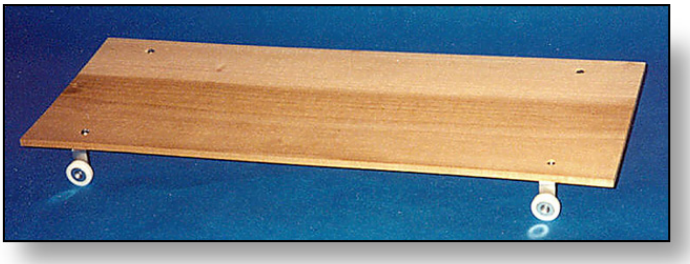

Figure 2. A simple, horizontal motion shake table. Wheels are nylon cabinet or drawer wheels and are attached to the board with "L" brackets, machine screws and nuts.

- Weights (steel washers) are attached to each floor and the roof. Small (5-g) horizontal accelerometers are attached to the shake table and to the top of the building. The results of shake table testing (acceleration versus time of the shake table and the top of the building as the shake table is moved back and forth) can be monitored on the computer screen or projected using an LCD projector for everyone to see.
- If accelerometers are not used,manually move the table back and forth at a constant rate. You will need to practice this. Masking tape applied to the surface on which the shake table sits will allow you to mark distances and that will allow you to push-pull the shake table at a more consistent rate and distance.
- Shake building at three frequencies – low, medium and high – and at three amplitudes – low, medium and high. An accelerometer on the base plate can be used to quantify the shaking and make comparisons between the testing of different buildings more consistent. A second accelerometer can be attached to the top of the building to observe amplification and resonance effects. Small, relatively inexpensive accelerometers, an analog to digital interface for the accelerometers (Serial Box Interface or LabPro), and software (LoggerPro) for the interface are available at Vernier Software (www.vernier.com) or other vendors of "probeware". High School or College physics departments often have Vernier or similar equipment, so you may only need to obtain the accelerometers.
- If your shake table is large enough (a convenient size is about 16 x 50 cm.), you can attach and test two or three buildings at the same time which provides an interesting comparison of building responses.
- After the initial testing, it is possible to illustrate specific design issue/problems with model buildings that were successful. For example, you can create the "soft first story" problem by reducing the shear support in the first story of the building. Sometimes buildings are damaged by a mainshock earthquake and then further damaged or destroyed in an aftershock. Also, poor quality construction or mistakes made in construction can result in specific weak elements of a building. These situations can be simulated in a model building by weakening an upright or a joint by cutting or partially cutting the poster board material or tape. Other building design and construction variations, such as very rigid or very flexible buildings, can be specifically built and tested. Comparing the responses and failure levels of these structures with the original designs that were successful is an excellent method of reinforcing the principles of effective building design and earthquake risk related to structures.
- If time permits, students can construct a second set of buildings that benefit from the lessons learned in the first building contest and shake table testing.

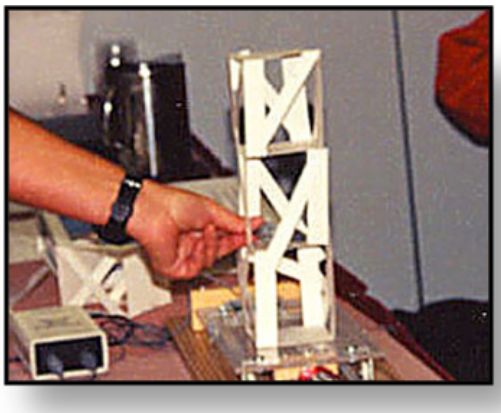

Figure 3. A model building on a shake table.

Alternate Activities: Constructing Earthquake-Proof Buildings

Grade: 6-8
Duration: 3-4 class periods

Discovery Education at http://www.discoveryeducation.com/teachers/free-lesson-plans/constructing-earthquake-proof-buildings.cfm. This site has a complete Lesson Plan for constructing Earthquake-Proof buildings.

In this activity, students explore different materials, shapes, and design options that affect the durability of buildings. This activity is much more material intensive, but is suitable for students in grades 6-8. It is also inquiry-based and requires students to test different variables in their construction. It is not a contest, but is more of an experiment on how different models (buildings) perform under controlled conditions.

Science Buddies at http://www.sciencebuddies.org/science-fair-projects/project_ideas/CE_p023.shtml. This site includes an activity that demonstrates how different soil types can affect structures during an earthquake. Simple to follow instructions, materials, and a video make it easy to understand. This activity is better suited for younger students, grades 4-6 (accessed July 26, 2011).

MCEER Building a Shake Table at http://mceer.buffalo.edu/infoservice/Education/shakeTableLessonPlan.asp. This site provides instructions for construction of two different styles of shake tables. Diagrams of the two models are below (accessed July 26, 2011).