SHAKE AND BREAK: An Earthquake Simulation

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Purpose of the Lab

1. How can we use a seismic table to demonstrate the behavior of different building structures during an earthquake?

2. How can we measure the damage inflicted upon structures during an earthquake?

3. How can we assess the damaging effects of an earthquake when the houses rest on different types of geological foundations?

Background

Scientists often use models to help them understand ideas that are complex, very big, or very small. Models of atoms (which are very small) can be built to help understand the structure of an atom. Biologists often use models of cells to understand the very fine structures found inside the cell. Astronomers use models of our solar system (which is very big) to show how the planets are arranged around the sun. Engineers use models of airplanes to show how a plane will function in flight. In this exercise you will use a "seismic" model to show how an earthquake causes damage. Since earthquakes are massive events, it is helpful to reduce the events to a smaller scale so that earth scientists can study their effects.

Earthquakes have been recorded in most parts of the world, but there are some areas where earthquakes occur more frequently than others. In general, the western part of the United States, especially California and Alaska, have more earthquakes than other regions. The most serious earthquake in the Eastern United States occurred in Charleston, South Carolina in 1886, killing 60 people. Even the Midwest has a seismic zone centered around New Madrid, Missouri, where several very disastrous earthquakes have happened. Other countries, especially those with mountain ranges near the coastline have many serious earthquakes. It is estimated that over 500,000 people died in an earthquake in China in 1976.

Why do so many people die each year in earthquakes? There are several answers to this question. One answer is related to the type of building material that is used to build houses, offices, and apartment buildings. Building materials vary from one region to another depending upon what is available and how expensive it is. In some areas most of the structures are wood and in other areas masonry buildings are more often built. In underdeveloped countries adobe mud bricks, and stones can be found in many of the structures. Not all construction materials behave in the same way during an earthquake. Wood, if used in the proper way, can be a surprisingly strong building material while masonry building can fall easily if not properly built. Modern masonry skyscrapers have been designed to endure strong earthquakes. You will test several types of construction materials in this laboratory activity.

Another answer to the question can be discovered by examining the type of geological foundation material used for buildings. Solid rock or bedrock is a very effective foundation, but solid rock often lies far below the surface making it difficult to place the foundation there. Loose foundation material such as sand which can become saturated with water is a particularly dangerous situation. Dry sand behaves like a solid because there is much friction between the individual particles of sand, but when the sand is saturated with water the sand begins to behave like a fluid because the water reduces the friction between the particles. This is called **liquefaction.** A similar phenomenon can be observed as you walk along a beach barefoot. If you walk near the water where the sand is saturated you tend to sink into the sand leaving a footprint that rapidly fills with water. When you walk on dry sand very few footprints can be observed because the dry sand acts like a solid and better supports your weight. Quicksand is another example of liquefaction. Liquefaction during an earthquake tends to cause the buildings to sink into the sand, especially on one side causing the building to tilt and fall to one side. Some of the most destructive effects of earthquakes have been caused by liquefaction. You will demonstrate liquefaction in this exercise.

Big earthquakes can cause widespread destruction in highly populated areas. The amount of energy released in large earthquakes is many times more powerful than the explosion of many atomic bombs. In a brief burst of energy, massive buildings over a wide area can be destroyed. The forces to do that much damage are tremendous. The **Richter Scale** has been developed to measure the amount of energy released in earthquakes. The Richter Scale is described in the table that follows:

**Table 1. The Richter Scale**

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| **Richter Magnitude** | **Earthquake Effects** | **Estimated Number per Year** |
| < 2.0 | Generally not felt, but recorded | 600,000 |
| 2.0 - 2.9 | Potentially perceptible | 300,000 |
| 3.0 - 3.9 | Felt by some | 49,000 |
| 4.0 - 4.9 | Felt by most | 6200 |
| 5.0 - 5.9 | Damaging shocks | 800 |
| 6.0 - 6.9 | Destructive in populous regions | 266 |
| 7.0 - 7.9 | Major earthquakes; inflict serious damage | 18 |
| > 8.0 | Great earthquakes; total destruction near epicenter | 1.4 |

Tarbuck, Edward J. and Lutgens, Frederick K. *The Earth: An Introduction to Physical Geology.* New York: Macmillan Publ. Co., 1993. p. 416.

Most often we tend to think of earthquakes as being only destructive. But it is important to remember that earthquakes are constantly changing the surface of the earth and they help build mountains. Living through an earthquake may not be pleasant, but the resulting scenery can be quite beautiful.

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|  | Lab Activity:  **Building the Houses** |  |

You will work in groups of four. Each group will build *two houses*. Check with your teacher to decide what type of houses to construct.

***Wooden Houses***

Materials

* 100 "Skill Sticks", snap-apart building sticks, broken into small sizes

Procedure

For wood structures, use the interlocking wood sticks that have been broken into pieces. It is not necessary to place a floor between levels. If your model is to be tested on bedrock, mortar the wood structure directly to the cardboard. Do not mortar the structure that is to be placed on the saturated sand.

***Concrete or Plaster of Paris Houses***

Materials

* 250 ml of plaster of Paris or\* 300 ml concrete mix
* 3 Plastic ice cube trays that have been cut about 1/2 inch from the top to serve as molds for the building blocks
* 1 paper cups to mix the plaster of Paris
* 1 quart size Zip Lock freezer bag to mix concrete
* water
* 2 popsicle sticks to serve as stirrers and trowels for mortaring
* 2 plastic spoons
* 1 graduated cylinder, 50ml
* 1 beaker, 250 ml, graduated or measuring cup
* 8 pieces of 3x5 index cards that have been cut into thirds along their width
* 2 pieces of cardboard cut into 6” squares
* 2 pieces of wax paper to cover the cardboard

**Procedure**

1. If you are making concrete or plaster of Paris houses, lay three ice cube trays on a piece of waxed paper which is wrapped around a piece of cardboard.

2. To make concrete blocks, mix 300 ml of concrete with 55 ml of water in a Zip Lock bag. Thoroughly mix the dry concrete with the water for several minutes until it is thoroughly mixed. Remove any large stones if necessary. Spoon the concrete mixture into three molds making each brick about the size of a domino. Set aside and allow to dry for 24 hours.

3. To make plaster of Paris blocks, pour 75 ml of water into a paper cup and add 200 ml of the dry plaster of Paris. Thoroughly mix with a popsicle stick. Work *very quickly* to fill the three molds. Set aside and allow to dry for 24 hours.

4. On the next day, remove the masonry blocks from the bottoms of the molds. Broken pieces can be used if they are mortared.

5. Obtain a paper cup and make a fresh mixture of plaster of Paris mortar according to the directions given above.

6. If your house will be tested on bedrock, obtain a piece of cardboard *without* wax paper. Mortar your house directly to the cardboard with plaster of Paris. If your house will be tested on water saturated sand, obtain a piece of cardboard *covered* with wax paper. Mortar your house on top of the wax paper. The wax paper makes it easier to remove the houses.

7. Use a popsicle stick to lay a line of mortar as a foundation. Work quickly because the plaster of Paris dries very fast. Stand one brick on its long edge in the foundation mortar and then mortar three more bricks to form a rectangular base. Mortar the top edge of each brick and lay a cut 3 x 5 file card to serve as a floor. Continue to build your house so that it has at least four stories with a floor in between layers. You may use a model or thedrawing shown below. Set aside and allow to dry for 24 hours.



**Testing the Houses on the Seismic Table**

**Materials**

* Seismic table with eccentric motor
* 1 cake pan filled with saturated sand
* Timer
* Tables to record the data
* Student-built houses
* Staple gun with 3/8” staples

**Procedure**

Your teacher has prepared the seismic table. Observe the table and read the directions before using.

1. One member of the group should serve as the timer, another should operate the table, another should record the results, and the fourth member is responsible for placing the structures on the table.

2. Start the table at speed # 2 and continue for 20 seconds. Increase the speed to # 3 for 20 seconds and continue with 20 second periods at higher speeds until the house falls.

3. The recorder should write as many observations in the table as possible.

4. Record the total number of seconds at the time the house falls or is broken. See the data table on the next pages.

5. For each house plot the time for destruction on the horizontal axis and speed on the vertical axis. Use a different symbol for each plot. Collect data from the entire class and plot on the graph.

Safety Notes

AVOID TOUCHING THE MOTOR OR MODULATOR WITH WET HANDS.



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| **Type of House** | **Speed** | **Time**  **(sec.)** | **Foundation:Bedrock or Sand?** | **Damage Description** |
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Questions

1. What type of construction is the strongest? Suggest a reason.

2. What type of construction is the weakest? Suggest a reason.

3. How did the wet sand foundation affect the type of damage?

4. If you were to build a house in a seismic area, how would you build your house?

5. Ask your parents if they carry insurance for earthquake damage. Discuss the advantages and disadvantages.

6. Write a building code for apartment buildings in earthquake active areas. Use evidence from your laboratory experiment to support your code.

7. What part of your houses was the weakest? Suggest a way to strengthen this defect.

8. Select another variable that was not tested and describe how you would test it.

9. Describe how you could improve the controls in this experiment.

10. What is the safest behavior in an earthquake? Where would you go?

More Ideas and Extensions

1. Relate the type of construction and underlying geological support to geographical areas where seismic activity is frequent. Use a variety of construction materials (stucco, adobe, mud, interlocking vs. stacked blocks, etc..) and architectural styles. Critically analyze the need for building regulations in areas with significant seismic activities.

2. Build and use a simple seismograph to record the activity of an earthquake.

3. Research the chemistry of concrete.

4. Learn about the causes of human fatalities in earthquakes.

5. Investigate Tsunami waves.

6. Investigate orogeny and the theory of plate tectonics.

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**Web Resources**

<http://earthquake.usgs.gov/earthquakes/>

<http://en.wikipedia.org/wiki/Earthquake>