Science Unit: ***Geology and Plate Tectonics***

Lesson 6: ***Earthquakes***

School Year:	2011/2012
Developed for:	Laura Secord Elementary School, Vancouver School District
Developed by:	Linda (Hanson) Herbert (scientist); Lesley Chambers and Phil Green (teachers)
Grade level:	Presented to grade 6/7; appropriate for grades 4 – 7 with age appropriate modifications
Duration of lesson:	1 hour and 20 minutes plus testing time (~30 min)
Notes:	The lesson requires the use of a shake table. Construction ideas are presented below including instructions for building a very simple one that will work for this lesson. This lesson focuses on building structures. For additional information on tectonic processes and earthquakes see lesson 5 in this unit.

Objectives

- To learn about earthquake resistant structures.
- To use knowledge of earthquake resistant structure to construct a tower and test it in a simulated earthquake.

Background Information

Due to its close proximity to all three types of tectonic plate boundaries (convergent, divergent and transform) southwestern British Columbia experiences frequent earthquakes, albeit the majority are too minor to be felt. Many older schools in BC have undergone seismic upgrades. Students attending schools where this type of construction is occurring are interested in how the changes they observe will help their school withstand future earthquakes. This lesson will help students understand some of the engineering techniques used to help buildings better withstand earthquakes.

Vocabulary

Shear wall:	A solid wall that helps counteract the effect of horizontal forces on a building.
Base isolation:	A structural technique that seeks to prevent the shaking motion of the ground being transmitted into a structure. The structures at the base of the building are meant to absorb/dissipate the shaking and thus isolate the rest of the building and prevent it from shaking in response to the earthquake.
Brace:	A structural component used to strengthen a building. There are various types of bracing, see lesson plan for examples.

Materials

- Scotch tape (1 m/group)
- pennies (20-50/group)
- film canisters (1/group)

For shake table (see separate instructions)

- 2 thin boards ~1m square
- 4 rubber bands

- tower templates
- cardstock (110 lb weight or heavier)
- blank paper or science notebooks (for planning)
- pencils
- metre stick or tape measure (to measure tape)
- 8 marbles or ball bearings
- 4 peri dish lids or similar
- 4 small screw in hooks (~1 cm)
- silicone or hot glue
- 4 screw in eye hooks (~1 cm)

In the Classroom

Introductory Discussion

This lesson was originally presented at a school that had recently undergone seismic renovations. The students were aware of some of the changes that had occurred in the building and how the new structures differed from the original state.

- As I promised last week, today we are going to learn more about earthquakes and how they affect buildings. As you're aware, your school has recent undergone seismic upgrades, i.e. renovations to make it better able to withstand earthquakes.
- What sorts of changes have you observed as part of the seismic upgrade process? (class brainstorm)
- To help prompt discussion (if needed) you can ask students how an earthquake can damage a building. What type of forces are involved? (Can pre-build some small structures to demonstrate different forces on the shake table or show some photographs or video clips if a projector is available.)
- Today we are going to build our own buildings and test them on our shake table to determine how well they can withstand an earthquake. Each group is going to build a tower using only cardstock and paper.
- Describe available materials: Each group will receive 4 platforms/floors, 4 large support beams, 8 small support beams and 1 m of tape.
- Describe construction rules/limitations:
    - Towers must be as tall as one piece of paper (i.e. 28 cm).
    - Each tower must have a minimum footprint equal to the size of the supplied platforms/floors.
    - Each tower must contain a platform (or roof) at a height of 28 cm that is the size of the supplied platforms.
    - The supplied materials can be folded, cut smaller as desired as long as you conform to the above rules.
    - The tower must be capable of supporting a 50 g weight on the top platform/roof (50 g is the weight of 20 pennies in a film canister).
    - The building materials are limited to the supplied cardstock and tape. In addition, you cannot obtain replacement materials so plan carefully before starting construction.
    - To facilitate testing, each group will receive 30 cm of additional tape to affix their tower to the test platform and secure their 50 g weight (i.e. do not waste your 1m of tape on this),
- After going over the rules have a class brainstorm to discuss ways of strengthening the towers (relating these to actual construction practices). Depending on their level of base knowledge, prompt them with questions to illicit ideas. How can engineers build stronger buildings? If the Earth is shaking

from side to side, the effect on a building is similar to pushing on the side of a building. How do engineers help buildings withstand sideways forces? How can they prevent buildings from shaking?

  - Use stronger materials. How can we strengthen or paper towers? (thicker paper, layer pieces together to increase thickness, fold paper in half)
  - Use shear walls, bracing, base isolation. Discuss how these can be used in the paper structures? (add shear walls made of paper, add braces, use paper springs to help absorb the shaking)
  - Add more floors (to help withstand sideways forces).

- Short description of other items to discuss or review.
- Review types of bracing as they are mentioned and/or prompt by drawing a simple structure on the board and asking students to suggest ways of adding braces. Common types of bracing include diagonal bracing, cross bracing, and knee bracing. See references for a link to a good website with diagrams of the different types.
- Write construction rules on the board or provide as a handout to each group,
- Remind students that their towers need to support 50 g of weight.

Briefly describe science experiment/activity.

- Students will use their new-found knowledge of structural engineering to build earthquake-resistant paper towers.
- Towers will be tested on a shake table to determine how well they can withstand an earthquake.

Briefly describe the processes of science that the students will focus on (prediction/hypothesis, observations, recording results, conclusions.)

Briefly describe safety guidelines.

- Remind students to keep their hands away from the shake table during testing.

Science Activity/Experiment

Activity Title: Building Earthquake-resistant Structures

Purpose of Activity: To gain practice applying structural engineering concepts to real structures.

Methods and Instructions:
Set-up prior to experiment:

- The teacher/scientist will need to construct a shake table. There are many plans available online for simple tables; including ones that can be powered by a drill to shake automatically (see references section). For this activity a simple manual shake table was constructed (i.e. it is shaken by hand).
- See separate shake table plans saved with this lesson
- Photocopy the tower material templates onto cardstock. To save time it is suggested that the teacher/scientist prepare all of the materials in advance including cutting them out with a paper cutter.
- Each group will require 1 sheet of support beams (contains 4 large and 8 small); 1/3 of a sheet of platforms (4 total) as there are 12 per sheet. Thus for a class of 30 you will need 30 copies of the support beam page and 10 of the platform page.

Brief description of how students will work in groups or pairs: Students will work in small groups (~4) to build their towers.

- Hand out materials to each group.
- Remind them of the construction limitations.

Give them 10-15 minutes to discuss and plan their towers with their group.

Provide 30-45 minutes for construction (depending on time available). Scientist and teacher(s) should walk around during the construction time and discuss the student's ideas with them and/or help any groups that are struggling or cannot agree on a single design idea.

As structures are completed, groups can tape them to the test table. You may need to run the tests in groups as all structures will not fit at the same time.

The 50g weights should be added just prior to testing.

When all groups are ready and the first batch of test towers is secured to the table, the tests can begin. You can have students predict which tower in each test group will be the most earthquake resistant.

When testing the structures the shake table should always be shaken by the same person to help ensure consistency of the test conditions.

The test should begin with a low intensity earthquake for ~30-60 seconds. The earthquakes can then increase in intensity. We used low, medium and high intensity quakes that lasted ~45 seconds each.

If any towers remain standing after the high intensity earthquake increase their weight load by 5 pennies and retest them in another high intensity quake. Continue until all structures fail.

Record the weight and earthquake intensity at which each tower failed on the board. There can be a small prize for the winning group if desired.

Closure Discussion

- Which structures did you expect to be the most earthquake resistant? Did the results fit with your expectations?
- How did the majority of structures fail? What structural elements could you change/improve to prevent this?

Which structural elements were the most successful overall? Did the "best" towers have anything in common? Which elements were the least successful? Why?

How would you improve your tower design if you had a chance to do this activity over? (Some classes may wish to repeat the activity at another time to give students a chance to apply new ideas.)

Discuss how different substrates will also affect the potential damage caused by an earthquake. A map of the substrates distribution in the Greater Vancouver area can be obtained from Natural Resources Canada to assist with this discussion (see reference information below). Since the majority of the Greater Vancouver Area consists of sediments, a liquefaction demonstration may also be of interest.

References

- <http://jclahr.com/science/earth_science/shake/srl_78-3_eq.html> Eduquakes. John Lahr. [Review of Educational shake tables and lots of links to resources.] Accessed June 1, 2012.
- <http://www.ideers.bris.ac.uk/resistant/resist_home.html> IDEERS Resistant Buildings. Earthquake Engineering Centre, University of Bristol. [web pages that explains how buildings vibrate during earthquakes and how they can be strengthened. Includes information on the various types of structural bracing.] Accessed June 1, 2012.

- <http://www.iris.edu/hq/programs/education_and_outreach/videos#O> IRIS Education Videos. Incorporated Research Institutions for Seismology. [website with video of various earth science, tectonic and earthquake concepts as well as teaching resources] Accessed June 1, 2012.
- <http://earthquake.usgs.gov/learn/photos.php> Earthquake Photo Collections. US Geological Survey Earthquake Hazards Program. [Photos of earthquake effects and damage from various major earthquakes in the United States.] Accessed June 1, 2012.
- <http://www.thetech.org/sites/default/files/pdfs/BuildingForTheBigOne.pdf> Building for the Big One. The Tech Museum of Innovation. [Lesson plan for an alternate structure building activity.] Accessed June 1, 2012.
- <http://geogratis.gc.ca/api/en/nrcan-rncan/ess-sst/76092c41-f567-5da5-830c-277da8bbaab3.html> GeoMap Vancouver, geological map of the Vancouver Metropolitan area. Natural Resources Canada. Open File 3511, 1998. [This map can be downloaded and printed from the website or can also be obtained from the Natural Resources Canada Bookstore in Vancouver.] Accessed June 1, 2012.

Extension of Lesson Plan

Liquefaction demonstration

- Fill a small clear plastic or glass container with 10-15 cm of sand.
- Slowly add enough water to thoroughly saturate the sand.
- Let the container sit for approximately 10-15 minutes to allow any excess water to rise to the surface.
- Remove any surface water with a paper towel.
- Show the students that the substrate is solid, have them push on it with their hands.
- Place a heavy object such as a dense rock, metal block or similar on top of the sediments to act as a simulated building.
- Simulate an earthquake. This can be done by:
    - Rapidly shaking the container with your hands or on a shake table (difficult)
    - Hitting the container with a large rubber mallet (more reliable)
    - Using a mechanical vibrating device such a vortex mixer from a laboratory or a small concrete vibrator used in construction (preferred method as it produces the best results)
- The “building” should rapidly sink into the substrate.
- Remove the building and show the students how the substrate is still solid and firm to the touch, it only acts as a liquid during the shaking period.
- Explain the science behind liquefaction: The shaking motion and vibration caused by an earthquake causes the sand particles to separate which allows water to surround the particles and effectively “floats” the sand creating a sand/water mixture that behaves like a liquid and hence the building sinks. Once the shaking stops the sand particles pack tightly together again and return to their more solid state.

Science Unit: ***Geology and Plate Tectonics***
Accompaniment to Lesson 6: Earthquakes

Simple Shake Table *(to accompany Lesson 6 Earthquakes)*

Developed by: Linda (Hanson) Herbert (scientist)

Materials

- 2 thin (1 cm or less, I used 0.5 cm) plywood or similar boards ~1m square. One board should be cut to be ~10 cm smaller than the other on all sides (i.e. 80 cm by 80 cm)
- 4 rubber bands (#16-#84 – best size will depend on the size and weight of the wood used) I used the red rubber bands that often come on produce.
- 8 glass marbles or metal ball bearings
- 4 peri dish lids or similar (~ 5 cm diameter) – small round dishes with a very flat, smooth inside and a lip/edge. Small yogurt lids could work. The lip must be lower than the height of the marbles.
- 4 small screw in hooks (~1 cm)
- silicone or hot glue to attach the lids to the board
- 4 screw in eye hooks (~1 cm)

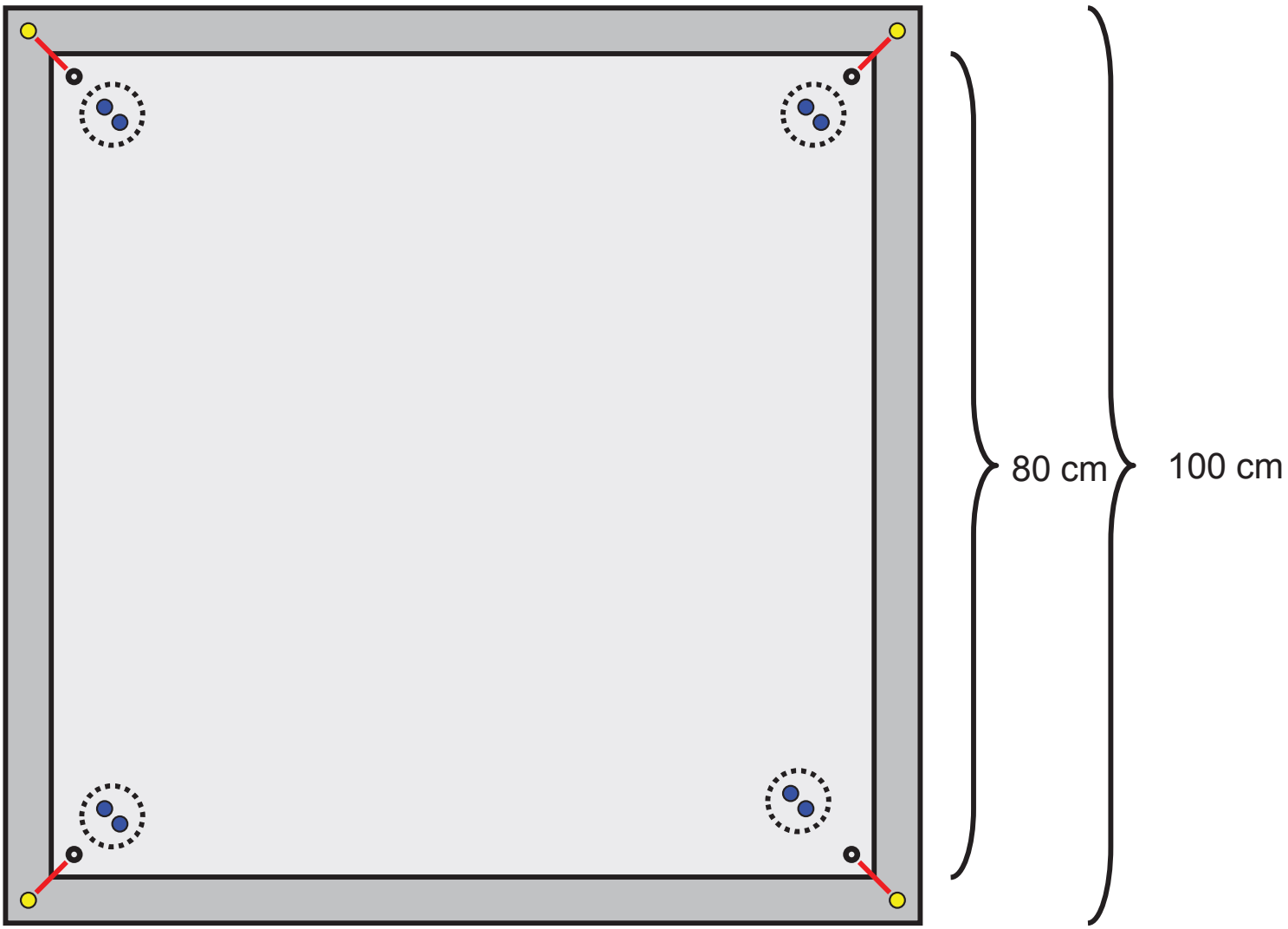
Methods and Instructions

1. Cut boards to desired size. The top platform should be approximately 20 cm smaller than the other in both length and width. The upper side of the bottom platform should be very smooth. It is suggested that a composite board with a smooth finish be used of that the board be very well sanded and possibly sealed coated with shellac.
2. Affix Petri dish lids to the underside of the top platform (so open end is away from board) using hot glue or silicone. Lids should be positioned near the four corners of the board. If you are using a large and/or heavier board you may wish to affix additional lids in the centre of the platform or at other points. Let dry/set.
3. Screw hooks into the four corners of the bottom platform as shown (on the upper side of the platform). Open side of hook should point towards the outer corner.
4. Screw eyes into the four corners of the top platform as shown (on the upper side of the platform).
5. Thread a rubber band through one of the eyes and hook it over the corresponding hook. Repeat on all four corners.
6. Lift up the upper platform and carefully place 1-2 marble under each lid (being careful not to dislodge the marbles placed in other locations). The marbles should roll freely when the board is moved from side to side.
7. To operate the shake table use your hand to rapidly move the top platform from side to side and/or rapidly pull and release one of the rubber bands. The best technique will depend on the exact construction of your particular table.

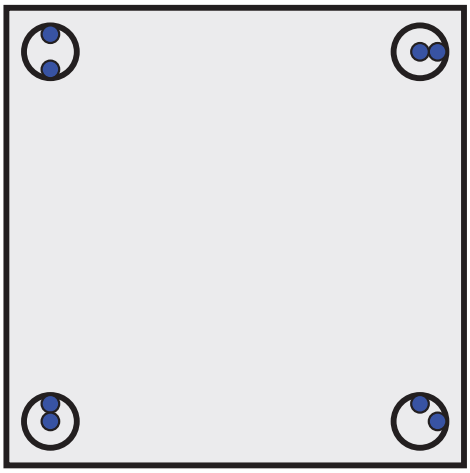
Links to other shake table plans (some that use a motor to shake automatically)

1. http://www.discoveryeducation.com/teachers/free-lesson-plans/constructing-earthquake-proof-buildings.cfm
2. http://www.exo.net/~donr/activities/Shake_Table.pdf
3. http://www.geo.mtu.edu/~jdiehl/ETM.pdf
4. http://jclahr.com/science/earth_science/shake/index.html
5. http://www.raftbayarea.org/readpdf?isid=374

Overhead view of shake table



Underside of top platform



- hook
- eye
- rubber band
- marble
- small lid
- location of small lid on underside of table