

## Performance Based Earthquake Engineering - Will Your City Survive?

### Subject Area(s)

Science & Technology

Physics

Physical Science

Problem Solving

### Associated Unit

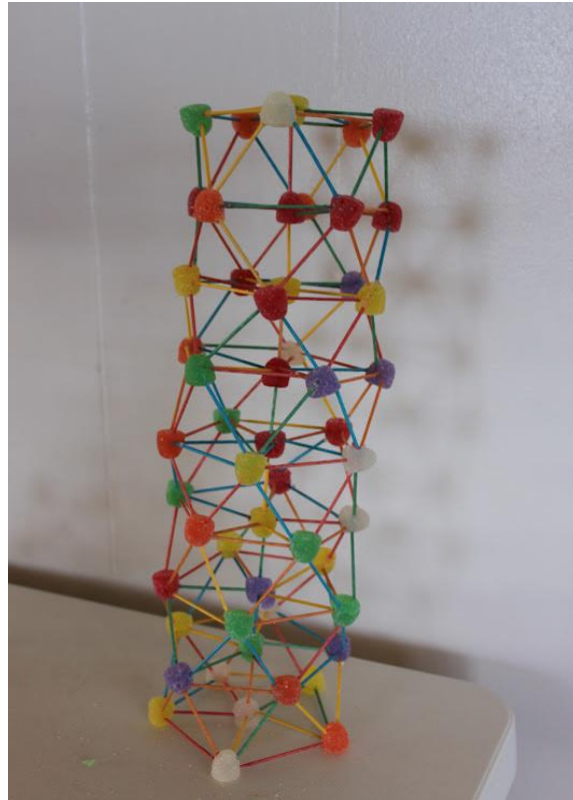
Not applicable.

### Associated Lesson

Performance Based Earthquake Engineering for Community Resilience

### Activity Title

Performance Based Earthquake Engineering - Will Your City Survive?



<http://ploener.blogspot.com/2012/07/challenge-from-kids.html>

Gumdrop toothpick structure

**Grade Levels:** 6<sup>th</sup> Grade

**Time Required:** 60-120 minutes

**Group Size:** 4-5 students

**Expendable Cost per Group:** < US \$3

## Summary

Students will take part in a design-build project where the goal is not to necessarily design a more resilient structure than other groups in the class, but for the entire class to work towards better community resilience.

## Engineering Connection

See associated lesson.

## Engineering Category = Lesson - 2 Activity - 3

Choose the category that best describes this activity's amount/depth of engineering content:

1. Relating science and/or math concept(s) to engineering
2. Engineering analysis or partial design
3. Engineering design process

## Keywords

Performance Based Earthquake Engineering

Hazard Analysis

Structural Analysis

Damage Analysis

Loss Analysis (focus)

Community Resilience

## Educational Standards

- Science Standards - Science
- Common Core State Standards - Math
- International Technology and Engineering Educators Association - Technology
- Texas TEKS Science

## Prerequisite Knowledge

Students should be able to measure length with a ruler, and have an understanding of seismic waves (as provided in the associated lesson)

## Learning Objectives

After this activity, students should be able to:

- Have a better understanding of the engineering design process.
- Explain the four types of seismic waves produced by earthquakes.
- Describe the purpose of shake tables and how engineers use them.

## Materials List

Each group needs:

- Toothpicks & gumdrops
  - Limit of 24 toothpicks per floor, give them 4 after each earthquake to repair
  - 12 gumdrops for 1 story and 6 gumdrops per additional story

To share with the entire class:

- Cards - designating groups to what type of structure they have to build, i.e. 2-story building, 3-story building, 5-story building, larger-base buildings or smaller-base buildings, etc. (just to mix things up and make it seem like an actual city/community)
- Makeshift or actual shake table - try to shake them all at once and see the aftermath
- A story-book that sets the scene before/during/after the earthquake and guides the activity through each of the three different earthquakes, e.g. a fire could have started after earthquake #3.
- Scotch/Duct Tape - anything works because the structures are really light
- [Shake It UP! Worksheet](#)

## Introduction / Motivation

How many different kinds of waves can you think of? (Listen to student suggestions and add others. For example, electromagnetic [light, radio], sound, ocean [water], seismic, pressure, compression, standing and sine waves.) No matter what kind of wave, what do they have in common? (Draw a wave on the board and identify its parts.) That's right: amplitude, wavelength, crest, trough, frequency.

What types of waves do we associate with earthquakes? That's right, seismic waves. Seismic waves are waves that move through the Earth, and are typically created by earthquakes. For all seismic waves, the amplitude or intensity of the wave is dependent on three things:

1. The depth at which the earthquake took place (the closer to the surface, the greater the amplitude of the wave)
2. The intensity of the earthquake (earthquakes with higher Richter scale ratings produce more intense seismic waves)
3. The composition of the Earth's crust

The people who work in "earthquake engineering" focus on protecting us and the natural and human-built environments from earthquakes. They want to limit our risk of death and damage from earthquakes. How can we possibly make sure that our school or stadium or a skyscraper or a freeway overpass will not collapse in a big earthquake? Well, engineers create shake tables to test the ability of buildings and other structures to withstand the seismic waves produced by earthquakes. To do this, they carefully design and construct shake tables that can accurately re-enact the ground motion of the Earth during earthquakes. Sometimes they test full-size buildings and sometimes they test small-scale model buildings or components. Some shake tables are large enough to put a real-size building on; others are smaller, even tabletop size. By doing this, engineers can test materials, designs, and construction methods to develop building codes and best practices that provide people living in earthquake-prone areas with safe and survivable surroundings.

Engineers must understand everything about the various seismic waves produced during

earthquakes and how they cause the Earth to move. Who can tell me the four types of seismic waves that engineers need to simulate? They are:

1. P-waves (or primary waves, a type of body wave)
2. S-waves (or secondary waves, a type of body wave)
3. Love waves (a type of surface wave)
4. Rayleigh waves (a type of surface wave)

What do you know about these different types of seismic waves? How are they different from each other? P-waves and S-waves are body waves, which travel through the body of the Earth. P-waves are the fastest of all the seismic waves and can travel through any medium, although they move through solids faster than through liquids and gases. P-waves vibrate parallel to Earth or in the direction of their propagation. They are similar to a compression wave moving through a slinky. S-waves are the second fastest type of seismic waves, and they can only move through solids. S-waves are transverse or shear waves and move the Earth perpendicular to the direction of propagation. Both P-waves and S-waves are types of body waves and travel through the interior of the Earth.

Love waves and Rayleigh waves are surface waves, which travel along the surface of the ground. In general, surface waves are slower than body waves—and more destructive. Love waves cause a horizontal shifting of the Earth perpendicular to the wave propagation. Rayleigh waves are a type of sinusoidal wave and move like ocean waves. They are produced by the interaction of P-waves and S-waves. Rayleigh waves are the slowest of all the seismic waves with a speed approximately equal to 3 km/second.

Smart design and testing make buildings resistant to the seismic wave movement of earthquakes. A properly engineered structure does not necessarily have to be extremely strong or expensive, but it must be correctly and intelligently designed to withstand the seismic waves while sustaining an acceptable level of damage. What are your ideas? Let's create our own shaker tables and model buildings to test them.



<http://seblog.strongtie.com/tag/northridge-earthquake/>  
A row of buildings after the Northridge 1994 earthquake

## Vocabulary / Definitions

Word	Definition
	<p>body wave: A seismic wave that travels through the Earth rather than across its surface.</p>
	<p>engineering design process: A series of steps used by engineering teams to guide them as they solve problems: define the problem, come up with ideas (brainstorming), select the most promising design, plan and communicate the design, create and test the design, and evaluate and revise the design. Also called the design-build-test loop.</p>
	<p>Love wave: A surface seismic wave that cause horizontal shifting of the Earth during an earthquake.</p>
	<p>model: (noun) A representation of something for imitation, comparison or analysis, often on a different scale. (verb) To simulate, make or construct something to help visualize or learn about something else (such as a product, process or system).</p>
	<p>P-wave: A seismic pressure wave that travel through the body of the Earth. The fastest of all seismic waves.</p>
	<p>Rayleigh wave: A surface seismic wave generated by the interaction of P-waves and S-waves at the surface of the Earth that move with a rolling motion.</p>
	<p>seismic wave: A wave of energy that travels through the Earth as a result of an earthquake.</p>
	<p>shake table: A device for shaking structural models or building components. The movement simulates the ground motions of earthquakes. Also called a shaking table.</p>
	<p>simulation: Imitating the behavior of some situation or process, especially for the purpose of study or experimental testing.</p>
	<p>surface wave: A seismic wave that travels across the surface of the Earth as opposed to through it. Surface waves usually have larger amplitudes and longer wavelengths than body waves, and they travel more slowly than body waves.</p>
	<p>S-wave: A shear or transverse body seismic wave, with motion perpendicular to the direction of wave propagation.</p>

## Procedure

## Before the Activity

Gather materials and make copies of the Shake It Up! Activity Worksheet.

Build the teacher's shake table that uses a variable speed drill to create the shaking movement. Or, if you do not want to build the drill-powered shake table, at the end, have the class select the best shake table from all the groups and use that one for the earthquake challenge.

Interactive project that progresses with a storyline that can be tailored to different levels (K-12)

1. Have them build a gumdrop-toothpick model (2-story homes) that will be shaken under different intensity (increasing return-period) earthquakes - each earthquake will be like a “cut-scene” in a game to which they will react to afterwards. Keep track of all the stuff they buy/spend - use this as the basis of our final discussion/reflection on their performance as a community.
2. Shake the structures with the 1st earthquake and see which ones fail - have them decide how they want to respond - come up with options for them to choose from. For example, give them like 2 more toothpicks and see how they would change their structure to make it more resilient for the next earthquake.
3. Shake the structures with the 2nd earthquake and repeat the above procedure, but now maybe have them decide what they want to do as the owners of the building (instead of giving them options). Then we can reflect on their choices and relate it back to PBEE.
4. Shake the structures with the 3rd earthquake and repeat the above procedure.
5. Have one student use a stopwatch to time how long each building survives the earthquake simulation. Remind groups to be ready to record the length of time their buildings lasted, the end building heights, as well as observations about how the building structures behaved under the shaking conditions. Have students watch all team tests to gather observations that they will use to finish the worksheet questions. **Failure:** If the building collapses or any part of the building besides its base touches the shake table, consider it failed, and note the time and stop the shake table. The building is not earthquake-safe for people. Once the shake table is on, measure the height of the building. **Success:** If the building survives for a full minute and is still one-foot tall, consider it a success—the group has engineered a solution to the challenge and is "hired" to design real buildings for their community. Record measurements and observations.
6. Reflect on the city’s performance/everyone’s decision making as a whole - so we get them thinking about community resilience.
7. Give them prizes if their structure survives all 3 earthquakes or if they survive the biggest earthquake (3rd earthquake) with the least amount of material used.

## Assessment

### Pre-Activity Assessment

Not applicable.

### Activity Embedded Assessment

Class discussions, but nothing formal.

### **Post-Activity Assessment**

*Descriptive Title:* What have you learned about earthquake engineering?

A quick quiz on earthquakes (what causes them, what magnitude and intensity are, etc.), PBEE (what each step in PBEE is, what the end goal of PBEE is, etc.), and seismic design (ways we can design against earthquakes).

### **References**

Gunay, M. S., and K. M. Mosalam. "PEER Performance-Based Earthquake Engineering Methodology, Revisited." (2012): 1-10. Web. 7 July 2017.  
([http://www.iitk.ac.in/nicee/wcee/article/WCEE2012\\_5606.pdf](http://www.iitk.ac.in/nicee/wcee/article/WCEE2012_5606.pdf))

### **Contributors**

This lesson plan was put together by NHERI undergraduate researchers Danielle Charleston and Tiffany La.

[Alterations made in blue by Erika White](#)

### **Supporting Program**

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UC Berkeley SimCenter

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### **Classroom Testing Information**

Teachers will tape the base of the students structures onto the shake table in a manner that would represent the layout of a city/community (templates will be provided). All structures are to be sufficiently attached to the shake table before each ground motion starts. Pictures will be taken before and after each earthquake to clearly show the aftermath to students. A video may be taken during the shaking for students to see how their particular structure performed and for them to learn from the response of other structures in the community.