Shake, Rattle and Roll: An Earthquake Simulation

Why Do Buildings Fall Down During Earthquakes?

How would a one or two-story building behave in an earthquake? How do the building's materials used affect the stability of the structure? How does the way those materials are joined or connected influence the behavior of a falling structure?

From the perspective of an engineer, failures are important. Houses are built to stand up; it's when they fall down that a problem presents itself. Each failure provides new information about how a house can fall down, about what works, and what doesn't. In this activity, you will investigate how a house collapses and then build a structure to test various ways to use materials to withstand an earthquake.

Can You Design a Structure to Withstand an Earthquake?

The first step is to understand how and why a structure collapses during an earthquake. How might a house frame behave in an earthquake, and what is the best way to make it earthquake resistant?

Earthquakes are usually measured using a seismograph, but this activity is more concerned with how structures are affected by the shaking caused by an earthquake. You will use meters per second squared (m/s2) to determine the acceleration of the structure. Fortunately, Google's Science Journal app makes this easy by utilizing the accelerometer built into many modern cell phone and tablet devices.

Set Up Your Own Earthquake Simulator

Gather the following materials:

- 2 equally sized pieces of cardboard (These must be larger than the size of the structure you will build so that the structure can rest on it.)
- 4 marbles
- 2 large rubber bands
- Device with the Science Journal app
- Tape

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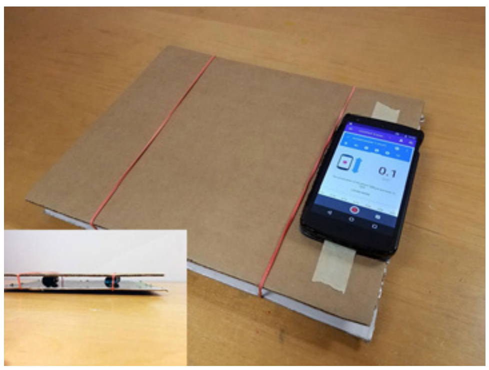
Evenly place the rubber bands around the two pieces of cardboard. Squeeze the marbles in between the two pieces of cardboard as evenly distributed as possible. If you tug on one of the cardboard pieces, it should shake.

You now have your earthquake simulator! The structure you build will go directly on top to test its earthquake readiness.

Next, tape your device with the Science Journal app onto the top surface of your earthquake simulator. Make sure to leave plenty of room for the structure you will create. Your setup should look similar to the image below:



Make sure the Science Journal app is measuring acceleration in the appropriate direction and give it a test. You should be able to get at least 6 m/s2 (meters per second squared) worth of vibration from your simulator.

Time To Build Your Structure

There are many things you can use and many ways to complete this activity. The following lists include potential materials to get you started. Feel free to experiment with other materials.

Edible Materials

- Graham crackers
- Frosting or fluff
- Plastic knives
- Popsicle sticks
- Tape
- Sugar cubes
- Cardboard or construction paper (to serve as a base for your structure)

Simple Materials

- Cardboard (ideally uniform pieces)
- Tape
- Scissors or crafting blade
- Popsicle sticks
- Rubber bands
- Cardstock/Construction paper

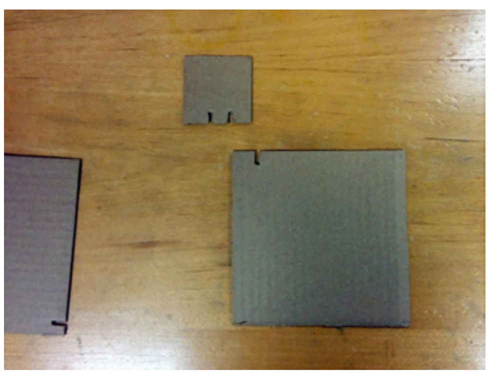
Some questions you need to answer before you begin construction are:

- How many stories will your structure be? Why?
- How will you connect and join the pieces?
- What will the overall shape of the structure be?

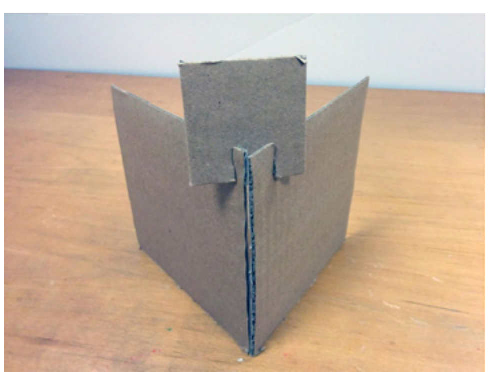
Once you've answered these questions and made your design choices, it's time to make your structure. This is your opportunity to let your creativity flow. Explore a variety of ways to use the materials you have chosen and see which proves most efficient.

Here are some ideas for joining two pieces of cardboard (or other materials) together:

Try using slots.

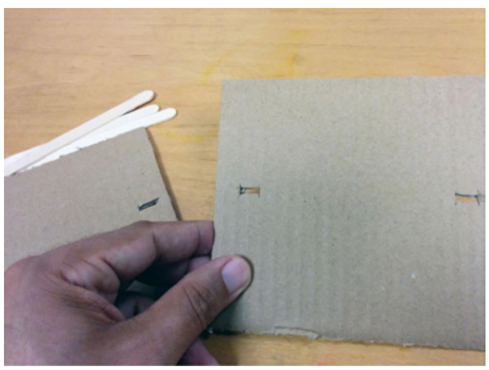


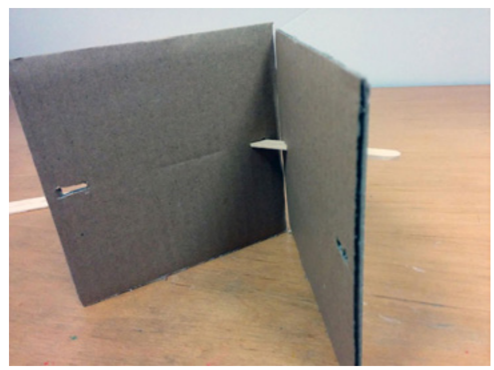
Slotted joints can be very effective depending on where your structure bears weight. Tip: When cutting slots, make sure they're not bigger than the thickness of the material, otherwise your joint will be very loose and unstable.

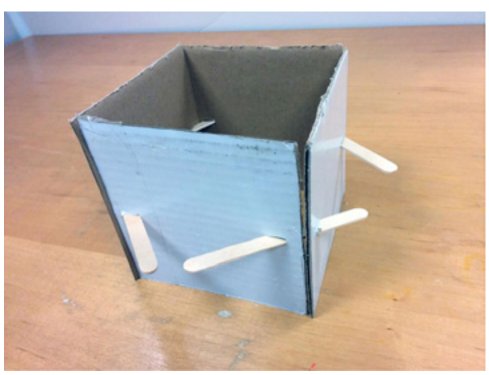


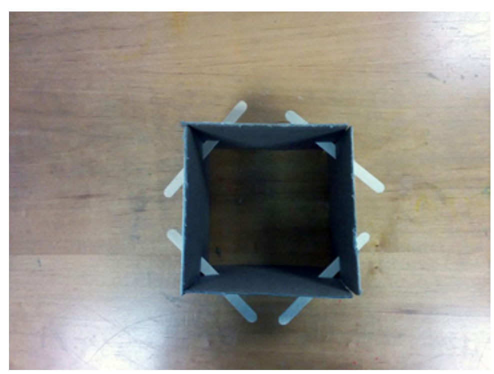
Don’t be afraid to try different shapes.

You can also try using popsicle sticks as cross-cutting beams.

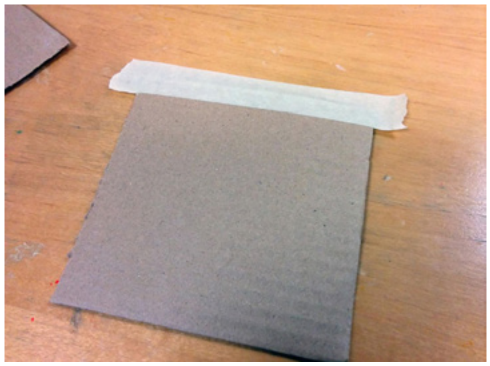


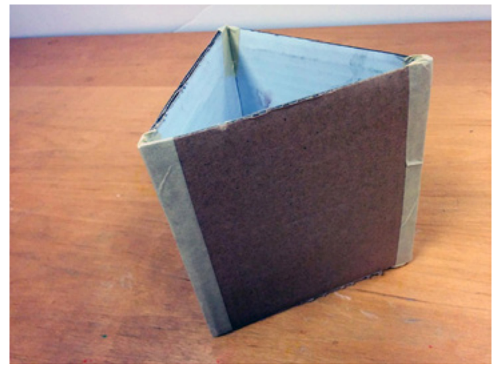






Of course, you can use tape or other materials you would like to experiment with to attach pieces.





In addition to the above ideas, there are plenty of resources online for different types of joints. Often, the type of joint you use will depend on the type of material you are using, but inspiration can come from imagining what is possible. Have a look at the following websites for possible ideas:

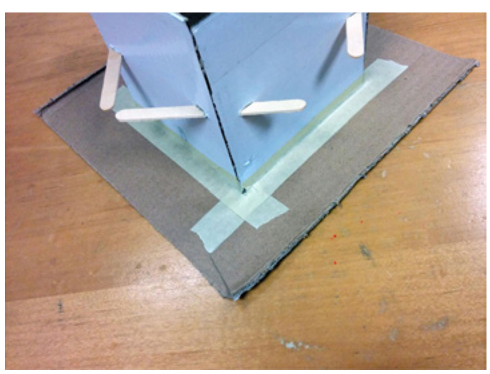
http://www.craftsmanspace.com/knowledge/woodworking-joints.html

http://cardboardchair.weebly.com/

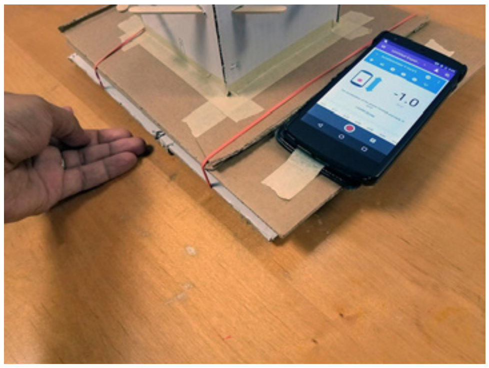
https://www.theartofed.com/2016/06/24/6-amazing-things-tab/

Building Tip:

Be sure to secure your structure onto the top of the earthquake simulator so that it does not slide off when it is being shaken!



Your finished structure should be fastened to its cardboard base. The cardboard base, the structure and the device with the Science Journal app should be fastened to the earthquake simulator like so:

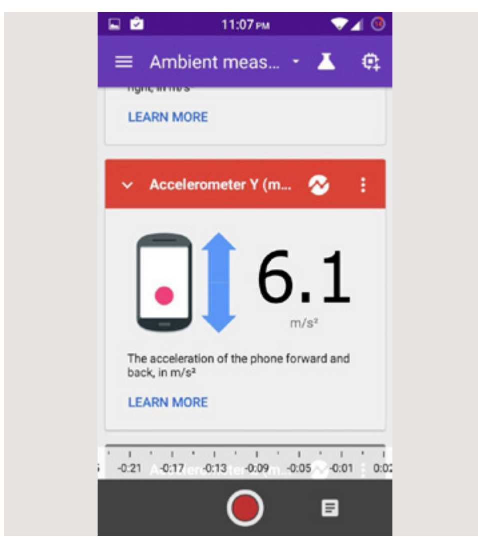


Make Predictions

Take a minute to predict what will happen to your building/structure. Do you think it will stay upright? How long do you think it will be able to withstand the earthquake? Can you predict what the weakest part of your structure is? To achieve a successful design, engineers imagine how a design might fail; their job is to identify (and prevent) each way the design could fail.

Shake The House!

Now imagine there is an earthquake and the ground beneath the house shakes. The average earthquake lasts between 10 – 30 seconds. Keep shaking your simulator for 30 seconds. Try to get the Science Journal app to a peak acceleration of 6 m/s2. What happens to the house?



Results—What Happened?

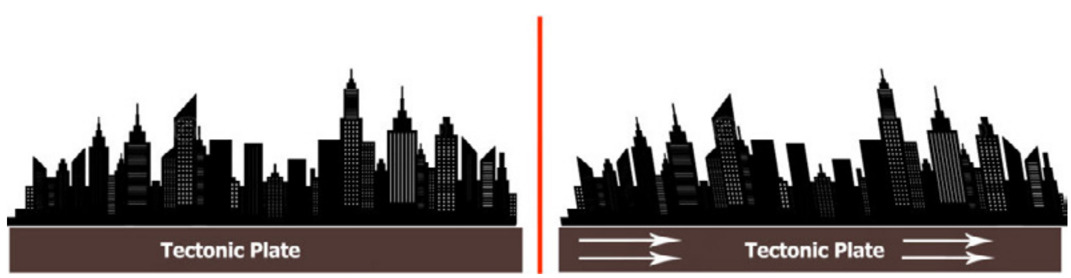
Evaluate the test results to determine why it may have failed. Now that you have seen how your design handled a simulated earthquake, there will be a whole new series of questions to answer. Was your guess about the weakest part of the structure correct? Did anything unexpected happen? How do you think the way you shook your structure comes into play – how would frequency, amplitude, and duration affect the results?

Redesign

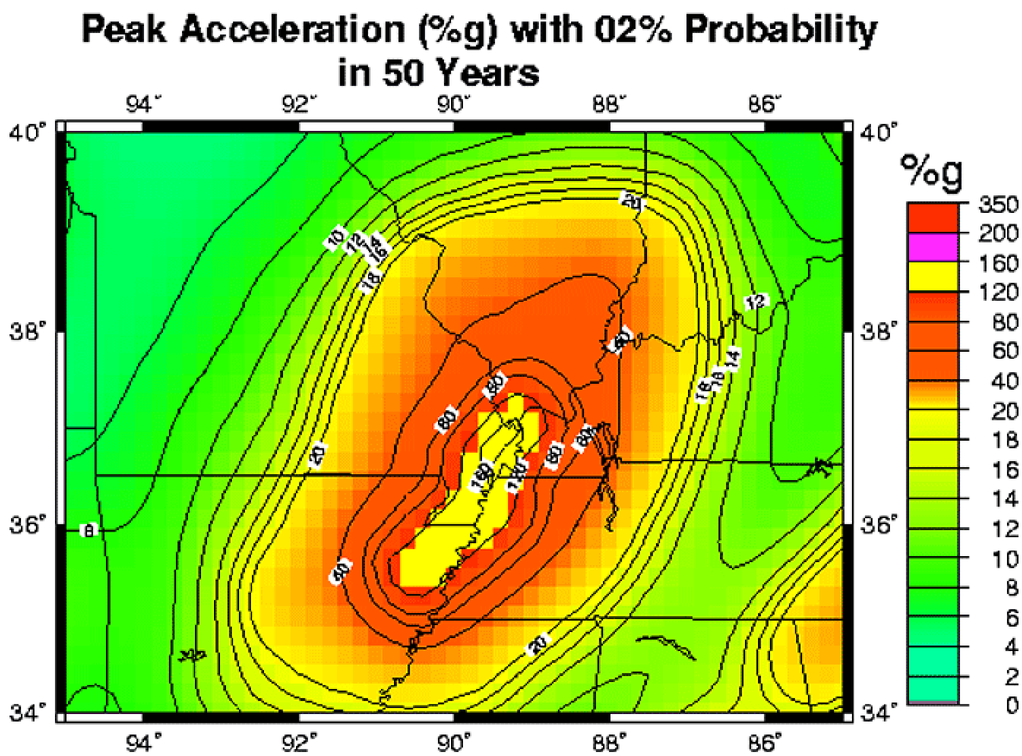
Making your observations and forming new questions will give you ideas to make improvements and prevent the same weaknesses from causing another failure. You can use the same materials. However, if you think one of the materials used was part of the problem, consider trying other materials.

Real Earthquakes

For this activity, we are just simulating earthquakes. The truth is, real earthquakes can be much more complex. An earthquake is the shaking of the Earth caused by pieces of the Earth's upper crust, or tectonic plates, suddenly shifting. This shifting of tectonic plates causes the ground to shake in many directions. When the shaking occurs, structures can potentially get thrown from side to side and/or up and down, but the structures have entropy; this means that a structure that is resting with no acceleration tries to remain at rest. The problem is, the tectonic plate that it's resting on is moving. This is illustrated below:



Another factor that affects structures during an earthquake is what that structure is built on. The surface over the tectonic plate can be hard rock of soft soil. Before actual construction workers begin the process of making a building there are many things to consider. Will the materials be strong, rigid and well reinforced, or flexible, thereby able to absorb movement without deforming? Also, is the planned construction site near a fault or in a place that has a higher chance of earthquakes? Often, hazard maps like this one will be used:



The green, outer portions of the map are farthest away from the fault line located in the center of the map. Areas closing in on the center gradually change colors from yellow to red indicating an increasingly greater risk of experiencing earthquakes. (Hazard Map courtesy of Dr. Robert Herrmann, Saint Louis University)

As you try this activity, we encourage you to learn more about earthquakes. Have a look at the research being run by the Multidisciplinary Center for Earthquake Engineering Research (MCEER). But most of all, we encourage you to try out your own ideas. There is nothing like learning first hand what works and what doesn't work.

Shake, Rattle and Roll — An Earthquake Simulation activity is made possible with support from Making & Science, an initiative of Google.