STEM Engineering Earthquake Challenge: Shakin' All Over

Overview

In this 2-class-period activity, students build earthquake-resistant 3-story structures and test them on an earthquake table. In doing this, they learn a reason for monitoring the lithosphere, and they design a structure to withstand an earthquake.

North Carolina Essential Science Standards

6.E.2.4 Conclude that the good health of humans requires: monitoring the lithosphere, maintaining soil quality and stewardship.

Background

Earthquakes come in all sizes. Some rattle the dishes on shelves, and some bring down buildings. Earthquake scales such as the Richter Scale measure the height of seismic waves generated by an earthquake. These scales are logarithmic, so that a magnitude 5 seismic wave is 10 times higher than a magnitude 4 seismic wave. As the scale goes up, the amount of energy released increases by about 32 times each step, making a magnitude 5 quake 32 times more energetic than magnitude 4. As earthquakes climb the Richter scale, buildings need to be much stronger to withstand them.

Earthquakes cannot be precisely predicted or prevented. To reduce earthquake damage, architects and builders modify buildings. They build on "stable" ground, firmly connect foundations, use materials that withstand shaking, and brace against swaying. To add even more strength, they build around core stairwells and elevator shafts. They might even include flexible dampers in the foundation to reduce the transfer of the shaking from the ground to the building.

Materials for the whole class

- 3 earthquake (shake) tables for testing structures (set-up instructions below)
- 4 bolts, 12 nuts, and 4 washers for each shake table
- single hole punches
- Support Document 1 (to project)

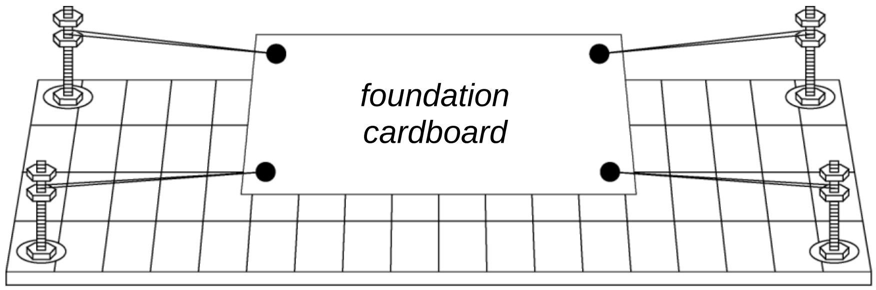
Materials for small groups (teams of 2)

- 1 piece of foundation cardboard
- 4 rubber bands
- 1 ruler
- building materials
    - 20 marshmallows
    - 20 tooth picks
    - 4 sticks of raw spaghetti
    - 4 sticks of fettuccini
    - 1 inch of masking tape

Materials for individual students

- Science notebook (supplied by teacher)

Preparation



Shake table

1. Set up the three earthquake tables as follows:
    - Position the shake table base with the grid up, insert a bolt upward (head down) through a corner hole, and place a washer over the bolt.
    - Screw a nut all the way down to secure the bolt tightly. Then screw a second nut about 1" down from the top of the bolt. This second nut keeps the rubber band from getting too low on the bolt.
    - Screw a third nut about ¼" down from the top of the bolt. This nut keeps the rubber band on the bolt.
    - Repeat for the other three bolts in each corner of the shake table.
2. Make the foundation cardboards as follows:
    - Punch holes in the 4 corners of the foundation cardboard about ½" in from the corners.
    - Loop a rubber band through each hole.
    - Students will attach the 4 looped rubber bands around the upright bolts in the base to suspend the foundation cardboards above the base, as shown above.
3. Decide whether students will collect the materials, or you will provide prepared bundles, and set up a system to distribute materials.

Exploration

1. Project Support Document 1 and let students know they will build a model structure that follows these rules. The building must:
    - be built from the given materials <u>only</u>,
    - be at least 3 stories tall: ground floor plus at least 2 floors above (the roof does not count as a floor),

- be built on the foundation cardboard or placed on it prior to testing,
- have each floor at least 6cm high,
- resist an earthquake without collapsing, toppling, or failing in any other way that the class decides upon.

2. Demonstrate the shake table and the magnitude of the earthquake. To find out how big an earthquake their building can withstand, students can increase the intensity of the earthquakes by deflecting the base 1 additional square at a time until the building fails.
3. Work with the class to decide the criteria for building failure. What if it partially comes apart without falling? What if a part breaks but it is still standing? What if part of it falls off but part of it remains? Would people inside the building have been injured?
4. Set up teams of 2. Give each team a standard set of materials (see *Materials* above) and let teams explore freely to build a structure of at least 3 stories. If materials break (e.g. spaghetti), provide new pieces. However, structures must be built using *only* materials in the standard set. Explain that when they are done exploring building for earthquakes with these materials, they will be asked to draw a building plan for what they will build. As teams explore, they may find materials that do not behave as they thought, and they might want to change their plans.
5. Ask teams to sketch plans for their building. Drawings must label the building materials used.

Procedure

1. After each team shows you a detailed plan, allow it to build the structure.
2. One at a time, place each structure upright on the earthquake table. If teams choose to fasten the structure to the cardboard, this is allowable. Pull the foundation cardboard one grid mark off center and release. Continue pulling the foundation cardboard one more grid mark and releasing until the building fails. Have the whole class watch as each group tests so that they can record successes and failures. Discuss how to record useful results. For example, use the drawn plan to record what broke, where it broke, and what might have caused it to fail. It is especially important to record results for their own model, but students can take notes on other models.
3. After all groups test, debrief what worked, what didn't, and what could be improved. Explain that everyone gets a chance to try again. Ask a few students to read from their notebooks about what broke, where it broke, what design problem might have caused it to fail, and what they plan to do differently next time.

Reflection/Discussion

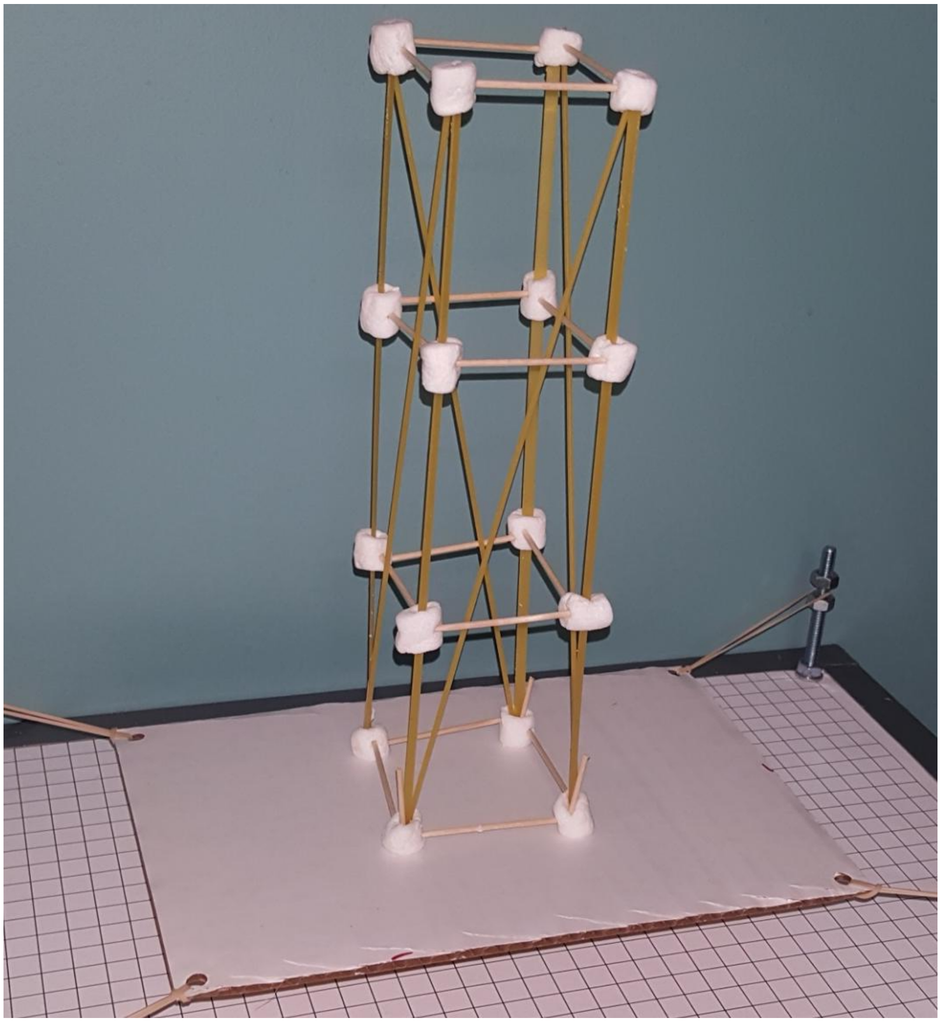
After the first tests, discuss as a class what worked and what didn't. For example, students will find that connecting the foundation and cross-bracing walls helps.

- Ask about characteristics of each building material and their performance. Toothpicks are short, but strong. Spaghetti is long, but breaks easily.
- Have the class share recording techniques that worked and did not work. For example, it's a good idea to label pieces and indicate exactly what broke and where.

Give students the opportunity to build and test a second structure, using ideas they may have learned from this discussion.

- After these second tests, discuss again what worked and didn't work.
- Discuss why it is important for engineers to know the geology of the location where they build a structure.

Below is an example of a 3-story structure that remained intact when the foundation cardboard was pulled 5 squares to the side and released. Notice the toothpicks fastening the base of the structure to the cardboard.



Your structure must:

- be built from the given materials only,
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- have each floor at least 6 cm high,
- be built on the foundation cardboard or placed on it prior to testing,
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