Activity Description & Estimated Class Time

In this 2-part activity, students first explore different types of earthquake waves, how they travel, and collect evidence on the damage created by the waves. In Part 2, which will take two class periods, students build earthquake-resistant 3-story structures and test them on an earthquake table. In doing so, they learn why humans monitor the lithosphere and design a structure to withstand an earthquake.

Correlations to NC Science Standards

ESS.6.2.2 Construct an explanation to illustrate how the movement of lithospheric plates can create geologic landforms and cause major geologic events such as earthquakes and volcanic eruptions.

Learning Target

Students will demonstrate knowledge and understanding of:

- how wave energy travels through the different layers of Earth during an earthquake in the form of seismic waves.
- the following terms:
  - primary waves (P-waves)
  - secondary waves (S-waves)
  - surface waves
  - focus
  - epicenter
- seismic waves by building an earthquake-resistant structure

Brief Science Background

Earthquakes occur in many different sizes. Some are so small they only cause dishes to rattle, while others are powerful enough to collapse buildings. Earthquakes begin at a point underground called the **focus**, where rocks suddenly break or shift along a fault. The point directly above the focus on Earth's surface is called the **epicenter**.

When an earthquake happens, it releases energy in the form of seismic waves. There are three main types of seismic waves. **Primary waves (P-waves)** are the fastest and travel through solids, liquids, and gases. **Secondary waves (S-waves)** move more slowly and can travel only through solids. Surface waves travel along Earth's surface and usually cause the most damage because they produce strong shaking.

Scientists measure the size of earthquakes using scales such as the **Richter scale**, which measures the height (amplitude) of seismic waves. The Richter scale is logarithmic, meaning each whole-number increase represents a wave that is 10 times larger in amplitude. However, the energy released increases much more dramatically, about 32 times more energy for each step up. For example, a magnitude 5 earthquake releases about 32 times more energy than a magnitude 4 earthquake.

Because stronger earthquakes release so much more energy, buildings must be designed carefully to withstand shaking. Although earthquakes cannot be precisely predicted or prevented, engineers reduce damage by improving building design. They construct buildings on stable ground, securely anchor foundations, use flexible and durable materials, and add braces to prevent swaying. Many buildings are strengthened around core stairwells and elevator shafts for added support. Some structures even include flexible dampers or base isolators in their foundations to reduce the transfer of ground shaking into the building.

Part 1 - Earthquake Energy

Materials

Materials for the whole class

- ability to project videos from www.ciblearning.org
- Earthquake Energy Student Activity Sheet, SD 1, one per student

Procedure

1. Give each student a copy of Earthquake Energy Student Activity Sheet, SD 1. Ask them to record their notices and wonders as they watch the video clip. Show the first 25 seconds of the video Earthquake Energy Video 1 from www.ciblearning.org, directing students to look carefully at what is happening in the room. Give students time to record their thoughts. Then have students watch the video a second time, paying careful attention to the shaking. Students should add to their notices and wonders on SD 1.
2. Discuss students' observations and their questions. If no one brings it up, be sure to ask students for their ideas on how the energy to create all the shaking and destruction is transmitted.
3. If students have not learned about waves yet, let them know that the energy from the earthquake's center spreads out in waves to many locations, near and far.
4. Let students know that they are going to look for all the ways that earthquake waves create changes.
5. Show Earthquake Energy Video 2. This video shows what happened when a man was swimming during a massive earthquake. Have students collect data on the movements and destruction caused by earthquake waves, recording their observations on SD 1 while watching he video. Discuss students' observations and thoughts.
6. Tell students that there are different types of earthquake waves. Ask them what in the video supports this idea? Students should point out the waves in the pool, buildings collapsing, TV studio movement, dash-cam video, dust cloud, etc. Some items moved side to side or up and down, while others moved like a wave on the surface.
7. Discuss with students the main types of earthquake waves, body waves (P waves and S waves), and surface waves. Use resources, such as Earthquake Energy Video 3 located on www.ciblearning.org or your own, to teach students these ideas.

Content Connection

Play the first video for the students one more time. Have students explain in writing or with a diagram how an earthquake in another part of Alaska may have caused the damage seen on the video. Have students explain the movement they saw in the video using concepts learned.

Students should note that the P and S waves traveled out from the epicenter and caused damage far away. Students should note seeing the classroom screen move up and down and then more violently side to side. Then the shaking stops, showing that the wave has passed.

Part 2 - Engineering Challenge

Materials

Materials for the whole class

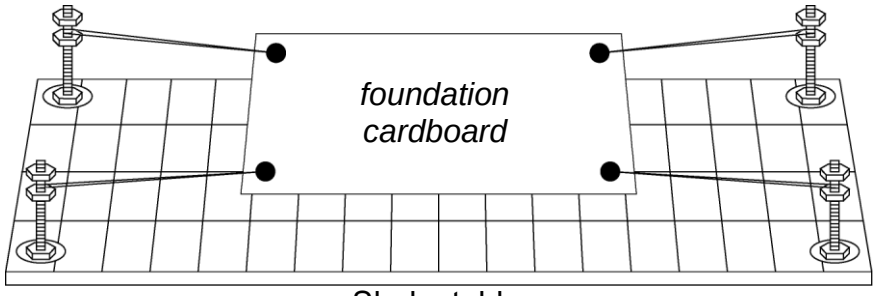
- 3 earthquake (shake) tables for testing structures (set-up instructions below)
- 4 bolts, 12 nuts, and 4 washers for each shake table
- single hole punches
- ability to project
  - video from www.ciblearning.org
  - Earthquake Challenge Rules, SD 2

Materials for groups of 2 students

- 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
- Earthquake Challenge Student Activity Sheet, SD 3, 1 per student

Preparation

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.



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.

Procedure

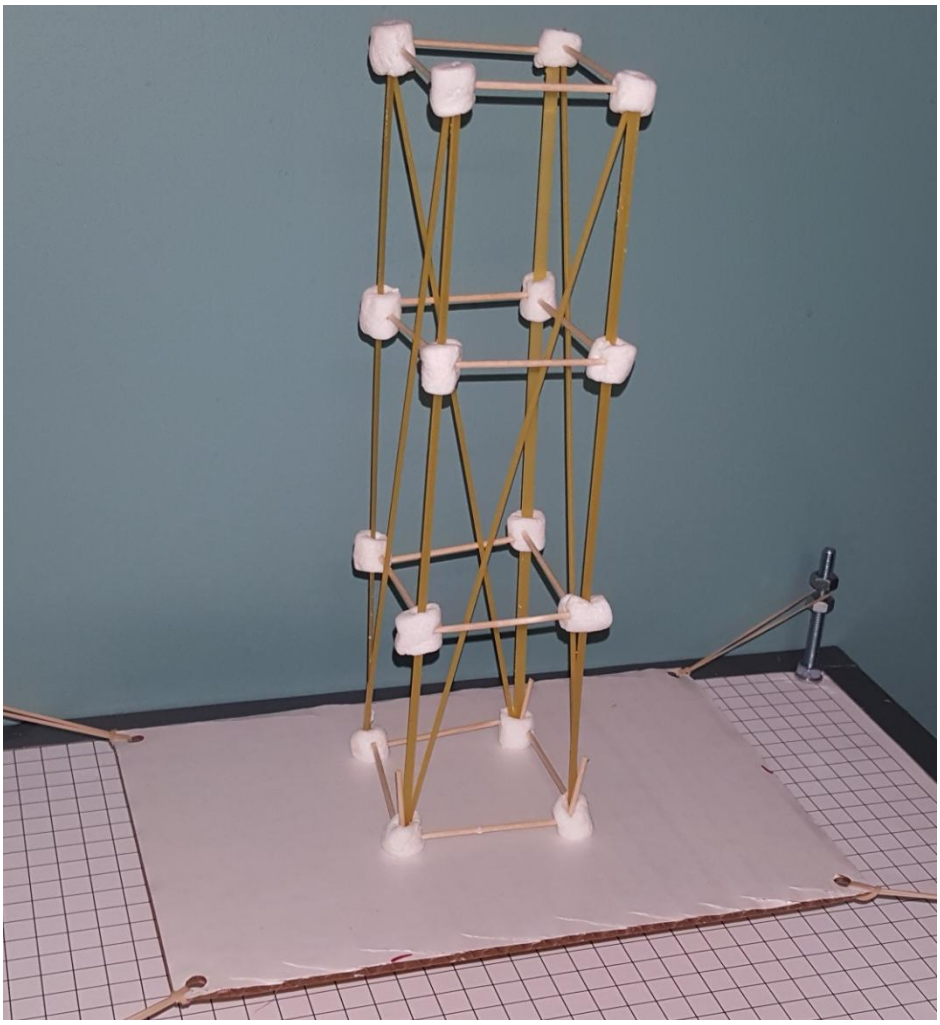
1. Tell students that they are going to use what they know about earthquake waves to design a structure that will withstand the waves.
2. Show Earthquake Engineering Challenge Video to introduce the idea. Ask students how this table could help when designing structures in earthquake prone areas.
3. Project Earthquake Challenge Rules, SD 2, and let students know they will build a model structure that follows these rules. The building must:
    - be built from the given materials only
    - 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.
4. 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.
5. Give each student a Earthquake Challenge Student Activity Sheet, SD 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? Have students record the criteria on SD 3.
6. 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. Have the students record their notes and observations about the building materials on SD 3. 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 how to build for earthquakes with these materials, they will be asked to draw a 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.
7. Ask teams to sketch plans for their building on SD 3. Drawings must label the building materials used.
8. After each team shows you a detailed plan, allow them to build the structure.
9. Place each structure upright on the earthquake table one at a time. 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.
10. After all groups test, debrief on what worked, what didn't, and what could be improved. Explain that everyone gets a chance to try again. Ask a few students to

Procedure cont.

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.

11. 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
12. Give students the opportunity to build and test a second structure, using ideas they may have learned from this discussion.
13. After these second tests, discuss again what worked and didn't work. Discuss why it is important for engineers to know how earthquake waves move. 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.



SD 1

Earthquake Energy Student Activity Sheet

Name:

Earthquake Energy Video 1

Record your notices and wonders below.

I notice...	I wonder...

Earthquake Energy Video 2

Record your observations and questions.

Observations of movement and destruction	This make me think...

Use what you have learned in this lesson to explain why the earthquake in the first video may have happened in a different part of Alaska. Explain the shaking you saw in the video. Use words or draw a picture, or both.

SD 2

Earthquake Challenge Rules

Your structure must:

- be built from the given materials only,
- be at least 3 stories tall: ground floor plus at least 2 floors above (the roof does not count as a floor),
- have each floor at least 6 cm high,
- be built on the foundation cardboard or placed on it prior to testing,
- resist an earthquake without collapsing, toppling, or failing in any other way that the class decides upon.

SD 3
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Earthquake Challenge Student Activity Sheet

Name:

1. Record the class's criteria for building failure.

2. Record your notes and observations about the building materials here. What surprised you?

3. Sketch and label your building plan. Include your reasons for these design choices.

4. What were your results? What design changes will you make after the trial? Why?

SD 3
pg. 2 of 2

Earthquake Challenge Student Activity Sheet

5. What were your final results? Which techniques and materials were effective? Which were not?

6. What type of wave was created most often when moving the shake table side to side?

7. Why do engineers need to understand earthquake waves when designing houses?