The EQ^s Project

Forces within the Earth are bending and straining the relatively thin crust we call home. Although scientists and engineers do not fully understand these forces, we know these forces sometimes cause Earth's crust to bend until it snaps. This action is called an earthquake.

Most earthquakes occur within Earth's upper crust, or about 15 miles from the surface. They do occur at depths as much as 460 miles below the surface, but the number of occurrences decreases with depth.

Earthquakes can cause tremendous changes in the Earth's crust. If they occur where man-made structures have been built, the result can be catastrophic destruction and loss of life.

Engineers and architects have been trying to understand the effects of earthquakes on structures for many years. Scientists have been studying how and why these tremors cause such tremendous damage. Working together, scientists and engineers are looking for ways to construct buildings that can withstand earthquakes.

Figure 1 – Building collapsed due to an earthquake

Figure 2 – A fault line

In this project, you will explore the causes of earthquakes and attempt to construct a model building that will withstand the tremors of an earthquake using the EQ^s Tremor Table. Like engineers, you will test the effects of an earthquake on your model structure and observe the forces that will shake the structure until it collapses.

A good understanding of the scientific knowledge behind an earthquake will make you a better engineer.

Earthquake Waves

There are many kinds of waves and many of them are invisible. Radio waves, heat waves, and sound waves are examples of invisible waves. An easily understood example of waves is the ripples that form when you drop a stone into a pond. The water is disturbed only where the stone enters the water, but shortly thereafter you can observe a regular series of ripples traveling out from the point of entry in all directions. These ripples are actually tiny waves.

The highest point of the wave is the ***crest***. The lowest point is known as the ***trough***. The distance measured from a point of a wave to the corresponding point of the next wave is called the ***wavelength***.

The number of waves that pass a given point in one second is the ***frequency***. The shorter the wavelength, the higher the frequency.

The material that carries a wave or transfers its energy is called a medium.

The distance from a wave's crest (highest point) to its trough (lowest point) is called ***amplitude***. The energy of a wave depends upon its amplitude. If you drop a small pebble into the water, the amplitude will be small. However, if you drop a large rock into the water, the amplitude will be greater.

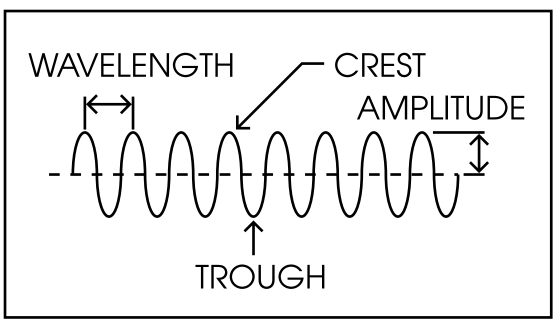


Figure 6 – Parts of a transverse wave

There are two types of wave motion. One type can be observed by tying one end of a rope to a chair. Shake the other end with a sharp up-and-down motion, and you will see the waves moving along the rope.

If you shake the rope hard enough, the waves will reflect back from the chair before they cease. Parts of the rope move up and down while the wave moves forward. This type of wave is called a ***transverse wave***, which is sometimes called a ***shear wave*** or ***torsion wave***. In a transverse wave, the particles of the medium move at right angles to the direction of the wave's motion.

Another type of wave motion can be seen by using a long coiled spring. Attach the spring at one end and give the spring a quick push-pull motion. This type of wave is called a ***longitudinal wave,*** or a ***compression wave***. A longitudinal wave is defined as one in which the particles of the medium move back and forth in the same direction as the wave itself moves.

Instead of crests and troughs, the coils compress and expand. The compressed part of the wave is called a ***compression***, and the expanded portion is called a ***rarefaction***.

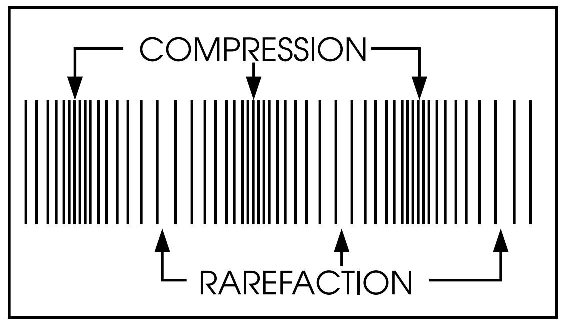


Figure 7 – Parts of a longitudinal wave

When you observe the wave action of the spring, notice that the waves move lengthwise along the spring. At no point does the turn of wire move along with the wave. Any turn of wire moves back and forth for only a short distance, but the energy of the wave is passed along the entire length of the spring.

The wavelength of a longitudinal wave can be expressed as the distance of one compression to the next, or from one rarefaction to the next. The amplitude is the greatest distance backward or forward from the rest position of the coils.

Earthquakes produce both types of waves. The longitudinal earthquake wave is called the primary wave. This is the push-pull force passing through all parts of Earth, including the central liquid core. A primary, or P wave, travels about five miles per second (.8 km/s), but its speed increases with depth, passing through the Earth's diameter in about 26 minutes. These ripples can be detected any place on Earth by a seismograph.

The transverse earthquake wave, also called the secondary or S wave, has a snake-like motion. A transverse wave – also called a twist wave – travels slower than a compression wave, moving at about three miles per second (4 km/s) through Earth's

Activity 2

Activity 2: Discovering Wave Mechanics

Materials Required

- EQ^s Tremor Table
- Tower block base
- Foundation block
- 1/8" (3 mm) welding rod
- 4 Pitsco rear dragster Px wheels
- White glue
- Hacksaw
- Drill

Construction

1. Drill 1/8" holes near each corner of the foundation block.
2. Glue the foundation to the middle of the tower block base.
3. Using the hacksaw, cut four lengths of welding rod to varying lengths between six inches and 20 inches.
4. Attach a wheel to each of the rods and push the rods into the holes drilled in the foundation block.

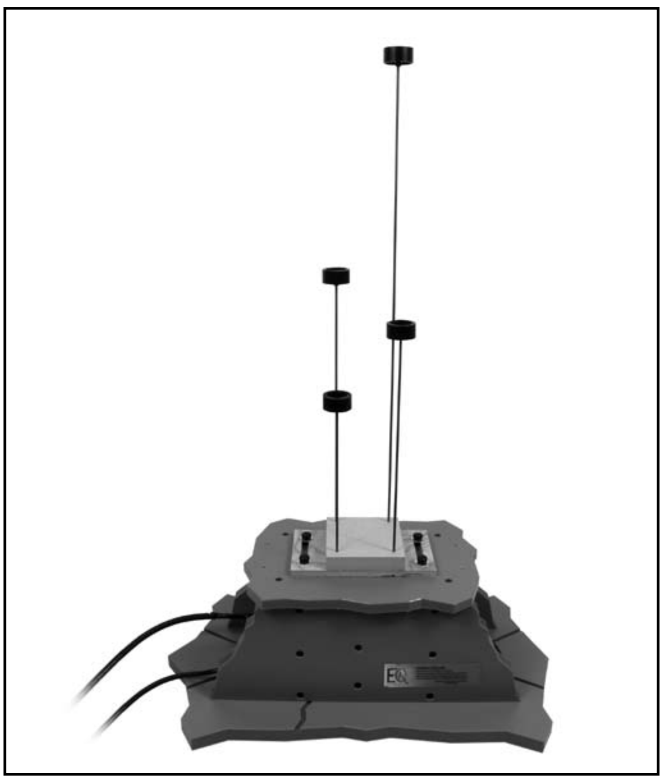


Figure 11 – Different length rods mounted on the EQ^s Tremor Table

Procedure

1. Next, attach the tower block base to the EQ^s Tremor Table as shown in the EQ^s user guide.
2. Follow Steps 1-5 in Activity 5 (see page 22).
3. Start the EQ^s following the directions in its user guide.
4. Observe how each welding rod tower vibrates. After 15 seconds, move the Rate slide control up to increase the cycles per second.
5. Observe the action of the towers at each setting.

Observation

1. Make a chart to record the setting on the EQ^s Tremor Table at which different length rods remain still, barely vibrate, vibrate violently, or resonate.
2. Explain why some rods act differently at the same EQ^s Tremor Table setting.

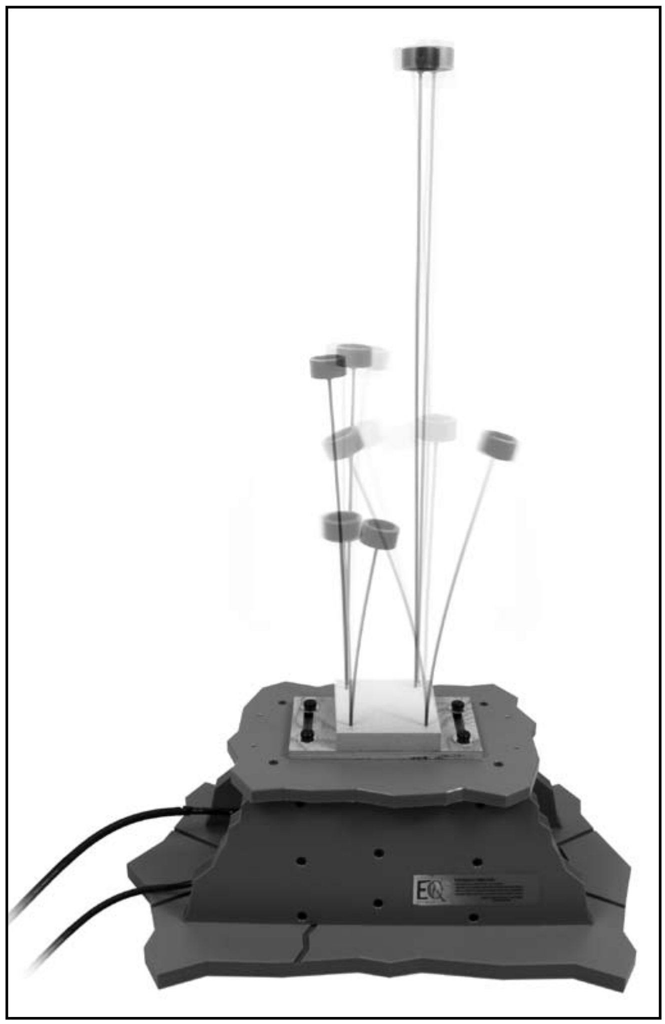


Figure 12 – The rods are in motion with the tallest structure just starting to vibrate at its resonance frequency

Activity 4

Activity 4: Building the Structure You Designed

Materials Required

- Foundation block, 3/4" x 3-3/4" x 4" (19 mm x 96 mm x 101 mm)
- Tower base block, 3/8" x 4" x 7" (8 mm x 101 mm x 177 mm)
- Wooden floor plates, 1/8" x 4" x 4" (3 mm x 101 mm x 101 mm), with each corner of the plate notched 1/8" x 1/8" (3 mm x 3 mm)
- Balsa wood or basswood strips, 1/8" x 1/8" (3 mm x 3 mm) (balsa wood is referred to in these instructions, but basswood can also be used)
- Glue (Pitsco Structures Glue or HD Bond adhesive is recommended)
- Paper-covered rigid foam, 3/16" x 12" x 24"
- T-pins or straight pins
- Masking tape
- Waxed paper

Tools Required

- Timber Cutter, hobby knife, or Lil' Termite Sander (recommended)
- Sheet of plain paper or graph paper, 12" x 24" (you might have to splice two sheets of paper together if you do not have paper this big)
- Ruler
- Pencil
- Small clamps (optional)

Before You Begin

Before building, you will want to refer to any specifications your teacher has provided for your tower. As you design a tower, consider the number of floors, total height, amount of materials available to use, and other factors as specified by your teacher.

Note: Measure the length and width of the foundation block. Use these measurements as you design and build your tower. Within these basic instructions, we will assume the foundation block is the standard size listed above. All remaining measurements for the tower construction will be metric.

Your tower will need to connect to the EQ^S Tremor Table by means of a foundation block and a tower base block. The tower base block has slotted holes for quick mounting to the EQ^S Tremor Table.

For basic tower building, build the tower around the foundation block and attach the completed tower to the tower base block for testing.

Construction

1. Draw two identical side views of your tower design on paper large enough to accommodate two sides of the tower. For a standard tower, these two sides should each be a rectangle 10.1 centimeters wide and 50 centimeters long. Make the lines for the sides of these rectangles 3 millimeters (mm) wide to represent the width of the balsa wood strips.

   Hint: To ensure the tower sides are drawn the correct width to fit the floor plates, hold a floor plate up to the drawing and see if the tower sides you drew align with the notches on the floor plate corners.

2. For the standard five-floor tower, space the floors 10 centimeters (cm) apart. On your drawing, measure down from the tower top and draw a 3 mm wide line indicating the position of each of the floors (the top floor will be at the very top of the tower). There should be floor plate lines at 10 cm, 20 cm, 30 cm, and 40 cm from the top of the tower. Approximately 10 cm will be left at the bottom of each tower side.

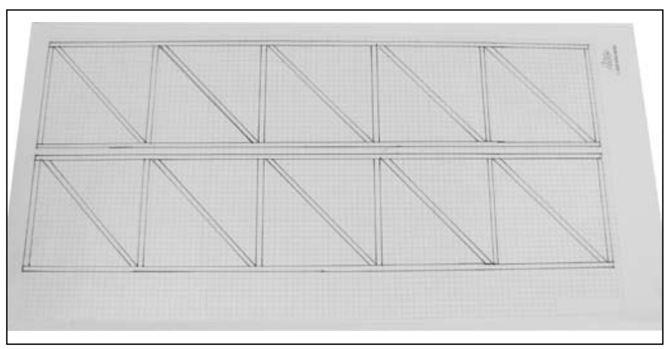
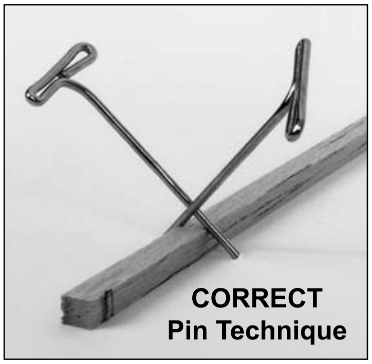


Figure 30 – Drawing of a tower

3. Draw diagonal bracing for the two tower sides. The bracing should be identical for each tower side to ensure symmetry within the structure (Figure 32). The number of diagonals and their placement is a design factor you must determine for your tower. Draw all diagonals as 3 mm wide lines – the width of the balsa wood strips.
4. Tape the drawing to the piece of paper-covered foam board, then tape waxed paper over the drawing.
5. Beginning with the long sides, measure the length of each piece needed, mark a piece of balsa wood at that length, and cut the balsa wood piece.

Activity 4

6. Place the piece over the drawing to be sure it is the correct length.
7. After the piece is the correct length, pin the piece in place. Do not push a pin through the balsa wood, as it will split the wood. Crisscross two pins over the balsa wood as shown in Figure 32.



Figures 31 and 32 – The wrong and correct methods of pinning balsa wood to the foam board

8. Measure, mark, and cut all the long pieces. Position them in place using pins (Figure 33).

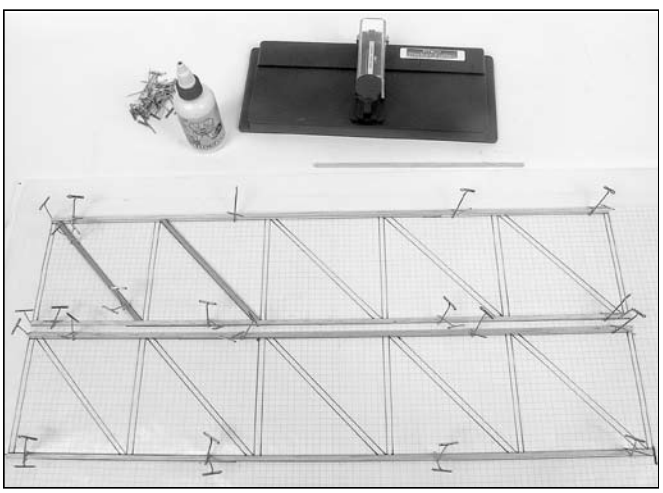


Figure 33 – Long balsa wood pieces pinned in place and some diagonal braces glued in place

9. Measure, mark, and cut one of the diagonal braces. You may need to cut one or both ends of the piece at an angle for it to fit correctly. Fit the brace over the drawing, making sure the brace does not cross into the space that will be taken by the floor plates. Remember, the position of the floor plates are indicated by the lines perpendicular to the long side pieces.

Caution: Be sure not to cut wood pieces and glue them in place in the vertical spaces where the floor plates will go.

10. After the fit is correct, add a small amount of glue to both ends of the brace and position it on the drawing. Use pins to keep the brace in position.
11. Repeat this procedure for the rest of the diagonal braces (Figure 34).

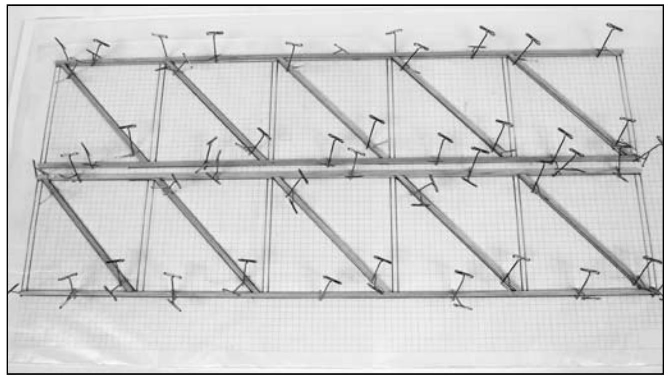


Figure 34 – Diagonal braces glued and pinned

12. Let the two sides of the tower dry overnight.
13. Mark the position of each floor plate on each long piece of the tower sides.
14. Remove the pins. Carefully, lift the two sides from the waxed paper.
15. Position one of the sides on the waxed paper so one long edge is positioned over a long edge of the drawing (still on the waxed paper) and the tower side is vertical (Figure 35). Positioning this side over the drawing will ensure square angles as the tower is constructed.

Figure 35 – One side in a vertical position and pinned

16. Pin the side in this vertical position.