

Curriculum topics:

- Structures
- Vibration
- Earthquakes
- Engineering

Subjects:

**Physical Science,
Earth/Space Science**

Grade range: 2 – 12

Who we are:

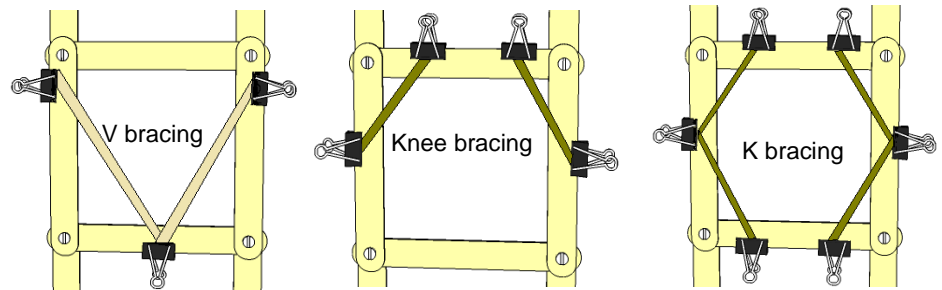
Resource Area for Teaching (RAFT) helps educators transform the learning experience through affordable “hands-on” activities that engage students and inspire the joy and discovery of learning.

For more ideas and to see RAFT Locations

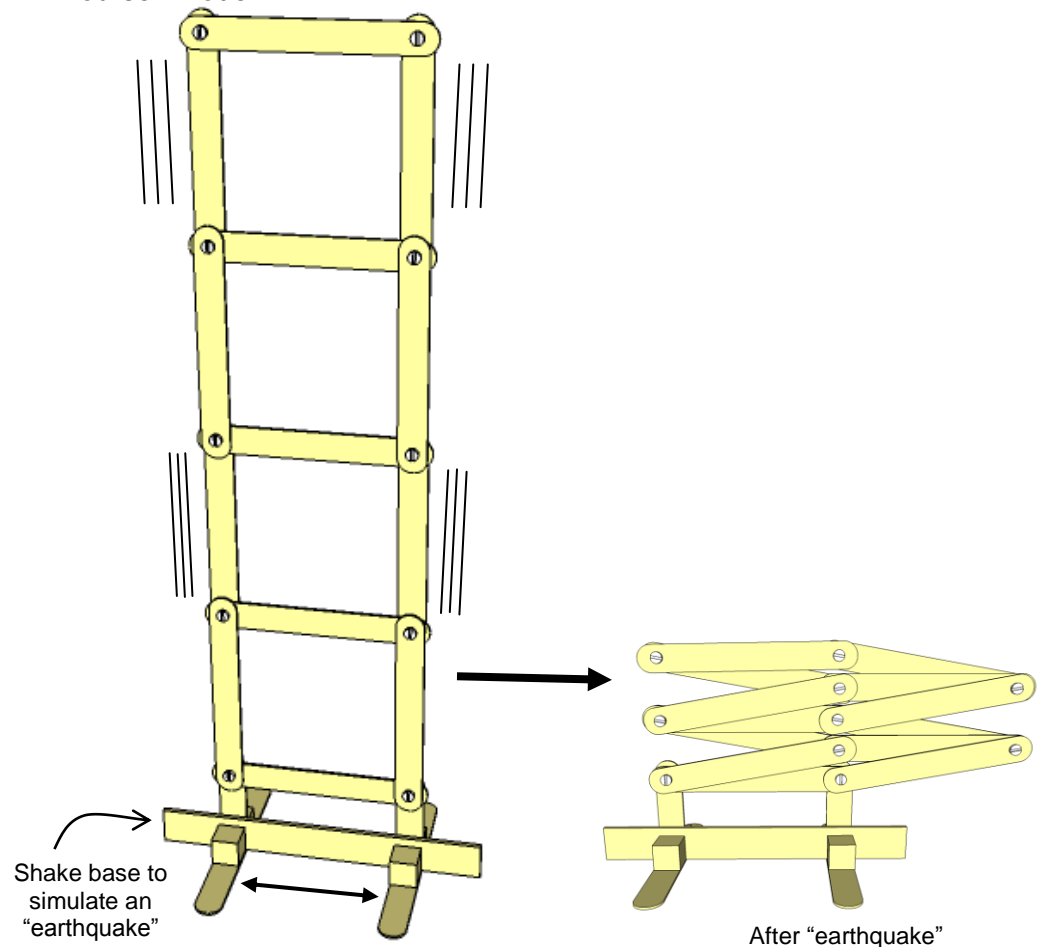
www.raft.net/visit-raft-locations

BRACE YOURSELF

What can keep a simple structure from collapsing during an earthquake?



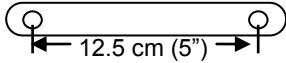
How will an earthquake, simulated by shaking, affect a “building” made of linked squares? How can the square “stories” be cross-braced to prevent the “walls” from collapsing? What dangers are there in building above a garage? Learn the answers to these questions and more by working with the Brace Yourself model.



Materials required

Per **Brace Yourself** unit:

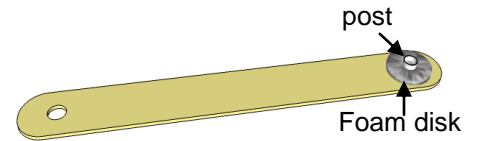
- Foam disks with center hole, 2 cm (~ $\frac{3}{4}$ "), ~3 mm (~ $\frac{1}{8}$ ") thick (can use EVA foam), 10
- Pencil (or dowel) with 6 mm ($\frac{1}{4}$ ") diameter
- Craft sticks, Jumbo, with two 6 mm ($\frac{1}{4}$ ") diameter holes with 12.5 cm (5") between the holes' centers. (Holes can be made with an adjusted 3 hole punch, using 2 of the punches, or the holes could be drilled), 13
- Craft sticks, Jumbo, no holes, 2
- Post & screw, plastic, 6 mm ($\frac{1}{4}$ ") tall, 10 pairs
- Adhesive disks, double sided, ~2 cm (~ $\frac{3}{4}$ ") diameter or double stick tape sections, 6
- Glue, white (suitable for wood)
- Paint stick, 9" long, 1
- Cubes, wooden, 2 cm ($\frac{3}{4}$ "), 4
- Binder clips, small, 12
- Craft stick, jumbo, $\frac{1}{4}$ " diameter holes on 5" center, stick cut in half, 4 halves
- Bracing materials: file folder strips, binder clips, regular craft sticks, coffee stirrers



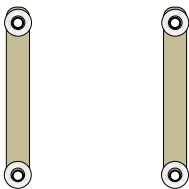
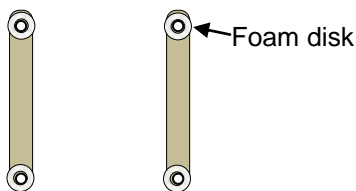
How to build it

Create Framework

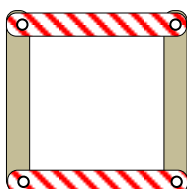
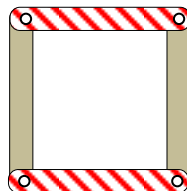
- 1** Enlarge the foam disks' center holes by sliding them onto a pencil.
- 2** Sandwich a jumbo craft stick (with holes) between a plastic post (not the screw part) and a foam disk as shown right. Repeat for the other hole. Repeat for 3 more jumbo craft sticks and two $\frac{1}{2}$ -craft sticks.



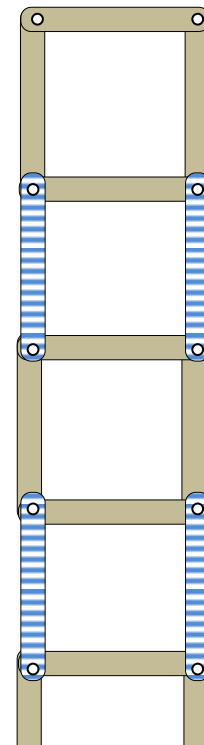
- 3** Arrange the craft sticks and $\frac{1}{2}$ -craft sticks as shown below.



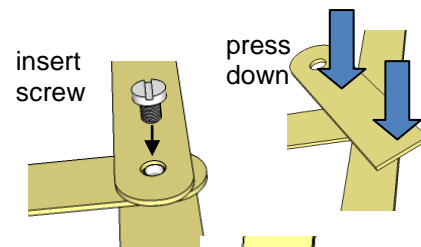
- 4** Lay 5 jumbo craft sticks (with holes) horizontally, as shown below. Position the holes in the craft sticks over the posts.



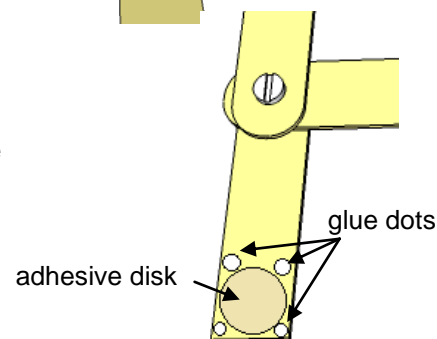
- 5** Lay 4 jumbo craft sticks (with holes) vertically, connecting the 3 sections, see below. Position the holes in the craft sticks over the posts.



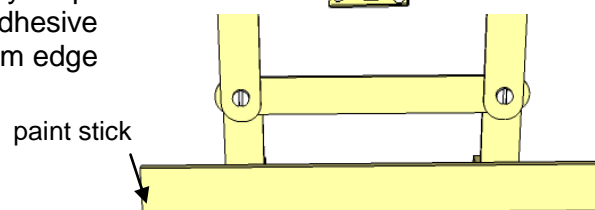
- 6** For each of the 10 junctions, in turn:
 1) insert a screw partway into hole in the post
 2) place the middle of a ½-craft stick over the screw head
 3) press down on the ends of the craft stick to force the screw into the post. [Alternatively, use the cut ends of the two ½-craft sticks as screwdrivers to snugly, but not too tightly, twist the screw and post pieces together.]



- 7** Peel the backing from an adhesive disk, place near the cut edge of the craft stick, as shown; press down. Repeat for the other ½-craft stick.

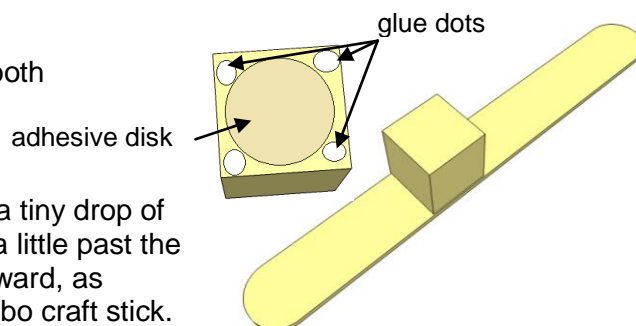


- 8** Peel the backing from both attached adhesive disks. Add 4 tiny drops of glue, as shown, by each adhesive disk over the glue and adhesive dots, aligning the bottom edge of the paint stick with the bottom edge of the cut craft sticks. Press down firmly to attach.



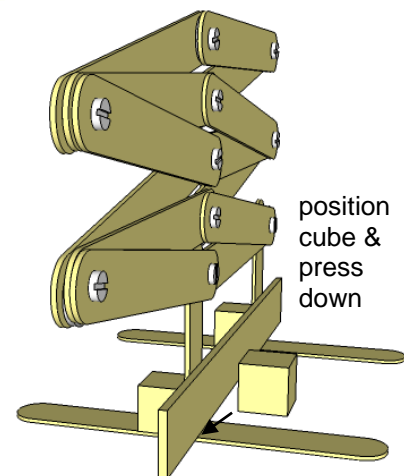
Create two stands

- 9** Peel the backing off an adhesive disk, attach to one smooth side of a wood cube. Repeat for 3 more cubes.



- 10** Peel the adhesive backing from a disk on a cube; place a tiny drop of white glue on each corner as shown; position the cube a little past the middle of a plain jumbo craft stick (no holes), glue downward, as shown. Press to attach. Repeat with another cube & jumbo craft stick.

- 11** Peel the backing from an adhesive disk on a loose cube, set down (adhesive upward) and add glue as above. “Accordion” collapse the framework. Press the framework’s paint stick and half craft stick next to a block on a plain craft stick. Turn the loose cube so the glue is downward and press a (non-adhesive) side tightly against the paint stick and ½-craft stick. Press the cube down onto the plain craft stick to attach and hold the framework tightly. Repeat to make a 2nd stand.



To do and notice

- 1** Set framework in stands and pull on the top to create a 4 story “building”. The posts & screws should be just tight enough so the building will stay standing when released. If the building does not stay upright use the remaining 2 half-craft sticks as screwdrivers to tighten the joints.
- 2** Give the paint stick a gentle back and forth motion, along the long dimension to simulate the shaking due to an earthquake. Increase the shaking speed until the building collapses. If the building does not collapse, unscrew joints until it will reliably collapse with enough shaking.
- 3** Discuss ways the building could be braced and prevented from collapsing during an earthquake.

Curriculum Standards:

Forecast catastrophic events and develop ways to mitigate their effects (Next Generation Science Standards: Middle School, Earth and Space Science 3-2)

Forces & Motion (Next Generation Science Standards: Grade 3, Physical Science 2-1 & 2-2; Middle School, Physical Science 2-2)

Waves (Next Generation Science Standards: Grade 4, Physical Science, 4-1)

Compare solutions, Combine designs (Next Generation Science Standards: Engineering Design, Grades K-2, 1-3; Grades 3-5, 1-2; Middle School, 1-2, 1-3, & 1-4),

Design criteria & Test variables (Next Generation Science Standards: Grades 3-5, Engineering Design, 1-1 & 1-3)

Science & Engineering Practices (Next Generation Science Standards: Grades 2 – 12)

Additional standards at: <http://www.raft.net/raft-idea?isid=734>

To do and notice (continued)

- 4 Use file folder strips and binder clips to model flexible bracing. Use different methods for each story of the building while leaving the top story unchanged to use as a control. Shake the paint stick until the top story collapses and observe how the other stories fared. Repeat until the top story has collapsed at least once to the left and once to the right, to check how effective the bracing is for both directions.
- 5 Use narrow craft sticks (replacing the file folder strips), to model rigid bracing and repeat the step above.
- 6 Develop and/or explore the common bracing systems of “K”, Knee, “V”, and inverted “V”. See page 1 and the first website under **Resources**.

The science behind the activity

Structures are formed by joining rigid (stiff) beams (such as toothpicks, straws, and craft sticks) into an assembled frame. A square can be made by joining 4 beams together at the ends. Pushing on the sides of a square can easily cause the square to deform as the force is focused on the joints – usually the weakest parts. With a triangular shape a pushing force causes the joints to be pushed together so the force is resisted mainly by the stiffness of the sides of the triangle.

How can rectangular shaped living spaces, with walls having large rectangular window openings, be kept from collapsing? One way is to include angled beams in such a way as to form smaller triangular shapes. These angled braces are added to square outlines in order to resist the potentially collapsing forces due to the wind, a high roof load or earthquakes.

Learn more

- Challenge students to create stable structures, of a given height, using mini marshmallows and toothpicks or spaghetti.
- Additional challenge: require the structure to support a set weight.
- Place completed structures on a shake table and test.

Related activities: See RAFT Idea Sheets:

Foam Faults - <http://www.raft.net/ideas/Foam Faults.pdf>

Motorized Shake Table - <http://www.raft.net/ideas/Motorized Shake Table.pdf>

Shake Table - <http://www.raft.net/ideas/Shake Table.pdf>

Talents of Triangles - <http://www.raft.net/ideas/Talents of Triangles.pdf>

Your Room in an Earthquake - <http://www.raft.net/ideas/Your Room in an Earthquake.pdf>

Resources

Visit www.raft.net/raft-idea?isid=734 for “how-to” video demos & more ideas!

See these websites for more information on the following topics:

- **Extensive information on earthquake effects and bracing** - http://www.ideers.bris.ac.uk/resistant/resist_home.html
- **Math behind bracing** - <http://webshaker.ucsd.edu/homework/Bracing.pdf>