Building Big: Engineering Marvels

# Activity 1: Tug-Push-Twist-O'War

## How tough is this stuff?

Have you ever seen a paper skyscraper? Probably not, because paper is not strong enough to withstand the forces acting on a skyscraper. Hold a "tug-push-twist-o'war" to find out which materials can best withstand different forces.

## What You Need

Three samples each of 6 or 8 materials, such as yarn, popsicle sticks, pipe cleaners, clay, sponges, erasers, rubber bands, paper-towel tubes, pencils, cardboard, aluminum foil, drinking straws, tiles, or cloth

## Make a Prediction

Before you test the materials, predict which ones will be strongest in tension, which in compression, and which in torsion.

## Try It Out

1. First make a table to record your results. You’ll rate each material for each type of stress.



2. Tug: To test the material in tension, pull on it from both ends. Record your rating and any observations in the table.

3. Push: To test the material in compression, push it together from both ends. Record your rating and any observations.

4. Twist: To test the material in torsion, twist the two ends in different directions. Record your rating and any observations.

5. Repeat Steps 2–4 for each material.

### Rating Scale

1 Very weak! It crumples or breaks with hardly any force.

2 Only fair—it can't withstand much force.

3 Pretty good—it takes a lot of force to break it.

4 Super strong! We can't break it.

## Explain It

Which materials were strongest in resisting each type of force? Did any of these results surprise you? Why or why not?

Which materials were strongest across all three tests? How would you describe those materials?

## Build on It

Does shape affect how well a material performs in the Tug-Push-Twist-O'War? Choose a material and design a test to answer this question.

# Activity 2: Straw Shapes

## Which shape is more stable, a triangle or a square?

You'll test the stability of a triangle and a square by standing them on a table and pressing on them. The one that changes shape less is more stable.

##

## What You Will Need

• 7 drinking straws

• 14 paper clips

## Make a Prediction

Predict which shape will be more stable. Why do you think so?

## Try It Out

1. Build a triangle and a square from the straws and paper clips.



To connect two straws, slip the wide end of a paper clip into the end of one straw. Hook a second paper clip to the first. Now insert the wide end of the second clip into a second straw.

2. Compare the stability of the shapes. Stand each shape up and press down on the top corner. What happens? How much does each one bend and twist? How hard can you press down on each shape before it collapses?

## Explain It

Compare the results of your tests on the triangle and square. Which shape was more stable? What do you think made it more stable? How might this shape be used in large structures?

## Build on It

• Can you reinforce the less stable shape by adding no more than 2 straws and 4 paper clips?

• Now that you know more about shapes, build the most stable structure you can using no more than 20 straws and 40 paper clips. How much weight can your structure support?

# Activity 3: Paper Bridge

## Can you build a bridge that holds 100 pennies, using 1 sheet of paper and up to 5 paper clips?

A bridge must support its own weight (the dead load) as well as the weight of anything placed on it, like the pennies (the live load). Your paper bridge must span 20 centimeters (about 8 in.). The sides of your bridge will rest on two books and cannot be taped or attached to the books or the table.

## What You Will Need

• plain paper

• 5 paper clips

• ruler

• 2 books or blocks

• at least 100 pennies or other small weights--if you don’t have pennies, think about what else you might be able to use for weights: Washers? Paper clips? Nuts (like the kind that go on bolts, not the kind you eat)? Note: Different materials will weigh different amounts.

• scissors

##

## Make a Prediction

Describe how you think the bridge should be constructed in order to support its dead load plus the live load of the pennies.

## Try It Out

1. Think about possible ideas with your partner before you start building. What can you do to the paper to make it stronger? When you have decided on a design, construct your bridge.

2. Place the bridge across two supports that are 20 cm apart. Remember that the space below the bridge must be clear to allow boats to pass!

3. To test your bridge, load it with pennies one at a time, until it collapses. Record how many pennies your bridge supported.

## Explain It

Describe how well your bridge supported its dead load and the live load you placed on it. Was the bridge as strong as you thought it would be? Where did it fail?

## Build on It

• Redesign your bridge and test it again, using a new sheet of paper. How does your second attempt compare? How can engineers test their plans for building a full-size bridge?

• Is there a difference in the load your bridge can hold if you put the load in the center of the bridge compared to spreading it out along the bridge? Make a prediction and test it.

# Activity 4: Suspension Bridge

## What's the secret of suspension?

A suspension bridge's cables are beautiful to look at, but they also enable the bridge to cross large spans. Make a model suspension bridge to see how it works.

## What You Need

• 7 drinking straws

• masking tape

• dental floss or thread

• scissors

• 4 large paper clips

• paper cup

• pennies or metal washers

• ruler

## Make a Prediction

After you test the strength of the beam bridge in Step 4, predict how many pennies your suspension bridge will support.

## Try It Out

1. Cut two short pieces of straw, each 3 centimeters (about 1.25 in.) long. For each tower, tape two straws on either side of a short piece of straw, as shown. Tape the long straws together at the top, too.

2. Tape one tower to the edge of a desk or chair. Tape the second tower to a second desk or chair of the same height. Position the towers 17 cm (about 7 in.) apart.

3. Place another straw between the towers so its ends rest on the short pieces. This straw is the bridge deck. Now you have a simple beam bridge.

4. Make a load tester by unbending a large paper clip into a V-shape. Poke the ends of the paper clip into opposite sides of a paper cup, near the rim. Use a second paper clip to hang the load tester over the bridge deck. Record how many pennies the paper cup can hold before the bridge fails.

5. Now change the beam bridge into a suspension bridge. Tie the center of a 100-cm (about 4 ft.) cable around the middle of a new straw. Place the straw between the towers. Pass each end of the cable over a tower and down the other side.



6. To anchor the bridge, wrap each end of the cable around a paper clip. Slide the paper clips away from the tower until the cable pulls tight. Then tape the paper clips firmly to the desks. Test it again.

## Explain It

Can you identify the forces acting on the loaded suspension bridge? Which parts of the bridge are in compression? Which parts are in tension?

## Build on It

Can you design and build a straw suspension bridge that spans a gap twice as wide and supports the same amount of weight? What parts of the bridge design need to change? Try it.

# Activity 5: Newspaper Tower

## What's the tallest tower you can build using only two sheets of newspaper?

Here's the challenge: getting the newspaper to stand up, without using tape, staples, glue, or other materials. But you can bend, fold, or tear the paper itself.

## What You Need

• 2 sheets of newspaper

• ruler

## Make a Prediction

Make a prediction about how tall a tower you can build. What is your prediction based on?

## Try It Out

1. Now construct your tower. If you think you can make it taller, keep redesigning it until you can't go any higher.

2. When you are finished building, measure the height of your tower.

## Explain It

• How did your result compare to your prediction?

Give possible reasons for any difference. What limited the height of your tower?

• If you could use one other material to make your tower taller, what would it be? Why?

## Build on It

• How much taller can you make the tower if you can add 20 centimeters (about 8 in.) of tape? (You can't tape the tower to the table.) How tall can you make the tower and have it support the weight of a pack of chewing gum?

• How well does your tower withstand environmental forces? Use a fan to imitate wind gusts or shake the table gently to imitate an earthquake. How can you change your design, using 2 sheets of newspaper and 20 cm of tape, to better withstand these forces?

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