# STRAW BRIDGES

## AT A GLANCE

Students work in engineering teams to design, build and test model bridges as they determine how shapes affect the strength of structures.

**OBJECTIVES**

Students will:

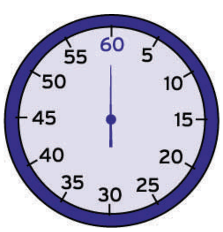
- Plan, design, build and test a model truss bridge.
- Identify effective geometric shapes used in bridge design.
- Identify several factors that engineers consider when designing bridges.

**KEY VOCABULARY**
Beam, beam bridge, bridge, dead load, deck, engineer, live load, loads, span, truss.

**SUGGESTED GRADE LEVELS:** 4—8

**ILLINOIS STATE LEARNING GOALS**
7: A, B, C; 11:A, B

**PACE YOURSELF**
60 MINUTES

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## ADVANCE PREPARATION

1. (Optional) If doing the Warm Up as a demonstration rather than a whole group activity, construct straw model shapes as pictured in the Warm Up section..
2. (Optional) Post the requirements for students' bridges.

## MATERIALS

**Per Group:**
20 plastic, non-bendy straws (29 if doing the Warm Up as a whole group activity)
Roll of clear tape
Scissors
Meter stick (or one for the class to share)

**Per Class:**
Small paper cup
200 to 300 pennies (to use as weight)
Two tables
(Optional) Balance (for weighing; or, count the pennies instead of weighing)

## WHAT YOU NEED TO KNOW

A **bridge** is a structure that **spans** a gorge, valley, road, railroad track, body of water, or any other physical obstacle, for the purpose of providing passage over the obstacle.

There are many types of bridges: beam, truss, arch, suspension and cable stayed. A **truss bridge** is a bridge that uses trusses, or a series of triangles, for support.

Truss bridge construction developed rapidly during the Industrial Revolution; they were first made of wood, then of iron and finally steel. During this time, different truss patterns also made great advances. The Howe Truss, one of the more popular designs, was patented by William Howe in 1840. His innovation was using vertical supports in addition to diagonal supports. The combination of diagonal and vertical members created impressive strength over long spans; this made the truss design ideal for railroad bridges.

Engineers must consider **loads** when building structures. Loads are weights and forces that a structure must withstand. The **dead load** of a structure is the weight of the structure itself. The dead load of a bridge, for example, includes beams, cables, and the deck. The **live**

**load** of a structure is the weight that is added to the structure, including people, cars, and wind.

Helpful vocabulary words and definitions:

**Beam** A long, rigid, horizontal support member of a structure.

**Beam bridge** A bridge that consists of beams supported by columns (piers, towers).

**Deck** The "top" of the bridge on which we drive or walk.

**Engineer** A person who applies her/his understanding of science and mathematics to create things for the benefit of humanity and our world.

**Span** The distance a bridge extends between supports.

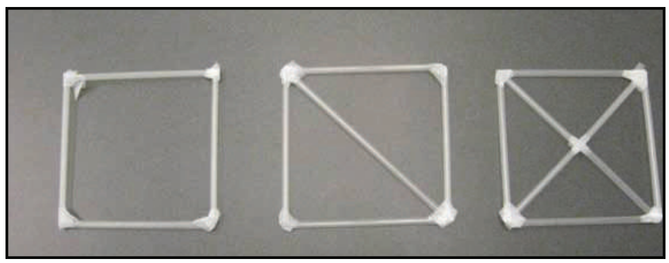
**Truss** A structural frame based on the geometric rigidity of the triangle and composed of straight members.

## WARM UP

This may be done as a demonstration or a whole group activity. Ask students, "Which shape is more stable, a triangle or a square?"

### As a Demonstration

1. Show students that squares are less stable than triangles by showing the example straw shapes made in advance as pictured at right.



2. Stand the shapes up on a desk and push down on the top of them. With very little force applied, the open square shape twists while the square shape composed of inner triangles withstands much more force.
3. Discuss with students that this is the reason triangles are used in structures such as bridges.

### As a Whole Group Activity

1. Divide students into teams of two. Give each group nine straws, scissors and tape.
2. Tell the students to construct two squares. In one of the squares place a diagonal piece, creating two inner triangles (like the middle square pictured above).
3. Have the students stand the shapes up on a desk and push down on the top of them. With very little force applied, the open square shape twists while the square with the inner triangles withstands much more force.
4. Discuss with students that this is the reason triangles are used in structures such as bridges.

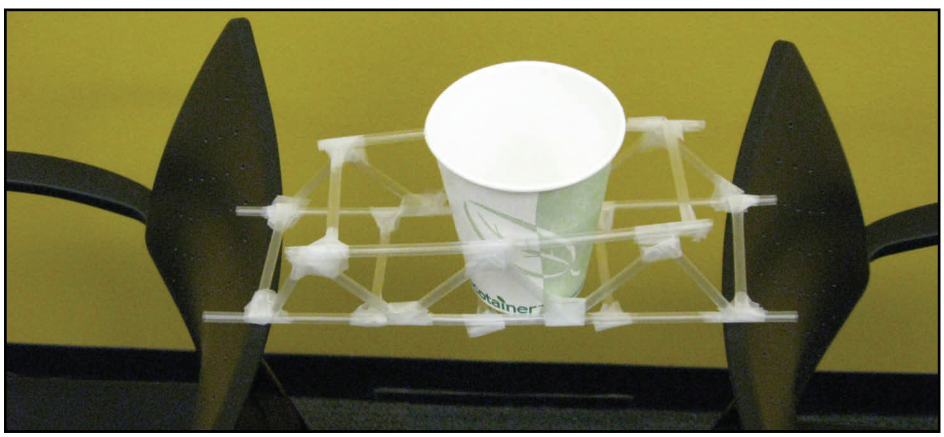
## ACTIVITY

1. Tell the students that for this activity they are engineers who have been hired to create a bridge that crosses a local river. Your bridge must meet these requirements:
    - The bridge must span 25 cm across two tables or chairs. It cannot be attached to the support structures in any way, so you may want to make your bridge slightly longer than 25 cm.
    - You will have limited supplies of clear tape and 20 straws. You can cut your straws to any length, but you will not be given any additional straws.
    - The bridge must support as much weight as possible. To simulate the load, your bridge must

securely hold a small cup. You will then place pennies into the cup and count how many your bridge can hold.

- Your bridge cannot disturb the river's fish population below, so your bridge cannot bend down more than 9 cm as pennies are being placed on it. This will be measured by placing a meter stick next to your bridge vertically as you place pennies on it.

2. Have students think critically bout the design of their bridge and start sketching a blueprint. Make sure they have enough time to brainstorm ideas, draw sketches, and make plans and calculations.
3. Give each team 20 straws, clear tape, and scissors. They are not allowed any extra supplies.
4. Have students build their bridge (allow about 20 to 30 minutes).
5. When they are finished, have each group predict how many pennies they think their bridge can hold. Record their predictions on the board.
6. Begin testing the bridges by placing a bridge on two tables or chairs that are 25 cm apart.
7. Position a small paper cup on the center of the bridge. Place a meter stick next to the bridge vertically, and use it to measure the bridge's height.



8. Gradually fill the cup with pennies until the bridge either collapses or bends down 9 cm (where the "water" would be).
9. Record the number of pennies each bridge was able to hold next to their hypothesis.
10. (Optional) Have students weigh the cup and the pennies on the balance and record the actual load next to their hypothesis.

**TIP**

Post the following criteria for students so that they can refer to it as they are designing and constructing their model bridge.

**Bridges must meet the following criteria:**

- It must span at least 25 cm.
- It must have a place in the center of the span that can securely hold a small paper cup.
- No part of the bridge may touch the "water" by dipping down 9 cm.
- The bridge cannot be taped to the support structure.
- Materials are limited. You can cut your straws to any length, but you will not be given any additional (or replacement) straws.

## WHAT'S HAPPENING?

Triangles are structurally the strongest shape because they allow weight to be evenly spread throughout a structure, allowing it to support heavy loads. Truss patterns are used in structures other than bridges when strength is a priority, such as on roofs, floors, ceilings, radio towers, crane arms, bicycle frames, and many other places.

## CHECK IN

Have students answer the following questions in their teams or as a whole group discussion.

1. Did your bridge meet all of the minimum requirements today?
2. If you had more time to make another bridge or change yours, would you do anything differently? If yes, what?
3. What part of today's activity was the most challenging for your group? Why? (Answers will vary.)
4. Can you think of any other places where you have seen truss patterns used for strength? (Refer to the What's Happening? section for possible answers).
5. What are two things engineers must consider when designing and building bridges? Possible answers: building materials, span, load requirements, budget, aesthetics, function.
6. Would you consider a career as an engineer? Why or why not? What do you think you would have to study in school? (Answers: math, science.)

**Deflection** is the distance a bridge bends down when a load is placed on it. In real bridges, deflection is normal as long as the bridge returns to its original position when the load is removed.

## DIFFERENTIATED INSTRUCTION

- For lower grades, allow students to include intermediate supports in the "water."
- For older or more advanced students, have them design and build a straw bridge that spans a distance of 50 cm using the same amount of material with no intermediate supports in the "water."

*Lesson adapted from Integrated Teaching and Learning Program, College of Engineering, University of Colorado at Boulder*