ALL ABOUT BRIDGES!

Application of Architectural Concepts

Age Level:

Third grade and up

Subjects:

Science
Engineering Design
Math
Art

Time:

Activity 1: 30 minutes

Activity 2: 30 to 45 minutes

Activity 3: 60 to 90 minutes

(If you decide to do all 3 activities, you will need to plan them over more than one session)

Materials:

- 20-30 plastic straws (straight straws, not the bendy straws) per team of 2 students
- More straws if you want each student to make their own squares in Activity 2
- Scissors
- Scotch Tape
- Rulers or yardsticks
- Plastic cup for the class to share
- Pennies, 200-300

Learning Objectives:

- Define a simple design problem reflecting a need or a want that includes a specified criteria for success and constraints on materials, time or cost.
- Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- Plan and carry out fair test in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

Design Professional:

Check with the teacher to confirm if the class has already had some conversation about the idea of compression and tension ahead of time. If that hasn't happened, you will want to present Activity 1 first or present the lesson "How it Feels to be a Structure" from Section 4 in this guide. Review compression and tension and the importance it plays in the design and reliability of bridges. You may want to have students look for examples of compression and tension around the classroom.

Examples of elements under compression: walls, vertical sides of doors or window frame, columns.

Examples of elements under tension: cables or strings hanging from the ceiling with an object attached to it, such as a map, poster, or screen. Arches and triangular structures are in both tension and compression.

Today's activity will be building a truss bridge, but still discuss with students the need for different styles of bridges - arch, suspension, and/or drawbridges. Discuss what engineers and designers have to consider when building a bridge, and what constraints may be placed upon the engineer and designer.

Engineers need to perform careful analysis of bridge geometries and the anticipated applied loads. They also need to consider the most effective materials to achieve a balance of tension and compression. Engineers determine the bridge type, design and materials; analyze site conditions, geologic and environmental factors; and establish detailed design plans and budget/funding schedules.

Bridges aren't just there to cover a gap. Bridge designers and engineers also need to think about the way they connect communities. The way bridges touch the ground on each side might be different because community A and community B might need different designs. One side of the bridge might land in an urban area and one side might be agricultural, for instance. Discuss with students what they think happens when communities don't have bridges. As an example, is it easier for each community on different sides of a body of water to evolve into different cultures? The built environment and how bridges are designed affect how we live, think and feel about a place.

Teacher:

Before beginning the bridge activities, it might be helpful to generally discuss concepts of compression and tension. Other lessons from the curriculum guide can be presented early in the residency or as a class before the design professional comes for a session, such as "What Makes Structures Stand Up?" and "How it Feels to be a Structure" both from Section 4 in this guide. Community focused lessons such as "Let's Get Out and See the World" and "What Will Cities Look Like in 25 Years?" could also be helpful.

Rationale:

Designing structures, including bridges, allows students to consider various ways to problem solve. In grades 3-5, students should be able to be more systematic and creative in their engineering design process. The design process can be thought of in three phases: Defining a problem, developing possible solutions, and improving designs.

Students are given criteria and constraints, which allow students to plan for the specific function of their design as well as the limitations of their supplies in building their specified design. They need to develop some alternative solutions and compare them to see which meets the criteria and constraints most successfully. Improving designs comes through the testing phase where students have built a model or prototype, subjected it to a test until it "fails". Then, if time students can rework their model and try again, or learn from successes of other models whose failure rates were later in the testing phase.

Presenting the Activity:

Suggested Dialogue...

> *"Over, under, or straight through the middle? It's a simple-sounding question, but it's challenged every great engineer since ancient times. We like highways and railroads to be straight and level, but Earth's bumps and wiggles make that kind of construction an amazing challenge. How do you take a highway through a valley or make a railroad cross a creek? The simplest answer is to use a bridge. Sounds easy, perhaps, but which type of bridge do you use? Why are there so many different types and how do they all work?*
>
> *"Let's take a closer look and find out more!*
>
> *"Forces make things move, but they also hold them still. It's far from obvious, but when something like a skyscraper looms high above us or a bridge stretches out beneath our feet, hidden forces are hard at work: a bridge goes nowhere because all the forces acting on it are perfectly in balance. Bridge designers, in short, are force balancers."*

Activity One:

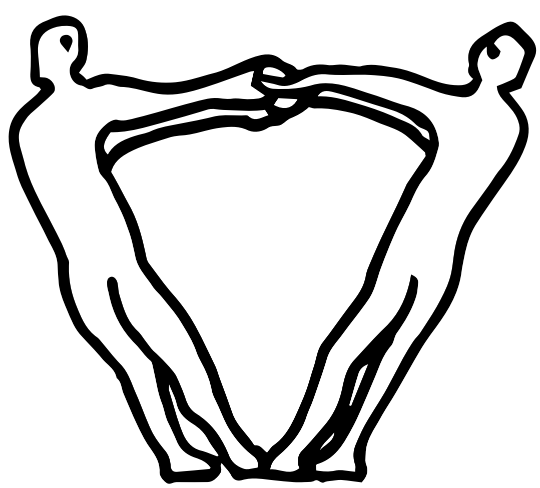
Define and demonstrate forces, compression and tension.

A. Part One (10 minutes)

Explain that a force is a push or pull on an object. When an object is at rest (not moving), the forces acting on it are balanced. Explain to students that compression is the act of being pushed or pressed together. Have students get a partner and stand facing each other (you can also do a group of three if you have an odd number of students). Students put their arms straight out towards each other with palms facing their partner.

Have students push against each others' palms. This pushing force is an example of compression.

Explain that tension is the act of being stretched or pulled apart. Still working with a partner, have students change their hands to carefully grasp each other's wrists. Pull back from each other. This pulling force is an example of tension.

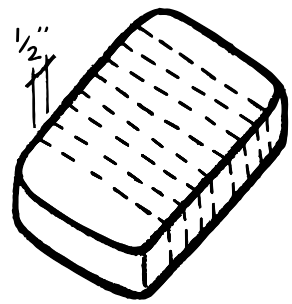


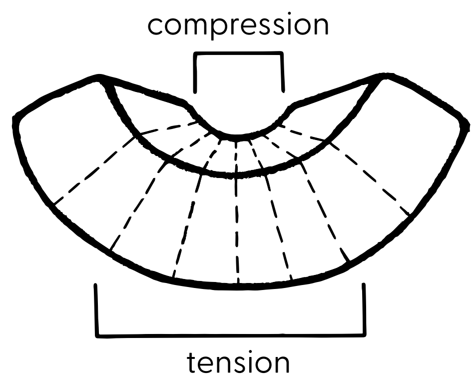
A. Part Two (20 minutes)

Ahead of time, get a large soft kitchen sponge (new sponges work best for this activity because they are flexible) and draw a series of lines approximately 1/2 inch apart crosswise around the sponge.

Next, pass the sponge around the class and have the students take turns bending the sponge into a U-shape and observe what happens to the lines. Let them describe what they observe. The lines inside the U-shape get closer together, while the lines outside the U-shape spread farther apart.

Ask which side of the sponge is in compression. Answer: The inside of the U-shape. Where is the sponge in tension? Answer: the outside of the U-shape. How could students balance out the forces of compression and tension acting on the sponge to make it stronger so it wouldn't bend so much (because we wouldn't want a bridge to bend like this)? Answer: Some ideas include using a stiffer material for the beam, or adding supports, such as knitting needles or pencils, to the sponge.





Activity Two:

Demonstrate how squares are less stable structures under pressure than triangles (30-45 minutes depending on if students make their own shapes with straws).

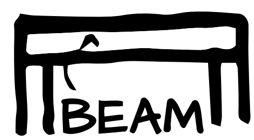
Ahead of time tape together a square made out of straws. Next, make two more squares made of straws: one with a diagonal straw through the middle so the square is divided into two triangles, the last square needs an X made in the middle, so that there are four smaller triangles. You will use these shapes in the demonstration. If you have time, you can have students make their own and test them. If you have students make them, you will need to make sure to have enough supplies.

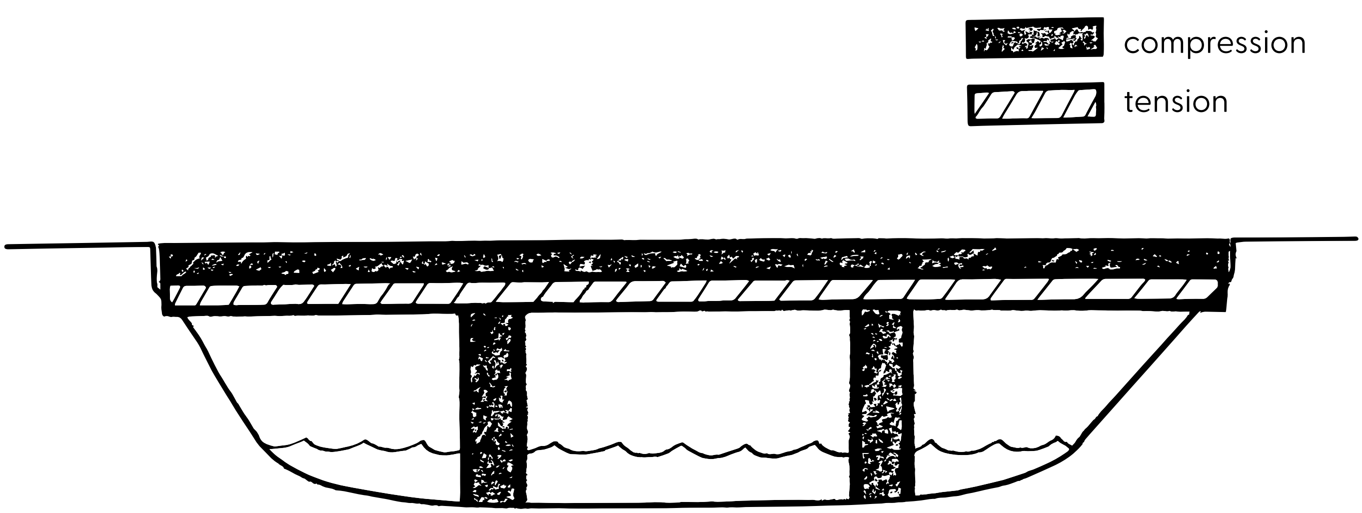
Ask students to vote by a show of hands to the following question, *"Which shape is more stable, triangles or squares?"* Tally their responses and write the totals on the board. Explain with visual demonstrations that squares are less stable than triangles. Stand the shapes up on a desk and push down 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.

Explain the following 3 basic types of bridges. If you want, you can show some examples of bridges from your area in Oregon or famous bridges throughout the world. See "Suggestions for further exploration" at the end of this lesson for resources.

1. Beam bridges are the most common type of bridges.

A beam is the simplest (and often cheapest) kind of bridge: a deck, spanning a relatively short distance, held up by a pair of abutments (the vertical supports at either end).





Beam Bridge

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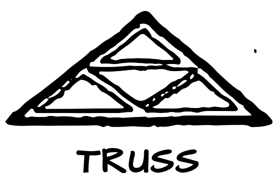
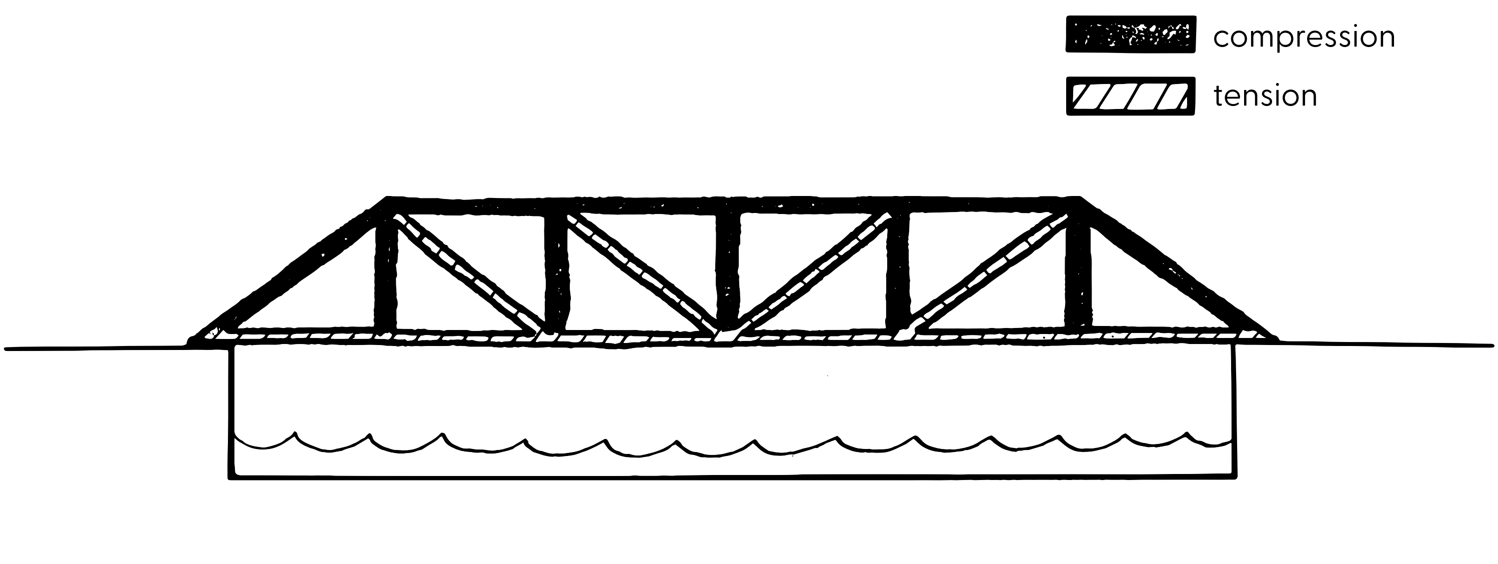
2. Truss bridges distribute forces differently than other beam bridges and are often used for heavy car and railroad traffic.

In a truss bridge, the beams are substituted by simple trusses, or triangular units, that use fewer materials and are simple to build. There are many ways of arranging trusses to support a bridge, giving a variety of intricate and often attractive lattice patterns.



3. If you need a bridge that spans even further, a Suspension bridge is really your only option. The genius of a suspension bridge lies in using very tall piers with huge, curving main cables strung between them. Dozens of thinner vertical suspension cables of varying length hang down from the main cables and support the immense weight of the deck and the loads it carries. Although people always notice the cables in a suspension bridge, they often fail to spot the girders and trusses reinforcing the deck underneath. This is a subtle and quite important point: most bridges are actually composites of two or more of the basic bridge types.



Truss Bridge

Activity Three:

The design professional and teacher will need to have students divided up into groups of 2 prior to doing this activity. Also before beginning, materials need to be divided equally among groups so students can follow instruction without waiting for materials. The design professional should lead the class through each step below.

Presenting the Activity:

Suggested Dialogue...

> *"Today you are going to be bridge engineers. Your design objective is to make a bridge that spans the river of 10 inches between two desks or chairs and can support the most weight. Your bridge must be strong enough to hold the most pennies in a cup, and cannot be held up by any other structure beneath it.*
>
> *"Your team's constraints are:*
>
> *"Materials: You should use only 20 straws to build your bridge. If you use more, that is considered going over cost for your materials budget. You will also be given paper clips, floss and a cup for the pennies.*
>
> *"Time: You have 35 minutes to complete your bridge. Failure to finish your project on time will mean you will lose money for your project.*
>
> *"Size: Your bridge needs to span 10 inches between two desks or chairs, while still being able to hold the largest weight load. It must be laid on two desks and cannot be taped to the desks for support. So you will want to consider how long to make your bridge so that it can cover the 10 inch span and still have room to lay on top of the two desks."*

After the time is up for building bridges, then the class begins the testing of the bridges. Each student places their bridge on two desks measured 10 inches apart. The cup is placed in the center of the bridge, and then pennies are counted into the cup. Counting stops when the bridge shows signs of failure. The team with the most pennies are the winners.

1. Cut two short pieces of straw, each 3 centimeters long. To make a tower, tape two long straws on either side of a short piece of straw. Tape the long straws together at the top, too. Repeat this to make 2 towers.
2. Tape one tower to the edge of a chair. Tape the second tower to a second chair that's the same height. Position the desks or chairs so the towers are 10 inches apart.
3. Put another straw between the towers so its ends rest on the short middle pieces. This is the bridge deck. Now you have a beam bridge.
4. Make a load tester. Unbend a large paper clip into a V-shape. Poke the ends of the paper clip into the holes on the sides/of your cup. Use another paper clip to hang the load tester on the bridge deck.
5. Make a hypothesis: How many pennies do you think your cup will hold before your bridge breaks? Write your guess down.
6. Test your load! Put pennies in the cup until your bridge fails. How many pennies did your bridge hold?
7. Turn your beam bridge into a suspension bridge. Take away the old bent straw and tie the center of your floss around the middle of new straw. Place the straw between the towers. Pass each end of floss over a tower and down the other side.
8. Anchor your bridge. Tie or tightly wrap or each end of floss around a paper clip. Slide the clips out until the floss pulls tight. Tape the paper clips firmly to the desk or chair.
9. Hypothesis #2: How many pennies do you think your new bridge will support?
10. Test it again. Add the pennies. How many did it hold?

Closure:

Take time after the activity is over to discuss with students how they felt about building the bridge. What was successful for them? What wasn't successful? Was it more difficult to build the bridge or easier than expected? What might they do differently if there were to do it again? What was some new learning they took away from the activity? How can they apply what they learned to other subject areas or projects?

Suggestions for Further Exploration:

There are many ways to build bridges using different materials. If you want to explore further, you can have students look at arch bridges and suspension bridges and use different materials to create those bridges and have the same weight load test.

Some classes create models of bridges as their final AiS residency projects. For a final project, you can have students design their own bridges either in groups or individually depending on class capability. Use varying materials such as balsa wood, cardboard, foamcore, chenille stems, popsicle sticks, recycled materials that students bring from home, string, rolled paper and paint, string, metal brads, etc.

Students can add their own touches with toy cars, miniature figures, plant materials. When designing their bridge, make sure that students are still thinking about load (referencing preliminary activity), styles of bridges and what their particular bridge would be used for in their community.

Allow each group time in class to research bridge engineering. They should find out the basic principles of the three main kinds of bridges: suspension, beam, and truss. Start the design process by brainstorming design ideas as a class, allowing students time to make sketches and choosing a final design for their bridge. Students can name their bridge and write a paragraph or two about why they designed it the way they did and what significance the bridge has in its community.

If final project bridges were designed and built in groups, take pictures to document bridges before or after the exhibit and then have a contest to see which bridge can hold the most load before it is demolished. That way you also avoid disagreements about who gets to bring it home.

For examples of bridge final projects other classes have done in the Architects in Schools program, go to our website at: www.af-oregon.org/architects-in-schools/

Discussion Questions:

1. *Suppose all the bridges in a city were closed. What effect would that have on that city? What are some specific ways that people would adapt to not using bridges?*
2. *Discuss how each of the three basic types of bridges—suspension, beam, and arch—transfers loads from the bridge to the ground. Describe where tension and compression occur on each type of bridge.*
3. *Many bridges are icons for their city or region. Why do you think people associate certain bridges with certain cities, while other bridges seem unremarkable?*
4. *Compare and contrast a beam bridge and an arch bridge. List at least three ways they are similar and three ways they are different.*

Resources:

Wortman, Sharon W. (2014). The Big & Awesome Bridges of Portland and Vancouver: A Book for Young Readers and Their Teachers, A Project of PDX Bridge Festival, Inc., in Cooperation with Portland Public Schools

Kaner, Etta. (1994). Bridges. Toronto: Kids Can Press.

Simon, Seymour. (2005). Bridges. San Francisco, CA: Chronicle.

Canizares, Susan, and Daniel Moreton. (1999). Bridges. New York: Scholastic.

Briscoe, Diana. (2005). Bridge Building: Bridge Designs and How They Work. Bloomington, MN: Red Brick Learning.

Sturges, Philemon. (1998). Bridges Are to Cross. New York: G.P. Putnam's Sons.

Furgang, Kathy. (2004). Building Bridges: Explore five kinds of bridges: how they are build, how they work, and more! Pelham, NY: Benckmark Education.

Hurley, Michael. (2012). The World's Most Amazing Bridges. Chicago, IL: Raintree.

Web Resources:

City of Portland Walking Tour: takes students over two of the bridges and to a place where all the bridges can be seen on a clear day. https://www.portland.gov/parks/environmental-education/field-trips

Teachers Guide: Bridges. http://www.kidsdiscover.com/free-lesson-plans/tg-bridges/

24 of the World's Most Amazing Bridges. www.cnn.com/travel/article/most-amazing-bridges/index.html

Bridge Basics. www.pbs.org/wgbh/buildingbig/bridge/

How Bridges Work. http://science.howstuffworks.com/engineering/civil/bridge.htm

Engineering a Bridge. https://thekidshouldseethis.com/post/spaghetti-bridges-engineering-challenge-activities-for-kids

Famous Bridges Around the World. www.touropia.com/most-famous-bridges-in-the-world/

Galloping Gertie, The Tacoma Narrows Bridge. https://wsdot.wa.gov/tnbhistory/bridges-failure.htm

Tacoma Narrows Bridge Collapse "Gallopin' Gertie." www.youtube.com/watch?v=j-zczJXSxnw

Teach Enginnering K-12, a source of background information for this lesson. www.teachengineering.org/

National Building Museum. www.nbm.org/learn/schools-teachers/

Oregon Covered Bridges. www.oregon.com/attractions/covered-bridges