STEM FOR STUDENTS
DRIVE IT HOME

STEM in TRANSPORTATION

Lesson 3: **Bridges**

Grade Level: 4-10

Virginia Department of Transportation

Bridges

Background Knowledge

There are over 21,000 bridges in Virginia. Some span small creeks, wet lands, or ravines, and others cross massive bodies of water to connect areas that you would otherwise have to travel much further or via boat to reach. These incredible structures use the laws of physics, geology, and chemistry in the best ways possible to make strong structures that we have come to rely on and take for granted in our daily commutes.

In this lesson, students will explore bridge types, basic bridge structural concepts, loads & forces, and design their own bridges.

STANDARDS OF LEARNING
PH.1, PS.1

Objective

Students will:

- Investigate bridge/structural design terms
- Utilize common objects to investigate techniques for strengthening structures

Materials

- 2 pieces of paper
- 2 books
- Balsa wood, flexible plastic rulers, other flexible "beams"
- Toothpicks
- Candy gumdrops

Time: 60 90 minutes

Activity 1: Introduce Bridges

Start by showing the Bridges PowerPoint slides. This presentation introduces types of bridges, forces to consider when designing bridges, and some structural concepts of bridge designs. Activities 2 -4 are included near the end of the presentation.

Activity 2: Investigating triangle strength

1. Have students set up an 8 – 9" span between two books.
2. Place one sheet of paper such that it is supported by the 2 books on each end. Notice how the paper bends in this instance.
3. Now take the 2nd sheet of paper and fold it in a fan manner with at least 4 back and forth folds.
4. Place the fan folder paper between the two books in the same orientation as the first sheet of paper. Notice how the paper reacts in this instance.

Note: Folding the paper in a zig zag manner will create strength in the length of the paper. It should not sag like the unfolded sheet of paper did. See Figure 1.

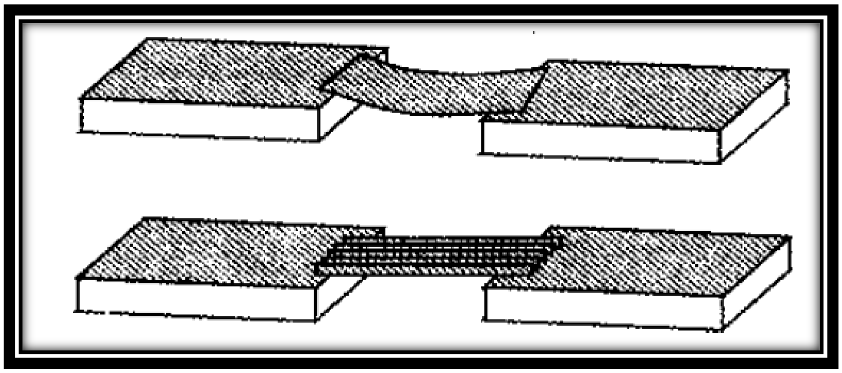


Figure 1

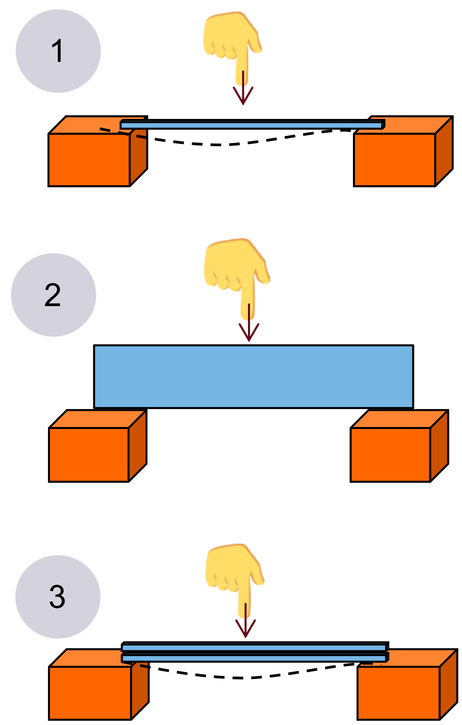
Activity 3: Investigate lamination

Materials:

- 2 plastic rulers, popsicle sticks, or similar flexible "beams"
- 2 books

Directions:

1. Suspend one beam between the ends of two books so that the larger flat surface of the beam is facing up. Apply light pressure to the middle of the beam. Notice the deflection (bending) of the beam.
2. Turn the beam 90 degrees so that the larger flat surface is pointing left or right, not up or down. Apply the same amount of light pressure to the middle of the beam. Notice how the beam deflects in this orientation.
3. Now stack two beams directly on top of one another lying flat, not standing up. Apply the same amount of light pressure to the middle of the two beams together and notice the amount of deflection.



Questions

1. *Which orientation of the beam allowed it to resist deflection better?*
2. *How can you apply what you've learned to bridge designs?*

Activity 4: Toothpick Bridge Building & Testing

Materials:

- Box of flat or round toothpicks
- Gumdrop candies
- Plastic container or box
- Items to make a gap or span for student bridges to cross (2 books or tables)
- Weighted objects for testing (toy cars, pennies, flat marbles, etc.)

* For older students, you may want to challenge them by requiring detailed 2D or 3D designs of their bridges and have them construct bridges out of balsa wood or popsicle sticks and glue. Building with glue and wood will take several days as the sides have to dry before connecting them.

Directions:

1. Have students sketch the side view of a bridge design on graph paper that can span the pre-determined gap you have created.
2. Give students toothpicks & gumdrops and have them construct their bridge structure.
3. Students can then test their structures by placing the container or box on their bridge and adding weights to the container.
4. Have students make observation about how their bridges and those of their classmates reacted to the weight being placed on it.
5. If time allows, have students try to strengthen their bridges by making modifications and retesting to see if their design changes resulted in a more stable structure.

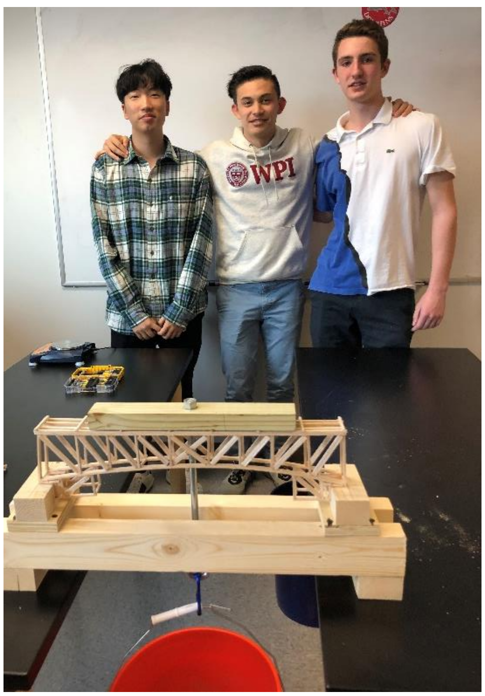
Extensions

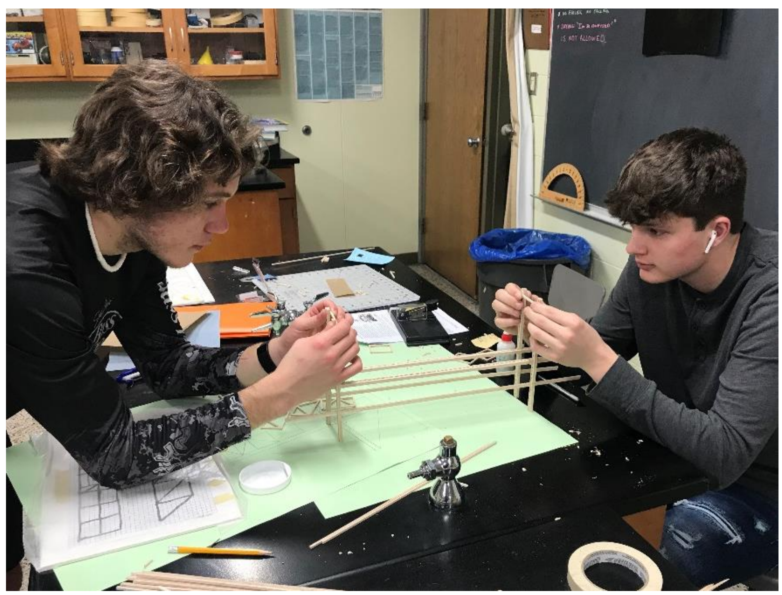
Have students investigate more complex types of bridges (suspension, cable-stayed, arch) and explain why different types of bridges would be used and in what situations.

You can have students visit http://www.pbs.org/wgbh/buildingbig/bridge/basics.html and complete the worksheet on pages 8 -9 for the labs about Forces, Materials, Loads, & Shapes. *Adobe Flash Player is required for the labs.*

Older students can create bridges using more challenging materials such as popsicle sticks or balsa wood. Drawings could include labeling members to show compression and tension forces.

Additional activities that allow for investigation of the mathematical relationships between bridge material length, width, and deflection can be found HERE.





Terminology

Abutment: A substructure composed of stone, concrete, brick or timber supporting the ends of a single span bridge or the extreme ends of a multi-span bridge.

Beam/Girder: That part of the superstructure which is subjected to bending forces along the span. It is the load-bearing member which supports the deck.

Bearing: A component which transfers loads from the girders to the piers while permitting angular and/or linear movement between parts.

Span: The distance between points of support (piers, abutment).

Tension: Outward force acting on an object that tends to pull the object apart or elongate it.

Compression: Forces acting on an object that squeezes materials together.

Live load: Are usually variable and moving loads (people, vehicles, wind)

Dead load: Static forces that are relatively constant (weight of the bridge, light poles, traffic signs/signals)

Deck: The bridge floor that directly carries traffic loads.

Cofferdam: An open box-like structure surrounding the area where an abutment, pier, retaining wall, or other structure will be placed. Water is removed from the enclosure so the 5 excavation for preparing a foundation and the abutment, pier, or other construction may be done in the open air.

Pier: A structure composed of stone, concrete, brick, steel, or wood that supports the ends of intermediate superstructure spans and which transfers loads on the superstructure to the foundations. Piers are compression members.

Pile: A rod or shaft-like linear member of timber, steel, concrete, or composite materials driven into the earth to carry structure loads through weak soil strata to soil strata capable of supporting such loads.

Substructure: that part of the structure below the superstructure, such as piers and abutments, which transfers the structural load to the foundations.

Superstructure: The structure of a bridge above the piers (could include the deck, slab, girders, etc.).

Truss: A truss is an assembly of beams that creates a rigid structure. In engineering, a truss is a structure that "consists of two-force members only". A "two-force member" is a structural component where force is applied to only two points and where those forces are equal in magnitude, acting along the same line, and in opposite directions. Reference: Wikipedia · Text under CC-BY-SA license

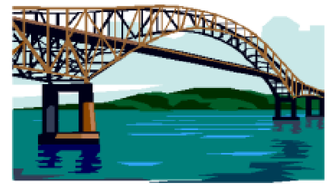
Extension

A full list of technical terms can be found here: GLOSSARY OF BRIDGE TERMS.doc (uscg.mil)

Careers to Explore

- Civil Engineer
- Bridge maintenance crew
- Bridge inspector

Bridges



tension
cost
compression
suspension
infrastucture
triangle
weight
load
arch
truss

Across

4. A structural frame such as in a bridge or A-line roof.
6. A shape often used in bridge design to help distribute forces in different directions.
8. Bridges must be able to support loads and the ______________ of the bridge itself.
9. Type of bridge that uses steel cables as part of its structure.

Down

1. Bridges are a vital part of our transportation ______________________.
2. In addition to supporting load requirements, you must also consider this in your bridge design.
3. When forces acting on a bridge member are pushing in toward one another.
4. When forces acting on a bridge member are pulling away from each other.
5. A type of bridge that utilizes rounded curves in its design.
7. The live ________ that the bridge must support includes the weight of people or vehicles that use the bridge.

Building Bridges

Go to:

http://www.pbs.org/wgbh/buildingbig/lab/forces.html

Complete the Forces, Load, Materials, and Shapes labs.

Answer the questions below for each lab.

FORCES:

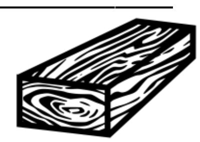
1. ____________________ is the force that squeezes a material together.
2. ____________________ is the force that stretches a material apart.
3. ____________________ is the action when a straight material becomes curved. One side is compressed and the other is stretched.
4. ____________________ is the force that causes parts of a material to slide past one another in opposite directions.
5. ___________________ is an action that twists a material.

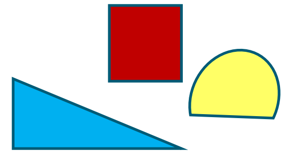
LOADS:

1. Forces that act on structures are called ______________.
2. The weight of the structure itself is called the _____________ ______________. It includes ________________, ________________, and ____________________.
3. The weight of the stuff on the structure is called the _______________ _________________. It includes _____________________ or _____________________.
4. Other loads that can affect a structure include ________________ _____________, __________________ _________________, ___________________ ________________.

MATERIALS:

1. Which materials cost the most? ________________________ & ___________________________
2. Which material weighs the least? _________________________________





SHAPES:

1. The shape of a structure affects how ________________ it is.
2. Three common shapes used in structures are ________________, ________________, and ______________________.
3. You can use a ________________ to strengthen a rectangle.
4. Draw a picture and label how you can strengthen an arc.

5. What is the weakest part of a triangle? ____

http://www.pbs.org/wgbh/buildingbig/bridge/

Complete the Bridge Challenge:

References

The five major parts of Bridges - Concrete Span Bridge | CivilDigital |