Bridge Physics

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Introduction

Milwaukee is home to many different bridges which help us get to and from places both in and out of the city. Examine how forces, geometry, and materials play a part of bridge design.

Think About This

- Why are there different bridge designs?
- How can you design a successful bridge?

Materials

- ☐ Paper (8.5" x 11")
- ☐ Tape
- ☐ Ruler
- ☐ Pen or Pencil
- ☐ Something to use as weights, such as
  - Coins
  - Paperclips
  - Rubber Bands
  - Candies
  - Small Batteries
- ☐ Heavy objects for a testing base
  - Stacked Books
  - Cups or Mugs (turned upside down)
  - Full Toilet Paper Rolls

Do Ahead of Time

- Create a testing base for the bridges to span. This will act like the land the bridges will connect. A bridge needs two bases, one for each side.
  - Each base should be the same height or very close.
  - Place the edge of the bases 9 inches apart.
  - The material shouldn't bend or move if weight is placed on the top or the edge.

Directions

Each bridge must be designed in a specific way. Build and test multiple bridges in this design activity to find out how much weight can each bridge can hold.

Simple Bridge

1. Lay a single sheet of paper across the gap between the two testing bases.
   - **a.** Make sure the paper will stay up without holding it or using tape
   - **b.** Avoid adding creases and folds to the paper.
2. Slowly and carefully place weights at the center of the bridge until the bridge falls.
   - **a.** Place the weights closely and carefully. Avoid dropping the weights from a too high.
3. Record the number and type of weights the bridge held (see the measurement section below).
4. Repeat steps 2 and 3 at least 3 times for this bridge.

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Measurement 1 – Simple Bridge:

Test (Number):	1	2	3	Example
Weight Held				2 Quarters
(Amount x Type):				8 Pennies

Observations - Simple Bridge

How did the bridge react to the weight?

Beam Bridge

Changing the shape of part of a bridge may help the bridge hold more weight. This can be done by adding folds or creases.

1. Using a piece of paper, fold the edge of the long side of the paper over about one inch.
2. Flip the paper over.
3. Take the edge that has just been folded and fold it over the same distance.
4. Flip the paper over.
5. Repeat steps 4 and 5 until the paper has been folded like an accordion on its long edge.
6. Crease and press all folds several times. Open up the paper slightly, until it is about 4-5 inches wide.
7. Lay this new bridge across the gap between the two testing bases.
8. Slowly and carefully place weights at the center of the bridge until the bridge falls.
9. Record the number and type of weights the bridge held (see the measurement section below).
10. Repeat steps 2 and 3 at least 3 times for this bridge.

Measurement 2 – Beam Bridge:

Test (Number):	1	2	3	Example
Weight Held				2 Quarters
(Amount x Type):				8 Pennies

Observations - Beam Bridge

How much weight did the beam bridge hold? Was it more or less than the simple bridge?

Arch Bridge

Changing the shape of a bridge may help the bridge hold more weight. Test an arch bridge to see how much weight it can hold.

1. Move the bases slightly closer together.
2. Place the short edges of a piece of paper where the bases meet the surface they are resting on. The paper should form into an arch shape.
3. Move one of the bases until the top of the arch is the same height as the bases.
4. Take another sheet of paper and lay it across the two bases and arch.
5. Slowly and carefully place weights at the center of the bridge until the bridge falls.
6. Record the number and type of weights the bridge held (see the measurement section below).
7. Repeat steps 2 and 3 at least 3 times for this bridge.

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Measurement 3 – Arch Bridge:

Test (Number):	1	2	3	Example
Weight Held				2 Quarters
(Amount x Type):				8 Pennies

Observations - Arch Bridge

What was different about how the arch bridge reacted to more weight? Was there a part of the bridge that fell first?

Take It Further

- Try different bridge designs using other shapes and materials
- Try using aluminum foil in place of paper
  - What do you notice about the aluminum foil compared to the paper?
  - Does shape or material matter more when trying to hold the most weight?

What's Happening?

There are two basic forces that bridges must withstand. A force that tries to pull things apart (**tension**) and a force that pushes things together (**compression**). Feel these forces yourself - curl your fingers towards your palm of both hands, flip one hand over so your thumbs are facing opposite directions and lock your hands together with your fingers in a C-shape. Now try to pull them apart – the force you feel is tension. Compression can be felt when you push your fists against one another. Bridges are designed to direct that pushing and pulling in order to span an empty space.

Bridge engineers and designers use shapes to direct the pushing and pulling of cars, trucks, people, and gravity that a bridge must deal with to stay upright. Some shapes are better at this than others. The first bridge you built had almost no shapes, the flat paper had no way to direct the compression of the weights to the bases it was lying on. When there was too much weight, it collapsed. This is why you don't see any bridges made of flat pieces, without other shapes to support it.

The second bridge probably held much more weight than the first. Look at the end of that bridge. The folds and creases made lots of triangular shapes. Triangles are good at moving the compression and tension, caused by the weight, to the bases where the bridge is supported. The strongest bridges use triangular shapes, such as the Historic Menomonee River Railroad Bridge here in Milwaukee

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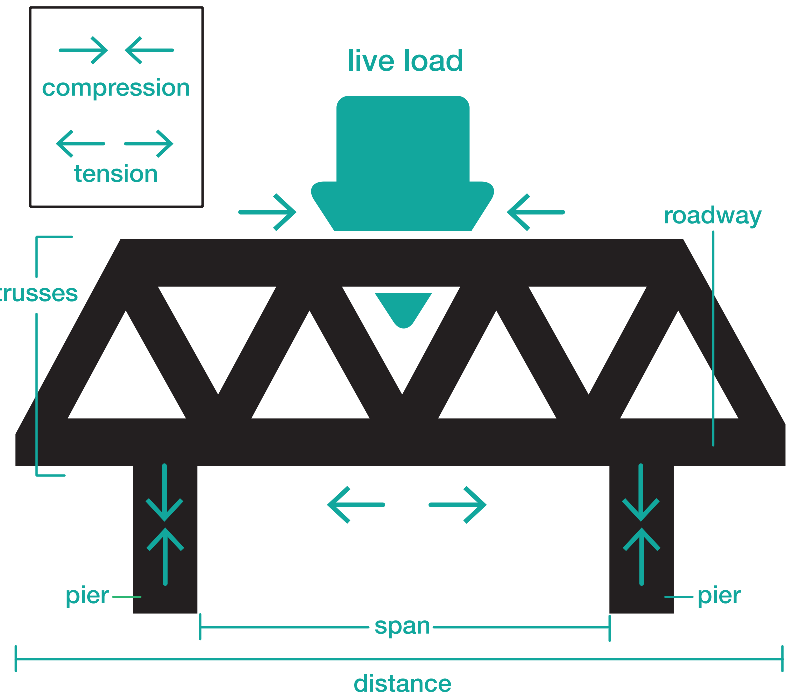
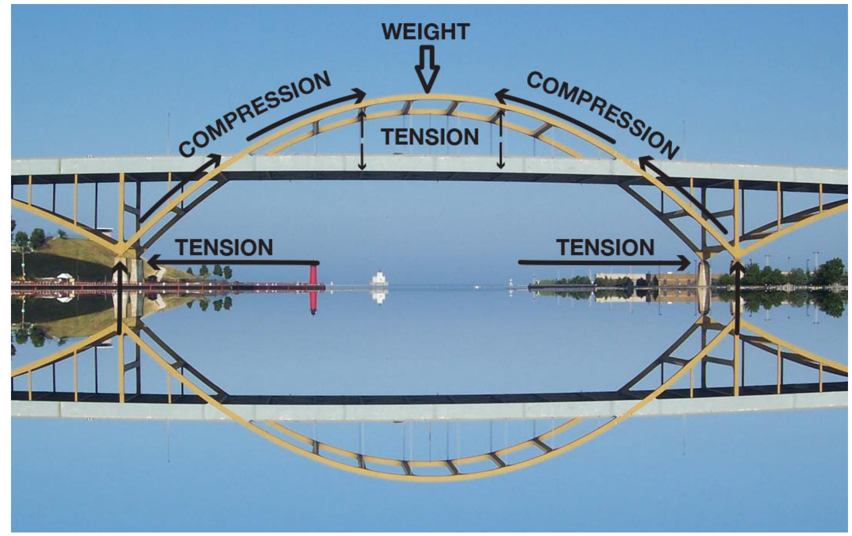
The compression and tension follow the shapes much like the picture below:





These investigations have focused on how triangles and arches can make a bridge stronger, but there are other shapes used in the bridges around our city. The Hoan Bridge and the Menomonee River Railroad Bridge look different, but the basic physics of them is the same. Each bridge uses shapes to do its job just right. Think about the different shapes and how they may be pulling or pushing on one another, each time you see a bridge in Milwaukee!

Other shapes can direct the tension and compression just as well as triangles. The third bridge you built had a single arch shape. The top of the arch was compressed by the weights while the bottoms of the arch were pulled apart from tension, eventually being held in place by your bases. Milwaukee's very own Hoan Bridge is this shape! The arch shape of this bridge makes it possible to span all the way across the water without having to use as many materials as a bridge made with only triangular shapes.

Which bridge held the most weight?
Show us your designs at
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