GYSTC
GEORGIA YOUTH SCIENCE & TECHNOLOGY CENTERS

Title: Awesome Arches STEM Challenge

Estimated Time: 1-2 periods

Core Ideas (GSE Standard and elements):

S8P3. Obtain, evaluate, and communicate information about cause and effect relationships between force, mass, and the motion of objects.

b. Construct an explanation using Newton's Laws of Motion to describe the effects of balanced and unbalanced forces on the motion of an object.

Or

S4P3. Obtain, evaluate, and communicate information about the relationship between balanced and unbalanced forces.

a. Plan and carry out an investigation on the effects of balanced and unbalanced forces on an object and communicate the results.

b. Construct an argument to support the claim that gravitational force affects the motion of an object.

Literacy Connections: Books	**Literacy Connections: Close Reads**
Zombies and Forces and Motion, Mark Weakland Pop's Bridge, CF Payne	Awesome Arches Close Read
Science and Engineering Practices: **Planning and Carrying Out Investigations:** Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation. **Constructing Explanations and Designing Solutions:** Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system.	**Crosscutting Concepts:** **Structure and Function:** The way an object is structured/designed determines many of its properties and functions. **Stability and Change:** For designed systems, conditions that affect stability and factors that control rates of change are critical to consider and understand.

STEM Challenge Overview:

In this STEM Challenge, the student's initial task is to build an arch using ice cubes made of Plaster of Paris. Their second task is to measure and compare the strength of two simple bridges- each made out of 2 pieces of cardstock paper. In each case, they actively investigate how the arch disperses forces and, in doing so, adds to the strength of the structure.

Ask	While bridges are constructed to be strong and durable, it doesn't always work out this way as a recent bridge collapse in Minnesota indicated. On August 1st of 2007, a major bridge collapsed across an eight lane interstate highway killing 13 people and injuring 145.

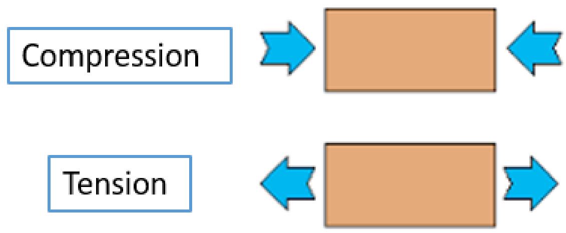
	 Bridge collapse in Minnesota in 2007 Show students some additional pictures of bridge collapses and allow them to **ask** questions and share ideas regarding their proper construction (see attached pictures for ideas).
Imagine/Brainstorm	Students **brainstorm** ideas that could serve as possible solutions that could be used to strengthen and fortify bridges to as to prevent future collapses. After doing so, they should consider the strengths and weaknesses of each idea.
Plan/Design	In order to learn more about topic, have them read the ***Amazing Arches*** article and discuss how arches are often used to dissipate forces that would otherwise cause these structures (often bridges) to collapse. After building a simple arch with Plaster of Paris cubes, students **plan** and **design** a simple beam bridge and a then a simple arch bridge. Depending on the level of your students and the time you have for this challenge, you can make this open-ended or guided inquiry for your students. If you take a more open-ended approach, provide a variety of materials that can be used to construct each type of bridge.
Create/Test	Students follow their plan, and **create** each type of bridge. Once it is created, students **test** their bridges in a measureable way to evaluate the effectiveness of their solution. Their results should be recorded, organized, and analyzed.
Improve	After discussing and evaluating their results, students improve their solution and re-test if possible.

Teacher Notes:

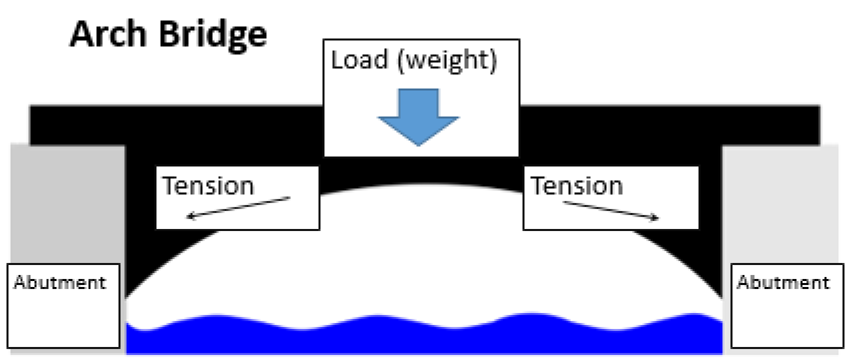
Forces are interactions between objects that cause a push or a pull between them. Forces can move objects that are at rest or stop objects that are moving. The force of gravity is the attractive force between any two objects that have a mass. The amount of attractive force depends on the mass of the objects and the distance between them. Since the earth is by far the most massive object in our vicinity, it exerts the strongest attractive forces on the objects around it. When building structures like a bridge that are impacted by this attractive gravitational pull, careful consideration and thoughtful engineering must be employed.

One of the coolest (and oldest) architectural applications involves the use of arches in bridge and building design. Arches truly are amazing structures. As curved symmetrical structures that span various openings, they are designed to support the weight (a measure of gravitational pull) of the bridge, wall, or roof that are above it. They are used in construction throughout the world. Stone arch support structures were first used widely by the Romans who built some of the most durable edifices ever made. Many of them are still functioning today.

For an arch to be effective in supporting large weights, it must withstand the specific forces acting on them without buckling or snapping. The two main forces that act on an arch are compression and tension. Compression is a force that acts to compress, or shorten, the object that it is acting on. Tension is a force that acts to expand, or lengthen, the object it is acting on.



If the compressive forces become too great an arch will have a tendency to collapse and if the forces of tension become to great an arch will often snap. To counter these forces, arches are designed to spread out the forces acting on them. By spreading out, or dispersing, these forces, no one area of the arch has to bear the brunt of a concentrated force. In the arch bridge pictured below, the force of tension is transferred from an area of weakness near the top of the arch to an area of strength (abutment) that is designed to handle this force.



In this STEM Challenge, the student's initial task is to build an arch using ice cubes made of Plaster of Paris. Their second task is to measure and compare the strength of two simple bridges- each made out of 2 pieces of cardstock paper. In each case, they should actively investigate how the design acts to disperse forces and, in doing so, adds (or fails to add) to the strength of the structure.

In order to prepare the materials for the first task, you need a couple of gallons of Plaster of Paris and 3-4 ice cube trays to make the cubes for each group of students. While this costs a few dollars and takes a little bit of time, the cubes are virtually indestructible so you can use them again and again. Just follow the simple instructions to make the Plaster of Paris, pour it into the ice trays, and then pop them out after a few minutes. Two gallons will make 9-10 sets of cubes so that you can have lots of groups.

In order for students to construct the first arch they need 10-11 cubes and a cookie pan or similar structure to serve as a support (abatement) for the arch. The arch can be built flat on the pan and then flipped up or built one cube at a time into the air. Once the arch is made and balanced it is quite strong and you should encourage your students to apply force (tension) to the arch and see how it responds.

The second task involves constructing an arch out of simple classroom materials. You can let students choose their own design and materials or you can specify. We have found that using 2 pieces of cut up cardstock, file folders, or poster board and two cans of pop for abatements works well. Students are challenged to use the cards to build two different bridges. For the first bridge, students build a simple beam bridge using the cardstock like boards across a creek. For the second bridge, students use one of the cards as an arch and one as a beam.

After constructing each bridge, students should measure and compare the strength of each. They should actively investigate how the arch disperses forces and, in doing so, adds to the strength of the structure. Depending on the level of your students and the time you have, you can make this as open-ended as you see fit. The Plaster of Paris cubes make for an excellent mass to test the relative strength of each bridge. Normally, the beam bridge can support only one cube (about 35 grams) whereas the arch bridge can usually support all ten. You can also let students decide which objects to use to apply force to the bridge.

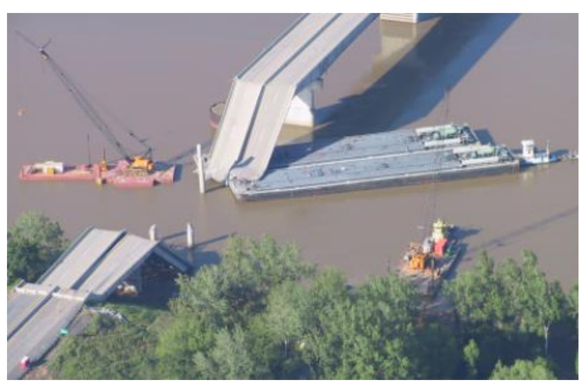
In wrapping up the challenge, have students discuss how they were able to use the arch to disperse the forces from areas of weakness to areas of strength. While a can of pop doesn't make for the most effective abutment possible, it does the job well enough.

With respect to crosscutting concepts, the arch bridge provides an excellent example of the relationship between structure and function illustrating quite effectively how the way an object is constructed determines many of its properties and functions.   The bridge also shows how, for designed systems, conditions that affect stability and factors that control rates of change are critical to consider and understand.

Materials Needed (per group:
10-11 Plaster of Paris cubes
A 9 x 13 cookie pan (Dollar Store)
Two 4" x 12" pieces of poster board, index files, or cardstock.
2 cans of pop or soda.
Assorted masses (or the cubes).

Note: You will also need 2 gallons of Plaster of Paris and 3-4 ice cube trays for the first time you do it.

Additional Collapsed Bridges:



Vocabulary Cards:

arch

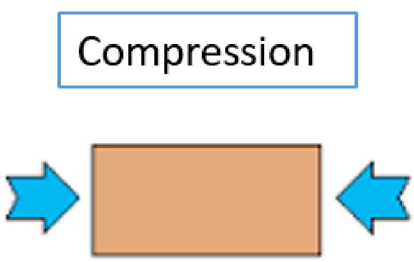
a curved symmetrical structure designed to support weight

force

a push or pull

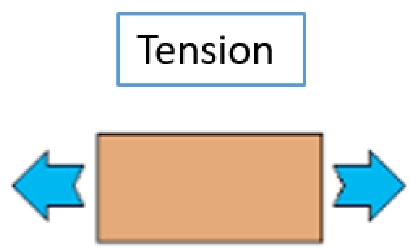
compression

a force that acts to compress, or shorten, the object it is acting on



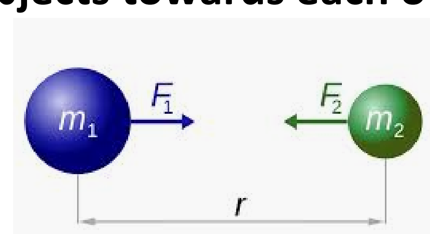
tension

force that acts to lengthen the object it is acting on



gravity

the force that attracts two objects towards each other



engineer

to design, build, and improve things

Amazing Arches STEM Challenge:

Can you use the power of an arch to disperse forces and build a functional bridge?

Constructing your Plaster of Paris Arch:

1. To construct your first arch, use 10 cubes of Plaster of Paris and a cookie pan to serve as a support (abatement) for your arch. The arch can be built flat on the pan and then flipped up or built one cube at a time into the air.
2. Once the arch is standing and balanced, carefully test its strength by applying force (tension) to the arch. Observe and record how it responds.

Constructing a Simple Beam Bridge:

1. Construct a simple beam bridge using 2 pieces of cut up file folders, or poster board. Build a simple beam bridge using the cardstock like boards across a creek. Use the cans of pop to serve as the abatements (supports) for the bridge. The abatements should be about 10 cm apart.
2. Test the strength of the bridge by adding masses to bridge. Calculate the amount of mass that the bridge is able to support.

Constructing a Simple Arch Bridge:

1. Construct a simple arch bridge using 2 pieces the same pieces of paper. This time, use one of the pieces as an arch and the other as a beam. Once again, use the cans of pop to serve as the abatements (supports) for the bridge. The abatements should be about 10 cm apart.
2. Test the strength of the bridge by adding masses to bridge. Calculate the amount of mass that the bridge is able to support.

Evaluating and Improving:

1. As a group, discuss how you were able to use the arch to disperse the forces from areas of weakness to areas of strength.

2. Describe one or two simple things that you think could be done to improve the effectiveness of the bridge.

3. With respect to crosscutting concepts, describe how the bridge provides an excellent example of the relationship between structure and function.

4. If time permits, design and build a structure that uses multiple arches to disperse forces.