BRIDGE UP!
ENGINEERING

LESSON 6 – GRADE 6

LESSON 6 – GRADE 6: Tension and Compression Forces

Big Idea

There are a variety of bridge types and each bears a load. Tension and compression forces occur fluidly across a bridge structure as a load passes over the deck surface.

Essential Questions

How does a bridge support the weight of vehicles?

Does a bridge support a load the same way across its entire structure?

Why are different bridge designs used?

What bridge design is best?

Background Information

Tension and compression forces occur fluidly across a bridge structure as a load passes over the deck surface. A bridge must be able to bear the load of its own materials.

Different types of bridges are used for different settings. While there is not a “best” bridge design, there are specific reasons for using a bridge type depending on the setting and needs of the site.

Arch Bridges

Arch bridges are made from one or more arches and abutments. The arches put the material that make up the bridge into compression. Most arch bridges are made of steel or concrete, which are good for compression.

Suspension Bridges

A suspension bridge is made of a platform that is held up by wires or ropes strung from the tops of piers. More recent suspension bridges use steel plates and steel cables that put material into tension. Steel is used for suspension bridges, because steel is strong in tension and concrete is not.

Truss Bridges
A truss bridge has a superstructure composed of elements connected to form triangles. Usually made of steel bars, truss bridges use a combination of compression and tension forces.

Beam Bridges
Beam bridges are made of a flat piece, or beam, laid across two or more supports. Newer beam bridges are typically made of steel or concrete and are often I-shaped. In the beam – which is horizontal - part of the material is in tension and part of the material is in compression.

Standards & Benchmarks

Minnesota Science Standards
6.1.2.1 Engineers
Engineers create, develop and manufacture machines, structures, processes and systems that impact society and may make humans more productive.

Benchmark: 6.1.2.1.4 Learning from Failures
Explain the importance of learning from past failures, in order to inform future designs of similar products or systems.

6.1.2.2 Practice of Engineering
Engineering design is the process of devising products, processes and systems that address a need, capitalize on an opportunity, or solve a specific problem.

Benchmark: 6.1.2.2.1 Applying a Design Process
Apply and document an engineering design process that includes identifying criteria and constraints, making representations, testing and evaluation, and refining the design as needed to construct a product or system that solves a problem.

MS-ETS1-3 Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Wisconsin Science Standards
B.8.3 Explain how the general rules of science apply to the development and use of evidence in science investigations, model-making, and applications.

C.8.4 Use inferences to help decide possible results of their investigations, use observations to check their inferences.

C.8.6 State what they have learned from investigations, relating their inferences to scientific knowledge and to data they have collected.

C.8.11 Raise further questions which still need to be answered.

Connections with Multimedia Program

Bridge Up! Fundamental Forces

Activity Description

Teams of students will be assigned a specific type of bridge model to build and test the strength of their design with a load. The areas where tension and compression forces occur will be identified as the load is moved along the structure.

Vocabulary

Arch bridge – A bridge made from one or more arches and abutments.

Bridge deck – The surface of a bridge where vehicles and pedestrians travel.

Buckling – Occurs when an object is not able to withstand compressive forces.

Compression – Pressure or force applied inward to points within a structure with a tendency to reduce the size of the section where force is applied.

Dead load – Loads that are constant over time, including the weight of a structure itself.

Extradosed bridge – A combination of a girder bridge and a cable stayed bridge. Instead of relying just on cables, the bridge deck is supported by tower sections and acts as a continuous beam. The cable tension compacts the bridge deck instead of supporting vertically, and girders provide additional support.

Live load – Temporary loads, as in a vehicle moving over a bridge.

Load – Forces applied to a structure.

Load distribution – When the force of a load is spread across an entire structure.

Mechanical stress – A measure of internal forces when an external force is applied to a structure or component of a structure.

Beam bridge – Beam bridges are made of a flat piece, or beam, laid across two or more supports.

Snapping – Occurs when an object is unable to withstand tension forces.

Suspension bridge – A bridge made of a platform that is held up by wires or ropes strung from the tops of piers.

Structural failure – Inability to support the load a structure experiences.

System – A set of interdependent parts that work as a whole.

Tension – A pulling force on an object or system with energy moving towards the ends or edges.

Transfer – How the energy of a load moves through a system.

Truss bridge – This bridge type has a superstructure composed of elements connected to form triangles.

Materials (for teams to choose from)

- Popsicle sticks (large, regular and small sizes)
- Glue (white and/or for glue gun) woodworking or Gorilla glue may be an option if suitable for group
- Glue gun(s)
- String
- Cardstock or cardboard
- Rubber bands in multiple sizes
- Small diameter dowels
- String or twine
- Pipe cleaners
- Wooden skewers (with pointed ends dulled with sandpaper or clipped off and smoothed)
- Water basin (for soaking dowels or skewers if students plan to bend them)
- Wire in assorted gauges
- Wire clippers
- Gram weights
- Pictures or illustrations of four bridge types:
  - Arch bridge
  - Beam bridge
  - Suspension bridge
  - Truss bridge

Individual materials

- Science journals
- Pencils

Optional materials per group (to hold bridges upright for testing)

- Sand
- Bucket

Procedure

Introduction

- Ask students to draw or sketch different types of bridges they have seen or traveled over in their science journals.
- As a group, share what they know and note similarities and differences in structures.

Activity Description

- Tell students that they will be working in groups to build four different types of bridges. The goal is that each bridge will be able to support a load (using gram pieces). Discuss what a load is, including live and dead loads.
- Divide class into four groups and assign them one of the following:
  - Arch bridge
  - Beam bridge
  - Suspension bridge
  - Truss bridge
- Depending on the size of your class and the amount of materials you have available, each of the four groups can then be divided into smaller working groups (three or four students per group).
- Give groups time to look at bridge types using sketches or drawings (see Other Resources section for links you can print from). Direct them to sketch a plan in their science journals before beginning to build, including materials they plan to use.
- Allow groups to collect needed materials and build their models. This part may take more than one day depending on glue used, if groups soak skewers or dowels in order to bend them or other factors.
- Introduce the terms tension and compression.
- Direct groups to determine where tension and compression may occur on their models and have them indicate the areas on their sketches in their journals.
- Using gram pieces, test different load weights either by placing the weights on top of their bridges or suspending them from the structures using string or rubber bands (this will depend on the design built).
- Have groups share their structures with the class, indicating what they noticed about load bearing abilities and any changes they would make to their design.
- Using the CGEE Bridge Up! site, students will work through the Fundamental Forces section to learn about the four bridge types listed above and identify tension and compression forces for each. Students will make sketches of the types with arrows indicating tension and compression sites for each in their science journals.

Assessment

On a blank sheet of paper, ask students to sketch one of the four bridge types with arrows and labels showing where tension and compression forces occur and what the terms mean.

Extensions

Research where different types of bridges are used and why or what types of bridges are used locally.

Other Resources

Five Bridge Types: Arch, Suspension, Beam, Truss, Cable-Stayed
http://www.aiacincinnati.org/community/ABC/curriculum/FiveBridgeTypes.pdf

Build a Bridge
http://www.pbs.org/wgbh/nova/tech/build-bridge-p3.html

How Bridges Work
http://science.howstuffworks.com/engineering/civil/bridge2.htm

History of Bridges
http://www.historyofbridges.com/

Bridge Basics
http://www.pghbridges.com/basics.htm