Bridge Design and Construction

Unit: Technology

Problem Area: Construction Technologies

Lesson: Bridge Design and Construction

Student Learning Objectives. Instruction in this lesson should result in students achieving the following objectives:

1. **Describe bridges and bridge forms.**
2. **Summarize the forces that act on bridges.**
3. **Review types of truss bridges.**
4. **Review record-holding bridges.**

Resources. The following resources may be useful in teaching this lesson:

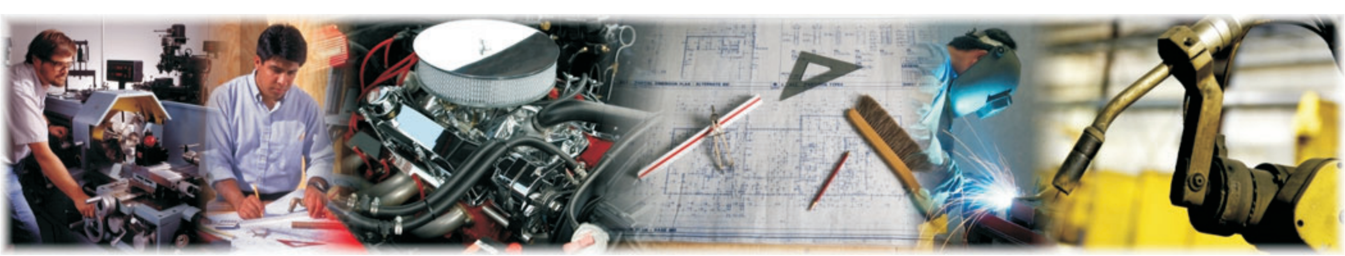
E-unit(s) corresponding to this lesson plan. CAERT, Inc. http://www.mycaert.com.

"Build a Bridge: NOVA," *PBS Learning Media™*. Accessed Feb. 25, 2016. http://www.pbslearningmedia.org/resource/phy03.sci.phys.mfw.buildbridge/build-a-bridge/.

"Building Big: Bridges, Domes, Skyscrapers, Dams, and Tunnels," *PBS.* Accessed Feb. 25, 2016. http://www.pbs.org/wgbh/buildingbig/.

Oxlade, Chris. *Bridges: Building Amazing Structures*, 2nd ed. Heinemann, 2006.

"Super Bridge: NOVA," *PBS.* Accessed Feb. 25, 2016. http://www.pbs.org/wgbh/nova/bridge/.



Equipment, Tools, Supplies, and Facilities

- ✓ Overhead or PowerPoint projector
- ✓ Visual(s) from accompanying master(s)
- ✓ Copies of sample test, lab sheet(s), and/or other items designed for duplication
- ✓ Materials listed on duplicated items
- ✓ Computers with printers and Internet access
- ✓ Classroom resource and reference materials

Key Terms.

The following terms are presented in this lesson (shown in bold italics):

- arch
- arch bridge
- beam
- beam bridge
- bridge
- buckling
- cable
- column
- compression
- dead load
- deck
- dissipation
- force
- I-beam
- live load
- load
- movable bridge
- pier
- resonance
- rigidity
- shear
- span
- stress
- structural efficiency
- suspension bridge
- tension
- torsion
- tower
- transference
- truss
- truss bridge

Interest Approach. Use an interest approach that will prepare the students for the lesson. Teachers often develop approaches for their unique class and student situations. A possible approach is included here.

> *Point out that everyone has seen a bridge. It is almost as likely that we have all traveled over one. Tell the students that if they have ever laid a plank or log down over a stream to keep from getting wet, they have constructed a bridge. A bridge is a natural part of everyday life. A bridge provides passage over some obstacle: a river, a valley, a road, railroad tracks, etc. Ask students to think about the longest and highest bridge they have ever crossed.*

SUMMARY OF CONTENT AND TEACHING STRATEGIES

Objective 1: Describe bridges and bridge forms.

Anticipated Problem: What are bridges? What are the main forms of bridges?

I. Bridge forms

A. A ***bridge*** is a structure that provides passage over an obstacle (e.g., a gorge, body of water, valley, roadway, or railroad tracks). A bridge spans a physical obstacle. A key difference between bridge forms is span or the length between two bridge supports. Bridge supports are columns, towers, or cliff walls (and other natural outcroppings). Four major types of bridges are beam, arch, truss, and suspension (BATS). Basic bridge terms are:

1. An ***arch*** is a curved structural member that spans an opening and serves as a support.
2. A ***beam*** is a rigid, horizontal bridge component that supports vertical loads by resisting bending. A beam is typically long, squared pieces of timber, metal, or concrete designed to handle the load. It is laid from one support to the next support. In beam bridges, the main structural system performs just like one continuous beam because it is supported where necessary.
3. A ***column*** is a vertical, structural element and is strong in compression.
4. The ***deck*** is the roadway, walkway, or railway part of the bridge, including any shoulders. Most bridge decks are constructed of concrete slabs, but timber and open-grid steel decks are used in some moveable bridges.
5. ***Force*** is any action that tends to maintain or alter the position of a structure (e.g., a push, pull, twist, or shear). In the case of bridges, force is the load.
6. ***Load*** is the weight distribution throughout a structure. Vehicles, pedestrians, wind, earthquakes, and gravity affect bridge load. ***Dead load*** is the static load

made up of the weight of the bridge's structural materials (e.g., steel, concrete, wood, stone, and cables). ***Live load*** is vehicle traffic, wind, water, and/or earthquake impact.

7. A ***movable bridge*** is a structure for passing an obstacle in which the deck moves to clear a navigation channel for foot, boat, or vehicle traffic. Types of movable bridges are drawbridge, bascule, and lift.
8. A ***pier*** is a vertical support for the middle spans of a bridge.
9. ***Rigidity*** is the measure of a structure's ability not to change shape when subjected to a load.
10. ***Structural efficiency*** is the ratio of load carried to bridge weight, given a specific set of material types. It is calculated by dividing the maximum weight a bridge can hold by the weight of the bridge itself. The bridge with the highest quotient is the most efficient.

B. Bridge forms

1. A ***beam bridge*** is a rigid, horizontal structure built of horizontal structural members that support vertical loads (classified as short-span or long-span). A beam bridge is the simplest bridge design, with a "girder" resting on two piers or abutments—one at each end of the beam. The supports directly carry the downward weight of the bridge and any bridge traffic. The beam's top surface "compresses," while the bottom edge stretches under "tension." A beam bridge is stiff to resist twisting and bending under a load. The farther apart the supports, the weaker a beam bridge becomes. As a result, many beam bridges have more than two supports to carry the load—continuous span beam bridge—without buckling.
2. An ***arch bridge*** is a structure whose main support is a curved structural member that spans an opening that serves as a support. An arch bridge relies on two separate constructions, with material arching between them. These constructions allow the load of the bridge to be transferred horizontally through the material that composes the arch and into the structures that support the bridge.
3. A ***truss bridge*** is a type of beam bridge structure primarily supported by groupings of triangles (latticework trusses) manufactured from straight steel bars. A truss bridge's triangular beams create strength to withstand the forces of compression and tension. A truss adds rigidity to an existing beam that greatly increases the beam's ability to dissipate compression and tension. A truss is able to dissipate (spread) the load through the truss work. As a result, a truss is able to transfer the bridge load from a single point to a much wider area.
4. A ***suspension bridge*** is a structure that carries its deck with many tension members attached to cables draped over tower piers. A ***cable*** is a part of a suspension bridge that extends from an anchorage over the tops of the towers and down to the opposite anchorage. Then suspenders or hangars are attached along the length of the cable to support the deck. A ***tower*** is a tall pier or frame supporting the cable of a suspension bridge.

C. Span

1. A ***span*** is the horizontal distance between two bridge supports, whether they are columns, piers, towers, or the wall of a canyon. A bridge span is often referred to as a continuous cantilever (beam).
2. The biggest difference between the three supports is the distance each can cross in a single span. For example:
   a. Modern beam bridges typically span a distance up to 200 feet (60 meters).
   b. Modern arch bridges safely span a distance of 800 to 1,000 feet (240 to 300 meters).
   c. Modern suspension bridges, the pinnacle of bridge technology, are capable of spanning distances up to 7,000 feet (2,100 meters).

Teaching Strategy: *Many techniques can be used to help students master this objective. Use VM–A through VM–D.*

Objective 2: Summarize the forces that act on bridges.

Anticipated Problem: What are the forces that act on bridges?

II. Forces acting on bridges

A. Bridges are classified by the way in which the forces of compression, tension, torsion, shear, and resonance are distributed through their structures. These forces are types of ***stress***, which is a force that tends to distort the shape of a structure. The main types of stress occur on the tops and bottoms of beams—where tension and compression occurs. The middle of the beam has little force acting upon it. Newton's three laws of motion explain forces and the general laws they abide by, such as the general reasons objects move (or do not move) as they do.

1. Newton's first law of motion (The law of inertia): An object at rest stays at rest, and an object in motion stays in motion with the same speed and in the same direction, unless acted upon by an unbalanced force. For instance, a person has a full cup of coffee in a car's cupholder when the brakes are applied. The road provides an unbalanced force on the spinning wheels to stop the car, and the coffee (that was moving) continues to move forward at the same speed and spills.
2. Newton's second law of motion: This law addresses the behavior of objects for which all existing forces are not balanced. The acceleration of an object is dependent upon two variables: the net force acting upon the object and the mass of the object. As the force acting upon an object is increased, the acceleration of the object is increased. As the mass of an object is increased, the acceleration of the object is decreased.
3. Newton's third law of motion: For every action, there is an equal but opposite reaction. So in every interaction, there is a pair of forces acting on the two

interacting objects. The size of the forces on the first object equals the size of the forces on the second object. The direction of the force on the first object is opposite to the direction of the force on the second object. Forces always come in pairs—equal and opposite action-reaction force pairs. When a car's wheels spin, they "grip" the road, pushing it backwards. In turn, the road "pushes" the car's wheels forward.

B. Compression and tension

1. ***Compression*** is a pushing force that acts to shorten or squeeze a structure or material. For example, the shorter a piece of wood is, the more compression it can hold. The longer a piece of wood is, the easier it bends. If a beam fails because of compression, it is said to buckle.
    a. ***Buckling*** is bending under compression. It occurs when the force of compression is greater than the object's ability to resist the force. If the span of a bridge between the supports is too great, the bridge will buckle (bend).
    b. Certain truss designs spread out the force so various internal parts will be in compression as well. Compression stress is the opposite of tension stress.
2. ***Tension*** is a pulling force (materials are lengthened and/or stretched). In terms of a bridge, tension pulls on the bridge material to lessen the bridge weight and keep it from falling. For instance, in a game of tug-of-war, the tension on both teams is similar to that of the tension on bridge structures.
    a. A spring is a simple, everyday example of compression and tension. When a person presses down or pushes the two ends of the spring together, it compresses. The force of compression shortens the spring.
    b. When a person pulls up or pulls the two ends apart, he or she creates tension in the spring. The force of tension lengthens the spring.
3. Compression and tension are present in all bridges. The objective of good bridge design is to manage these two forces that interact when one has an I-beam. An ***I-beam*** is a girder support in the shape of an I- or H-shaped cross-section (e.g., when a person "cuts" a section through the beam and looks at it "head on," it appears to be an "I" or "H" in shape).
    a. An I-beam is a good design choice to handle the forces that a bridge experiences. An I-beam is able to dissipate the force placed on top of it throughout the length of the beam.
    b. Because of its design structure, the I-beam withstands a great deal of compression without buckling. It is an excellent choice when selecting bridge-building materials.

C. Torsion, shear, and resonance

1. ***Torsion*** is a twisting force. Wringing the water from a towel is the application of torsion to the cloth. A bridge designer attempts to reduce as much torsion as possible in the structure. Modern materials have eliminated torsion in bridges, except for the suspension bridge. High winds can cause the sus-

pended roadway to rotate and twist in a "wave" motion. Also, a designer may now use deck-stiffening trusses to minimize torsion.

2. ***Shear*** is a force that moves a material or structure in a sideways motion; it requires two opposing forces acting on the same point. Shearing stress occurs when two fastened structures (or two parts of a single structure) are forced in opposite directions. For example, if a person holds a piece of wood with both hands next to each other and pushes up with one hand and down with the other hand, shear is applied to the piece of wood.
3. ***Resonance*** is vibrational stress. It is the equivalent of a snowball rolling down a hill and becoming an avalanche, except that—in the case of a bridge—the "snowball" is a harmonic sound (often produced by wind). Resonant vibrations, if unchecked, can increase drastically and travel through a bridge in the form of torsional waves. For example, when an army marches across a bridge, it often breaks cadence because the rhythm of the marching could cause a resonance vibration throughout the bridge.

D. Dissipation and transference

1. ***Dissipation*** is the act of "spreading out" a force (stress) over a greater area so no one spot bears the brunt of the concentrated force. An arch bridge is a good example of dissipation design.
2. ***Transference*** is moving a force (stress) from an area of weakness to an area of strength (an area designed to handle the force). A suspension bridge is a good example of transference design. Suspension bridges transfer most of the weight or load of the bridge through the cables to the anchorage systems (e.g., piers and abutments) fixed in solid rock or concrete blocks. Inside the anchorages, the engineers spread the cables over a large area to evenly distribute the load and to prevent the cables from breaking free of the support anchors.

Teaching Strategy: *Many techniques can be used to help students master this objective. Use VM–E through VM–H. Watch the Tacoma Narrows Bridge collapse due to resonance vibration on YouTube at https://www.youtube.com/watch?v=3mclp9QmCGs. Assign LS–A.*

Objective 3: Review types of truss bridges.

Anticipated Problem: What are types of truss bridges?

III. Truss bridge types

A. Truss bridge structure

1. A ***truss*** is a framework of girders (latticework structure)—some in tension and some in compression—comprising triangles and other stable shapes coupled at the joints (called nodes). A truss is an engineering design choice when load support is required in a structure. A truss counteracts the forces acting on

bridges and other structures. It uses beams and/or I-beams to build highly efficient bridges.

   a. A truss bridge is a type of beam bridge structure primarily supported by groupings of triangles (latticework trusses) manufactured from straight steel bars.
   b. A truss bridge's triangular beams create strength to withstand the forces of compression and tension.

2. Single beam versus truss
   a. A single beam spanning any distance experiences compression and tension. The top of the beam experiences the most compression, and the bottom of the beam experiences the most tension. The middle of the beam experiences little compression or tension.
   b. A truss is more rigid than a single beam because it has the ability to dissipate the load through the truss work (latticework).
   c. If a beam could be designed more efficiently in terms of its own structure and weight, more material would be placed on the top and bottom. Then the beam would be able to handle more compression and tension force than one with equal material distribution from top to bottom. An I-beam is an example. Cutting a section through the beam and looking at it head-on, it looks like the letter "I" and has additional material on the top and the bottom.

B. Truss bridge types (examples)

1. A Bailey bridge is a truss-type structure primarily used by the military. It was developed by the British during WWII to provide temporary crossings for foot and tank or vehicle traffic. This bridge type has the advantage of requiring no special tools or heavy equipment to assemble and is used extensively in civil engineering projects today.
   a. A Bailey bridge is often prefabricated and "delivered" to the site. It is comprised of two parallel beams running the span with vertical supports placed between the two beams. Then diamond-shaped braces are created between each set of vertical supports.
   b. The roadbed or pedestrian bed is located at the bottom of the truss bridge.
2. A Pratt truss uses two parallel beams bridging the span with vertical supports. Then it uses diagonal beams sloping down to the center of the bridge between each vertical support. Pratt truss was a common type of bridge used in the late 1800s and early 20th century to span distances of 250 feet or less.
3. A truss arch is a bridge supported from the bottom. Horizontal beams span the gap while an arch built between the supports of the bridge uses trusses to battle the forces of compression and tension. Many truss arch bridges place the roadway at the top of the truss instead of at the bottom, as in the first two examples.

Teaching Strategy: *Many techniques can be used to help students master this objective. Use VM–I through VM–L.*

Objective 4: Review record-holding bridges.

Anticipated Problem: What are some record-holding bridges?

IV. Record-holding bridges

A. World records (at this writing)

1. The world's longest bridge is the Danyang-Kunshan Grand Bridge in China on the Beijing-Shanghai High-Speed Railway. It was opened in 2011 and is 540,700 feet long (about 102.5 miles). Technically, the bridge is classified as a viaduct, which is a structure that contains several small spans.
2. The world's highest bridge is the Si Du River Bridge in China at a height of 4,010 feet above the water. Height is measured as the distance from the top of the bridge deck to the surface below the bridge. Si Du River Bridge is a suspension bridge that opened in 2009.

B. United States records (at this writing)

1. The Lake Pontchartrain Causeway, New Orleans, LA, is currently the longest bridge in the United States at 23.83 miles long (a measure of the longest span). It is also the world's longest bridge over a body of continuous water. It is composed of two parallel bridges crossing Lake Pontchartrain. A causeway is a raised road or path across wet ground or water. The bridge is supported by a series of trestles. A trestle is a frame that supports a small span of the bridge decking. It was opened in 1956.
2. The Royal Gorge Bridge is a suspension bridge located 955 feet above the Arkansas River in Colorado and is the highest bridge in the United States (measured from the top of the bridge deck to the river). It was opened in 1929.

Teaching Strategy: *Many techniques can be used to help students master this objective. As an example, use VM–M and VM–N. Share the "10 World's Scariest Bridges" at https://www.youtube.com/watch?v=Ll2cUw-HsCU.*

Review/Summary. Use the student learning objectives to summarize the lesson. Have students explain the content associated with each objective. Student responses can be used in determining which objectives need to be reviewed or taught from a different angle. Questions at the ends of chapters in the textbook may be used in the Review/Summary.

Application. Use the included visual master(s) and lab sheet(s) to apply the information presented in the lesson.

Evaluation. Evaluation should focus on student achievement of the objectives for the lesson. Various techniques can be used, such as student performance on the application activities. A sample written test is provided.

Answers to Sample Test:

Part One: Matching

1. f
2. k
3. h
4. j
5. d
6. i
7. e
8. b
9. c
10. a
11. g

Part Two: Completion

1. span
2. torsion
3. buckling
4. suspension
5. compression; tension
6. transference
7. dissipation
8. rigidity
9. resonance
10. shear

Part Three: Short Answer

1. The four major types of bridges are beam, arch, truss, and suspension.
2. Answers will vary but should be similar to the following: Dissipation is the act of "spreading out" a force (stress) over a greater area so no one spot bears the brunt of the concentrated force. An arch bridge is a good example of dissipation design.

Sample Test

Name ______________________________

Bridge Design and Construction

Part One: Matching

Instructions: **Match the term with the correct definition.**

a. arch bridge
b. beam bridge
c. bridge
d. compression
e. deck
f. force
g. load
h. suspension bridge
i. tension
j. truss
k. structural efficiency

_____1. Any action that tends to maintain or alter the position of a structure (e.g., a push, pull, twist, or shear)

_____2. The ratio of load carried to bridge weight, given a specific set of material types

_____3. A structure that carries its deck with many tension members attached to cables draped over tower piers

_____4. A framework of girders (latticework structure)—some in tension and some in compression—comprising triangles and other stable shapes coupled at the joints (called nodes)

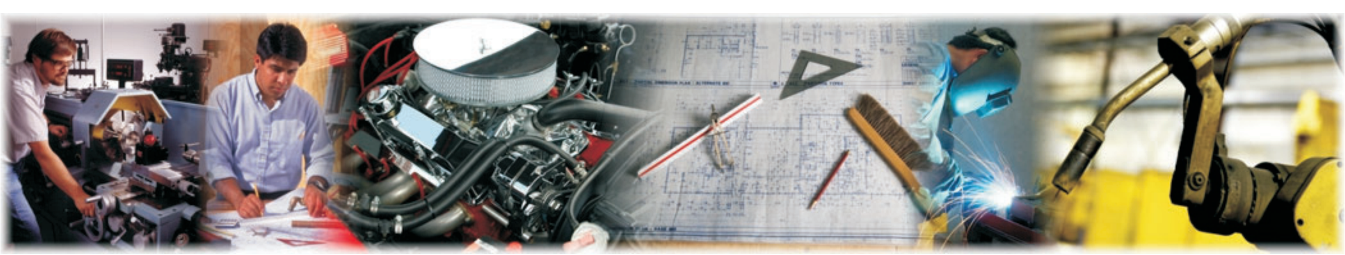
_____5. A pushing force that acts to shorten or squeeze a structure or material

_____6. A pulling force (materials are lengthened and/or stretched)

_____7. The roadway, walkway, or railway part of the bridge, including any shoulders

_____8. A rigid, horizontal bridge structure built of horizontal structural members that support vertical loads

_____9. A structure that provides passage over an obstacle (e.g., a gorge, body of water, valley, roadway, or railroad tracks)



____10. A structure whose main support is a curved structural member that spans an opening that serves as a support

____11. The weight distribution throughout a structure

Part Two: Completion

Instructions: **Provide the word or words to complete the following statements.**

1. The distance between two bridge supports is a/an ________________________.
2. Wringing the water from a towel is the application of ________________________ to the cloth, which is a twisting force.
3. To bend under compression is called ________________________.
4. The bridge form able to span the longest distances is ________________________.
5. The top of a beam spanning any distance experiences the most ________________________, while the bottom of the beam experiences the most ________________________.
6. Moving a force (stress) from an area of weakness to an area of strength is the process of ________________________.
7. The act of “spreading out” a force (stress) over a greater area so no one spot bears the brunt of the concentrated force is termed ________________________.
8. The measure of a structure’s ability not to change shape when subjected to a load is termed ________________________.
9. Vibrational stress is termed ________________________.
10. A force that moves a material or structure in a sideways motion is termed ________________________.

Part Three: Short Answer

Instructions: **Complete the following.**

1. List the four major types of bridges.

2. Explain dissipation in bridge design.

BEAM BRIDGE

A beam bridge is a rigid horizontal structure. It is built of horizontal structural members that support vertical loads. The supports for this beam bridge are built from the bottom of this body of water, and the beams lay across the top from one to the other. Is this bridge a simple beam or a continuous-span beam?

ARCH BRIDGE

An arch bridge is a structure whose main support is an arch (a curved structural member that spans an opening and serves as a support). This image is the Stone Arch Bridge spanning the Mississippi near Minneapolis, MN.

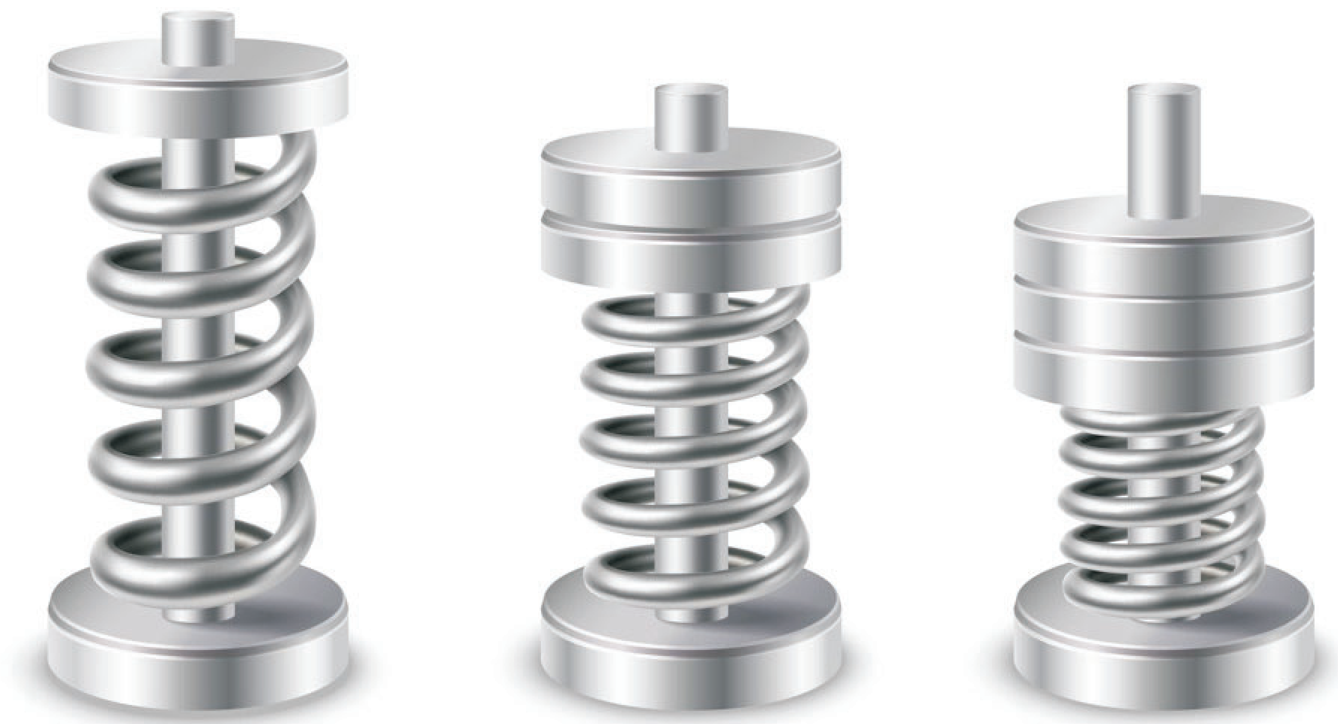
TRUSS BRIDGE

A truss bridge is a type of beam bridge structure primarily supported by groupings of triangles (latticework trusses) manufactured from straight steel bars. A truss bridge's triangular beams create strength to withstand the forces of compression and tension. The truss bridge pictured here is the Chain of Rocks Canal Bridge in southwestern Illinois, near St. Louis.

SUSPENSION BRIDGE

A suspension bridge is a structure that carries its deck with many tension members attached to cables draped over tower piers. The suspension bridge in this image connects Portugal and Spain and spans the Guadiana River. Notice the tall supports and the cables supporting the bridge deck.

FORCES THAT ACT ON BRIDGES: COMPRESSION



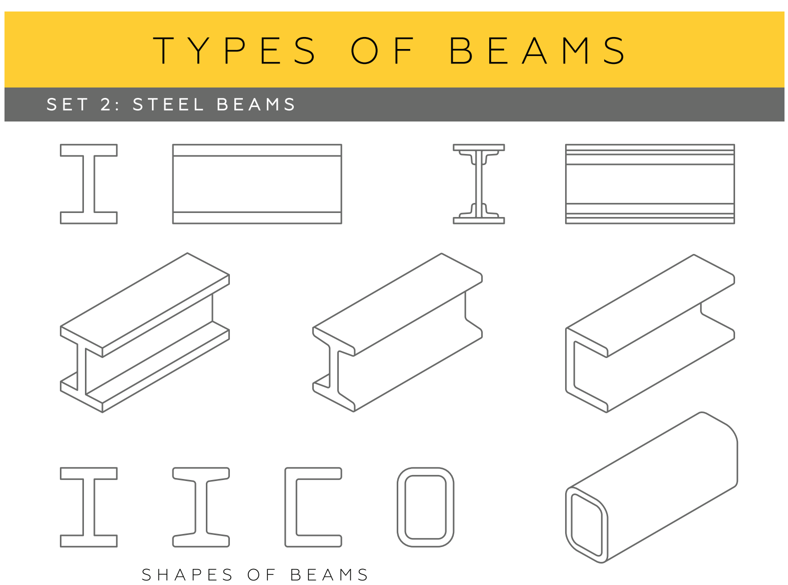
Compression is a pushing force that acts to shorten or squeeze a structure or material. For example, the shorter a piece of wood is, the more compression it can hold. The longer a piece of wood is, the easier it bends. The springs in this image are being compressed by the weights placed on top of them. Just like a bridge, the heavier the load or decking becomes, the more compression the bridge supports experience. Too much compression leads to buckling.

FORCES THAT ACT ON BRIDGES: TENSION

Tension is a pulling force. In terms of a bridge, tension pulls on the bridge material to decrease the bridge weight and keep it from falling. As in a game of tug-of-war, the tension on both teams is similar to that of the tension on bridge structures. One of these two springs represents compression, and the other represents tension. Which is which?

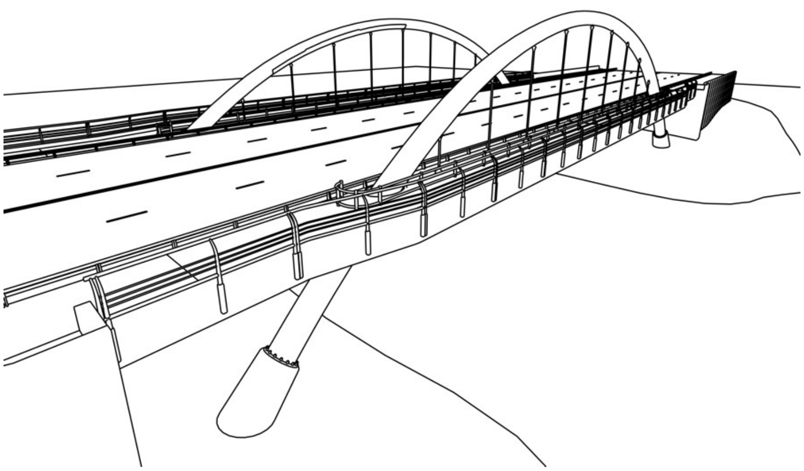
FORCES THAT ACT ON BRIDGES: DISSIPATION

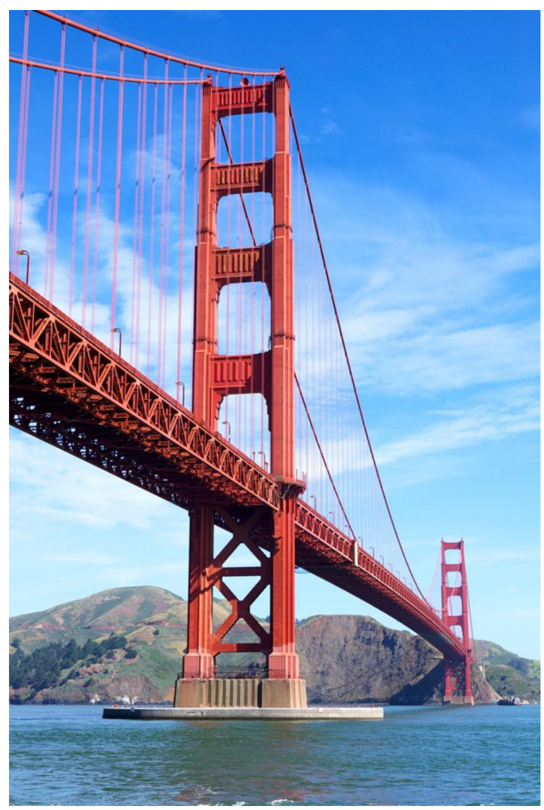
Dissipation is the act of “spreading out” a force (stress) over a greater area so no one spot bears the brunt of the concentrated force. An arch bridge is a good example of dissipation design.



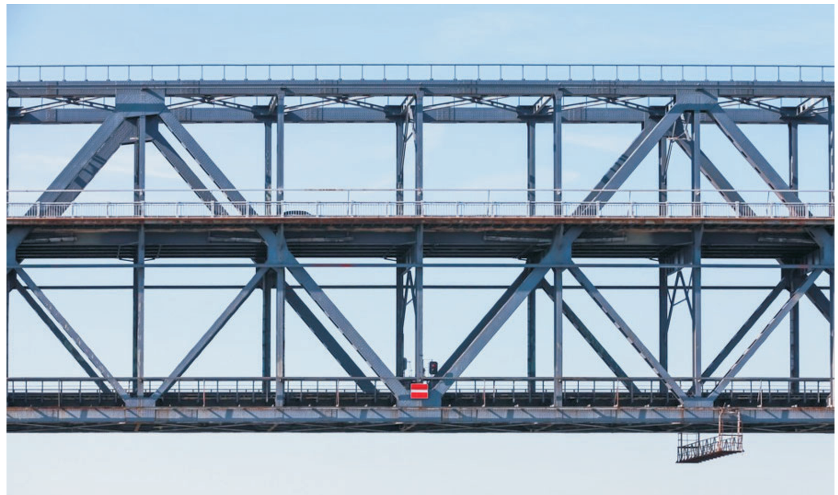
FORCES THAT ACT ON BRIDGES: TRANSFERENCE

Transference is moving a force (stress) from an area of weakness to an area of strength—an area designed to handle the force. A suspension bridge is a good example of transference design, as the weight is transferred to an area of strength. How is force transferred in this design for the Golden Gate Bridge?





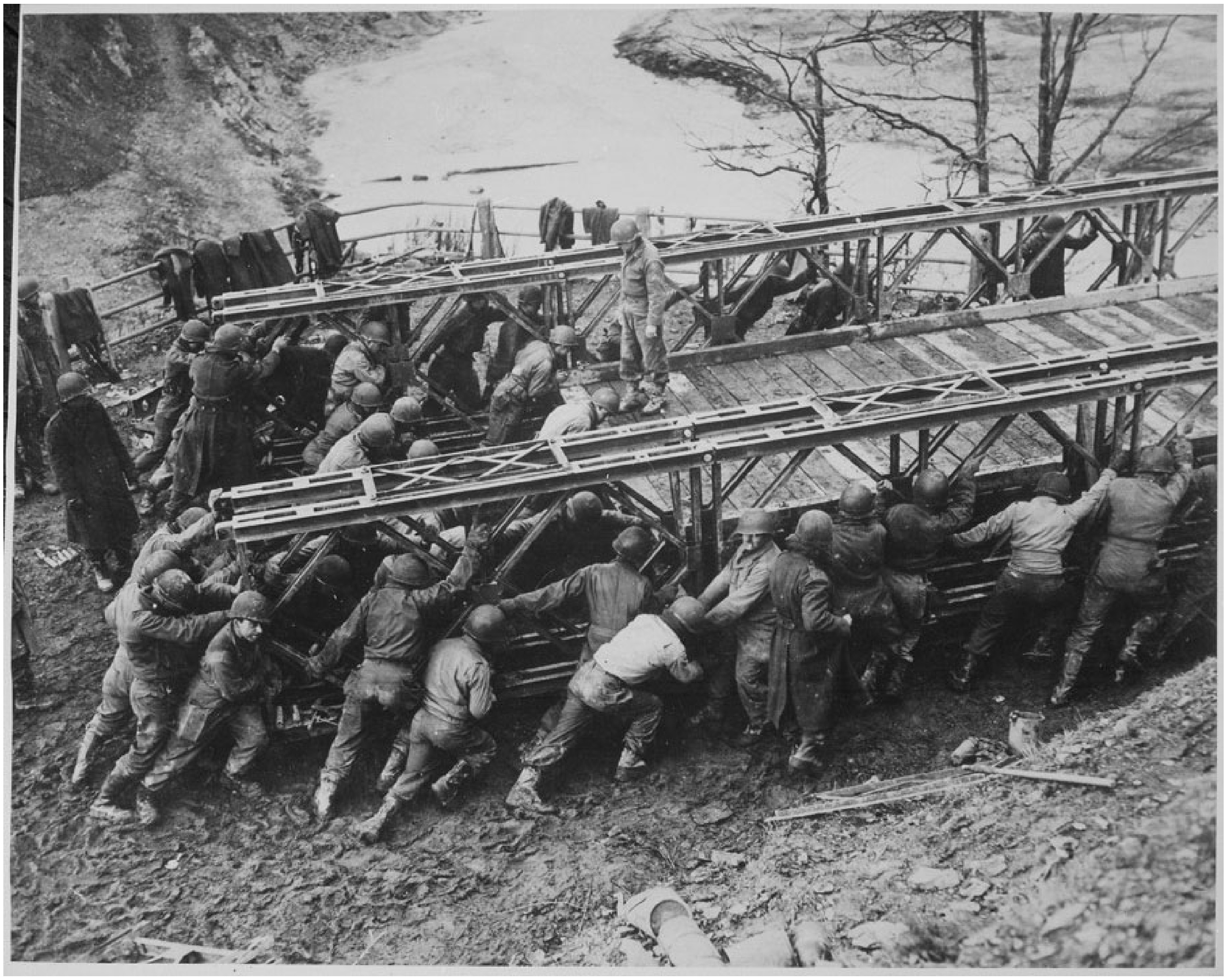
TRUSS BRIDGES



Trusses are strong, rigid beam systems often constructed of I-beams. Look for them in structures that need support. This bridge fragment illustrates a steel truss bridge with two levels for vehicle traffic. Notice the diamond-shaped supports between the vertical supports to tie together the horizontal beam that runs the span.

Each spring, the city of Chicago, IL, opens its series of drawbridges along the Chicago River to allow sailboats passage to Lake Michigan and dock space in a marina for the summer. Drawbridges are moveable bridges and require rigid structural supports. They used trusses to build these bridges.

BAILEY BRIDGE



(Courtesy, National Archives and Records Administration)

A Bailey bridge is a truss-type structure primarily used by the military. It was developed by the British during WWII to provide temporary crossings for foot and tank or vehicle traffic. This bridge type has the advantage of requiring no special tools or heavy equipment to assemble it. As a result, it is used extensively in civil engineering projects today. The image here is of U.S. troops launching a Bailey bridge across a gap by hand.

PRATT TRUSS BRIDGE

This bridge is an example of a Pratt truss. What distinguishes this design, as a Pratt-style truss, are the diagonal beams sloping toward the center of the bridge. This rail bridge crosses the “narrows” over the Battle River in Saskatchewan.

TRUSS ARCH BRIDGE

The Navajo Bridge over the Colorado River in Page, Arizona, is an example of a truss arch. Can you find the truss nodes in this image? NOTE: This is a good example of the bridge deck being above the supports for the bridge load.

WORLD'S HIGHEST BRIDGE

Currently, the world's highest bridge is the Si Du River Bridge in China at a height of 4,010 feet above the water. Height is measured as the distance from the top of the bridge deck to the surface below the bridge. Si Du River Bridge is a suspension bridge that opened in 2009.

U.S. RECORD-HOLDING BRIDGES

The Lake Pontchartrain Causeway is a bridge in New Orleans classified as a trestle as it is composed of numerous short spans from beginning to end. This bridge has a bascule, which is more commonly known as a drawbridge. It is the longest bridge in the United States.

The Royal Gorge Bridge stretches over the Arkansas River in Canon City, CO, at a height of 955 feet. It is the highest suspension bridge in the United States and opened in 1929.

LS–A

Name ____________________

Construct a Suspension Bridge

Purpose

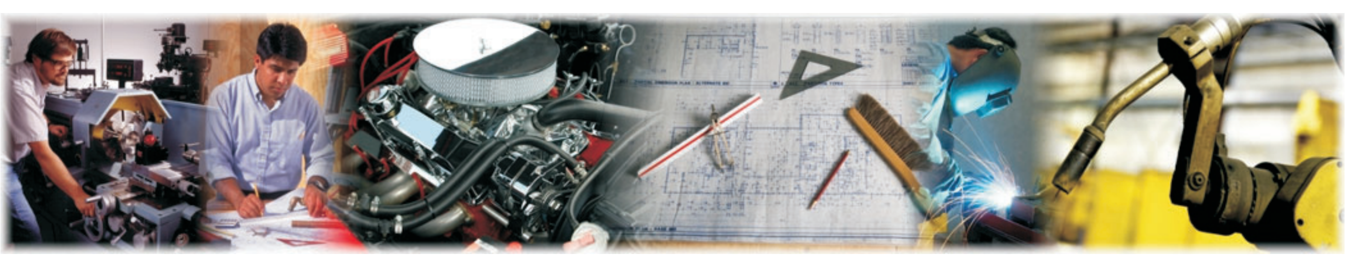
The purpose of this activity is to design, construct, and test the strength of a simple suspension bridge.

Objectives

1. Design a simple suspension bridge.
2. Experiment with the way forces act on a suspension bridge.
3. Test the strength of your designs.
4. Demonstrate your experiments to another group.
5. Write three questions about your experimental designs.
6. Write other questions you would like to test.

Materials

- lab sheet
- paper
- writing utensil
- class notes
- string
- shoe
- drinking straws (7 per group)
- masking tape
- dental floss (or thread of a similar tensile strength; about 4 feet per group)
- scissors
- large paper clips (4 per group)
- paper cups
- weights (pennies, metal washers, or other small objects, as needed)
- rulers
- anchorage items (books, bricks, paint cans, etc., as needed)



Procedure

1. Tie a piece of string to a shoe or other weight. Can you lift this shoe in the air by pulling down on the string? This basic suspension bridge design can be applied using other materials to build larger, stronger bridges.

2. Review your notes about suspension bridges and the forces that act on bridges.

3. Break into groups of three to design, construct, and test a suspension bridge structure using the materials provided. Each design should include a minimum of:

    a. A tower

    b. Decking

    c. Floss/thread to hold up the decking

    d. Two anchorages (You may use a wall, door, or cabinet as desired in addition to those items listed.)

4. Test the strength of your bridge by placing the weights on top of your decking one at a time.

    a. Count the number of weights your first design holds, and list it on your paper.

    b. Then remove the weights and adjust the floss/thread placement as needed to make your bridge even stronger.

    c. Count the number of weights your second design holds, and list it on your paper.

5. On your paper, answer the questions below by experimenting with your materials:

    a. How do forces act on a suspension bridge?

        (1) Write a short response on your paper.

        (2) Experiment with attaching cables from the bridge deck only to the tops of the towers, instead of extending them down to the surface at the ends of the bridge.

        (3) On your paper, describe and/or draw what happened when you attached the cables from the bridge deck only to the tops of the towers.

    b. On a scale of 1 (low) to 4 (high), how strong is this suspension design?

    c. Explain your strength rating on your paper.

6. Partner with another group. Demonstrate to the other group the experiments you conducted with your bridge. Then explain the results you discovered. Allow the other group time to explain their findings.

7. On your paper, develop three questions about the performance of your bridge during the two tests. (For example: “Why did our bridge behave differently when we adjusted the placement of the materials?”)

8. List questions (on your paper) that you have and were unable to test.

Construct a Suspension Bridge

1. Begin showing students that by pulling the string over the back of a chair and then down to the ground, the shoe can rise. This is the basic premise of a suspension bridge.

5a. Possible responses include but are not limited to:

(1) Adding cables to the straw bridge and anchoring the cables on both sides significantly increased the load the bridge can support.

(2) A suspension bridge's cables and towers transmit the "dead" load of the bridge deck and the "live" load of the traffic to the massive anchor blocks at each end of the bridge.

(3) The tension in the cables leading up from the bridge deck is balanced by the tension in the cables leading to the anchor blocks as well as the compression in the towers.

(4) The anchor blocks must be massive enough to resist the tension in the cables caused by the weight of the bridge deck.

5b. Sample response: "This suspension bridge model is weaker than the model in which the cables extend down to the ground on the other sides of the towers. A load on the bridge deck pulls the tips of the towers inward, and there is no balancing tension pulling the towers out toward the ground."