PENSACOLA BAY BRIDGE
REPLACEMENT PROJECT

Popsicle Stick Bridge Lesson Plan – Unit II

BRIDGE CONSTRUCTION AND DESIGN

Objective: "Bridge Construction and Design" examines bridge design, construction, the forces of compression and tension, and the basics of how they work interchangeably with each other. After this activity, students should be able to do the following:

- define four major types of bridges, including a beam or truss bridge; an arch bridge; and a suspension bridge;
- describe and locate the compressive and tensile forces acting on various types of bridges; and
- explain situations for which different types of bridges would be best suited.

Summary: Through a PowerPoint presentation, students are introduced to two natural forces—tension and compression—common to all bridges and structures. They will review the PowerPoint and complete a quiz - individually or as a team. The PowerPoint presentation will emphasize that bridges are incredible pieces of engineering, and to understand the basics of design that go into them, you need BATS—that is, Beams, Arches, Trusses and Suspensions, which are the core components of bridge construction.

Materials:

- PowerPoint presentation - Unit 1 Bridge Types
- Activity #1 information and worksheet

ACADEMIC STANDARDS

Objectives:

SC.6.P.13.1

Investigate and describe types of forces including contact forces and forces acting at a distance, such as electrical, magnetic, and gravitational.

SC.6.P.13.3

Investigate and describe that an unbalanced force acting on an object changes its speed, or direction of motion, or both.

SC.7.P.11.2

Investigate and describe the transformation of energy from one form to another.

SC.7.P.11.3

Cite evidence to explain that energy cannot be created nor destroyed, only changed from one form to another.

SC.8.N.1.1

Define a problem from the eighth grade curriculum using appropriate reference materials to support scientific understanding, plan and carry out scientific investigations of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions.

SC.8.N.1.5

Analyze the methods used to develop a scientific explanation as seen in different fields of science.

SC.8.N.1.6

Understand that scientific investigations involve the collection of relevant empirical evidence, the use of logical reasoning, and the application of imagination in devising hypotheses, predictions, explanations and models to make sense of the collected evidence.

s. 1003.41, Florida Statutes
Rule 6A-1.09441, F.A.C

Vocabulary:

Compression: A pushing force that tends to shorten objects.

Engineer: A person who applies her/his understanding of science and mathematics to create things for the benefit of humanity and our world.

Tension: A pulling or stretching force that tends to lengthen objects.

Live load: Weight of traffic on the bridge, e.g., trucks, buses, cars, and pedestrians.

Dead load: The stationary weight of the component parts of a bridge.

Procedure:

1. Explain to students “Bridge Design,” the Basics, focusing on BATS[1]; see paragraph below:

   Bridges are incredible pieces of engineering, and to understand the basics of design that go into them, you need BATS—that is, Beams, Arches, Trusses, and Suspensions, which are the core components of bridge construction, not the flying creatures.[1]

   There are many different styles of bridge design, but each one can be broken down into combinations of these core components. Designs can be simple, focusing on a single core component, as seen in a suspension bridge or truss bridge, or they can offer more complex designs using more than one core component, such as a cable-stayed bridge. What dictates the kind of design used in any bridge is the length it is required to span across—that is, the distance between bridge supports. Bridge supports hold up the entire bridge and are the parts that touch the surface below. They can be simple, such as the sides of the crevasse the bridge is going over, or, in the case of a multiple-span bridge, they are often concrete, brick or steel columns rising up from the ground to the bridge’s height.

   How far a given bridge design can span between supports does vary, and the materials used in construction do have some effect; however, with modern bridges, a beam bridge can span about 200 feet, but a modern arch bridge can still go further and can safely span between 800 and 1,000 feet. This provides an idea of the way in which design affects bridge performance, but the king of spans is no doubt the modern suspension bridge, which can safely reach up to 7,000 feet.

2. Show students the Unit 2 presentation of the bridge’s forces.

3. During the presentation phase, each slide will ask the following questions. (Use the discussion questions provided below as an icebreaker prior to beginning the activity.)

   Discussion questions: Ask the students the following and discuss the questions as a class:

   - After the beam bridge slide, ask the students the following:
     - Where are the compressive forces located?
       (Answer: The compressive forces are located on the top.)
     - Where are the tensile forces located?
       (Answer: The tensile forces are located on the bottom.)

Procedure continued...

- After the arch bridge slide, ask the students:

Credit The term “BATS” and it’s explaination obtained from https://science.howstuffworks.com/engineering/civil/bridge.htm

- What kind of force do the abutments impose on the arch, pushing (compression) or pulling (tension)?
  (Answer: The abutments push back on the arch, as the arch is pushing on the abutments.)

4. To increase understanding of the different types of forces, students will watch a video produced by Teach Engineering and will then complete a quiz - individually or as part of a team.

ACTIVITY #1

Watch the video by Teach Engineering: Bridge Types: Tensile & Compressive Forces
https://www.youtube.com/watch?v=33ZfJw8cEFY

ACTIVITY #2 WORKSHEET

Timed Quiz

How fast can you answer the following questions about bridges?

1. **The distance between two bridge supports is called the ____________________:**
    a. Arch
    b. Span
    c. Fathom

2. **Which of the following is not one of the two major forces exerted on bridges?**
    a. Momentum
    b. Compression
    c. Tension

3. **What determines the distance a beam bridge can span?**
    a. The materials of the beam
    b. The size of the beam
    c. The density of the beam

4. **What can be added to make beams taller?**
    a. Concrete
    b. Trusses
    c. Suspensions

5. **What gives an arch bridge its strength?**
    a. Its shape
    b. Its size
    c. Its material

6. **What part of a suspension bridge receives the most compression?**
    a. The cables
    b. The deck
    c. The towers

7. **Tension acts primarily on which part of a suspension bridge?**
    a. The anchorages
    b. The cables
    c. The towers

ACTIVITY #2 ANSWER KEY

Question #1

ANSWER = b. Span

Bridges are differentiated by the distance they can cross, also known as their span.

Question #2

ANSWER = a. Momentum

Compression is a force that acts to compress or shorten the object it's acting on; tension is a force that acts to expand or lengthen the object it's acting on. These are the two main forces that bridges must contend with.

Question #3

ANSWER = b. The size of the beam

The size of the beam (in particular, its height) controls the distance that the beam can span.

Question #4

ANSWER = b. Trusses

Supporting lattice work, or a truss, adds rigidity to the existing beam, greatly increasing its ability to dissipate the compression and tension.

Question #5

ANSWER = a. Its shape

Due to their curved shape, arch bridges don't need additional supports or cables; they're naturally strong bridge structures.

Question #6

ANSWER = c. The towers

A suspension bridge's cables transfer the bulk of the compression to the towers. The towers transfer the compression through the foundations into the earth.

Question #7

ANSWER = b. The cables

The supporting cables running between the bridge's two anchorages receive most of the tension. They're literally stretched from the weight of the bridge and its traffic.

Credits: Bridge Quiz obtained from http://quizzes.howstuffworks.com/quiz/bridge-quiz

TEACHER BACKGROUND INFORMATION

Bridge Design – The Basics

Bridges are incredible pieces of engineering, and to understand the basics of design that go into them, you need BATS—that is, Beams, Arches, Trusses and Suspensions, which are the core components of bridge construction, not the flying creatures.[1]

There are many different styles of bridge design, but each one can be broken down into various combinations of these core components. Designs can be simple, focusing on a single core component, as seen in a suspension bridge or truss bridge, or they can offer more complex construction, using more than one core component, such as a cable-stayed bridge. What dictates the kind of design used in any bridge is the length it can cross in a single span—that is, the distance between the bridge supports. Bridge supports hold up the entire bridge and are the parts that touch the surface below. They can be simple, such as the sides of the crevasse the bridge is going over, or, in the case of a multiple-span bridge, they are often concrete, brick, or steel columns rising up from the ground to the bridge's height.

How far a given bridge design can span between supports does vary, and the materials used in the construction do have some effect; however, with modern bridges, a beam bridge can span around 200 feet, but a modern arch bridge can extend even further and can safely span between 800 and 1,000 feet. This provides an idea of the way in which design affects bridge performance, but the king of spans is no doubt the modern suspension bridge, which can safely reach up to 7,000 feet.

Differences in Design

As we have seen, different designs provide very different results when it comes to spans. An arch bridge can span much further than a beam, while the suspension bridge can manage to go even further. The reason for this difference is the difference between how each design deals with the two major forces at play on a bridge, compression and tension.

Compression is the force that squeezes the bridge components together, trying to shorten their length. In terms of the design of a bridge, engineers refer to this force as compressional stress.

Tension is the opposite of a pulling force. Think of a rubber band. If you stretch it, you are applying tension force to the rubber band, and the same force, applied to a bridge, leads to tensional stress.

Both compression and tension apply to every bridge that has ever been built and can damage the bridge significantly if not managed correctly. As the loads on a bridge change, whether from the things moving across it or from other factors such as wind and so on, both tensional stress and compressional stress alter, and it is this change in the stresses that can cause a bridge to fail.

There are two main ways a bridge can fail - buckling or snapping. Buckling is when the compressional stress is more than the bridge component can withstand, while snapping occurs when the tensional stress is more than the bridge component can endure.

TEACHER BACKGROUND INFORMATION CONTINUED

Bridge design deals with these powerful forces by dissipating them. To dissipate force, a bridge design must spread the load of the force over a greater area, thereby preventing any single component from being overloaded by the force stress. The idea is to share the load between as many parts of the bridge as possible so that each takes on less force. Imagine a heavy desk. One person cannot lift and move it on his or her own, but 4 people can lift and move it easily, as they all share the load. This is dissipation.

Beam Bridge Design

This is the simplest bridge design of all. Sometimes referred to as a girder bridge, the beam bridge is composed of a rigid horizontal structure, which forms the bridge itself and is known as the beam, and two supports at either end, which are known as piers. The beam bridge uses the pier supports to support the entire weight of the bridge and anything on the bridge, with all the weight pushing straight down on the piers. The greater the distance between the piers, the weaker the beam will be, which is why beam bridges offer the shortest spans.

Both compressional and tensional stresses are exerted on a beam bridge, and it is the two together that can cause a beam bridge to fail. If we create the simplest beam bridge of all—a plank or wood laid across two boxes, one at either end—and add weight to the middle of the plank, it will start to bend. If we keep adding weight, the plank will eventually break, as the top side will buckle under compressional stress, and the underside of the plank will snap under tensional stress.

Truss Bridge Design

To expand on the beam design by strengthening its ability to cope with these forces and therefore allow for greater spans, designers added latticework sides, or a truss, to the beam, thereby creating the truss bridge. The truss adds rigidity to the beam and allows for a much greater dissipation of the compressional and tensional stress. This is because, when the beam starts to compress, the force is spread to the truss rather than just to the beam.

Because the truss design is usually built around triangles, the truss itself is a very good dissipater of force, transferring loads across a much wider area while retaining high levels of rigidity. This is the key to the truss design's increased strength over the basic beam.

However, even with this added ability to dissipate force and the increased rigidity, a truss bridge still features span limitations. Eventually the limits of the design will be felt, which means something else is required for bigger spans.

TEACHER BACKGROUND INFORMATION CONTINUED

Arch Bridge Design

Arch designs have been in use for over 2,000 years and can still be seen in the ruins of ancient Rome today. Used widely in all kinds of construction, the semicircular design dissipates compression forces outward to the two abutments at either end that hold the arch up and also push back to keep the arch in shape. This makes it ideal for bridge construction as well.

Another clever feature of arch construction from an engineering point of view is that tensional stress is almost completely eliminated, as the curve of the arch naturally pushes outward with compression, thereby reducing the tension forces significantly. In fact, the compressional forces pushing outward are so great that the Romans built arches from stone, thus using no mortar at all. The entire bridge was held together by the compressional force acting throughout the arch. Some of the ruins of ancient Rome today still contain arches built this way, having survived for two millennia. The tricky part is building them, as they require a lot of support scaffolding. This is because, until the two central stones are in place, the arch will not support itself.

However, the larger the arch radius, the greater the compression forces in the material. These forces can exceed the capacity of the stone and cause it to crush and the arch to collapse. Arches do not experience tension due to their shape. Other elements of the bridge may experience tension, but the arch is in compression. Modern materials have greatly expanded how far an arch bridge can reach. The use of steel and prestressed concrete allows for spans of up to 800 feet in most cases, but some arch bridges exceed this length. An arch bridge in West Virginia, the New River Gorge Bridge, has an arch measuring 1,700 feet in length and was for a while the largest single-span arch bridge in the world. That honor now goes to the Chaotianmen Bridge in China with a span of 1,811 feet.

Suspension Bridge Design

Suspension bridges are identified by their appearance, with towers and massive cables holding up the main bridge roadway. Perhaps the most famous example of this type of bridge in the world is found in San Francisco with the Golden Gate Bridge.

They can span huge distances because they distribute forces incredibly effectively. The design ensures this dissipation in the way it causes the roadway to be suspended by the cables and by means of the large towers that hold up those cables. The bridge's cables, from which the roadway is suspended, support the weight of that roadway, which includes both the roadway and everything on it. The weight of the load acting on the roadway is dissipated up the cables and is transferred to the large towers as a compression force. The towers then dissipate this force into the earth. At the same time, the supporting cables, which run horizontal to the bridge between the end anchorage points, receive the tension stress from the bridge and dissipate it through the large anchorages into the ground.

TEACHER BACKGROUND INFORMATION CONTINUED

A development of the suspension bridge is the cable-stayed bridge, which looks much like a suspension bridge without the horizontal support cables and huge anchorage points that dissipate the tensional stress. However, there are many differences. A cable-stayed bridge requires a single tower rather than two, and the cables are arranged radially to meet the road in several places and the tower at a single point, or parallel, in which case the cables attach to the road and the tower at different points.

The first cable-stayed bridges were constructed after World War II in Europe, although the Croatian inventor Faust Vrancic is thought to have drawn the first design for one as far back as the 16th century in his book *Machinae Novae*.

Cable-stayed bridges are popular today because they require fewer materials and are quicker to construct than suspension bridges. This is because they enable the use of more precast concrete components and require much less steel cable. With a span of up to 2,800 feet, they provide all the same advantages.

However, bridge design does not need to be this complex. Remember, a plank of wood placed across the banks of a stream is still a bridge.

Credit The term "BATS" and it's explaination obtained from https://science.howstuffworks.com/engineering/civil/bridge.

ASSESSMENT UNIT 2

The purpose of this lesson is to provide a visual interpretation and understanding of the effects of compression and tension forces on an object. The presentation will show that forces acting on the objects can affect the strength and length of a bridge.