PENSACOLA BAY BRIDGE
REPLACEMENT PROJECT

Popsicle Stick Bridge Lesson Plan – Unit VI

STRENGTH TESTING OF MATERIALS

Objective: After this lesson, students should be able to:

- list common materials used in the construction of bridges;
- describe several factors that engineers consider when selecting materials for the design of bridges; and
- explain the advantages and disadvantages of steel, concrete, and wood used in the construction of bridges.

Summary: Students will learn about the types of materials used by engineers in the design and construction of modern bridges. They will also be introduced to the basic properties of the materials that are important to bridge construction and review the advantages and disadvantages of using each material (steel, concrete, iron and wood).

Materials:

- PowerPoint showing the different materials used to build a bridge
- Strength of Materials Vocabulary 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.13.2

Explore the Law of Gravity by recognizing that every object exerts gravitational force on every other object and that the force depends on how much mass the objects have and how far apart they are.

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:

Alloy: A metal made by combining two or more metallic elements, especially to give greater strength or resistance to corrosion.

Blast furnace: A smelting furnace in the form of a tower into which a blast of hot compressed air can be introduced from below. Such furnaces are used chiefly to make iron from a mixture of iron ore, coke, and limestone.

Brittle: The ability of a material to show little or no yielding (or stretching) before failure.

Cement: A powder made of a variety of materials (usually certain types of clay and limestone) that hardens when mixed with water. Cement is an ingredient of concrete.

Compressive strength: The amount of compressive stress (pounds per square inch) that a material can resist before failing.

Concrete: A combination of cement and aggregate into one solid mass. Example: Gravel, sand, cement and water were mixed to create our concrete sidewalk.

Ductile: The ability of a material to be subjected to large strains before it ruptures or fails (to bend before breaking).

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

Furnace: A device used for high-temperature heating. It is an enclosed structure in which material can be heated to very high temperatures, e.g., for smelting metals.

Girder: A large concrete or steel beam or compound structure used for building bridges and the framework of large buildings.

Iron ore: A rock that contains a high concentration of iron.

Member: A constituent part of any structural or composite whole, such as a subordinate structural beam, column, or wall.

Modulus of elasticity: Indicates the stiffness of a material.

Pig iron: Crude iron as first obtained from a smelting furnace, in the form of oblong blocks.

Prestressed concrete: A form of concrete used in construction that is “pre-stressed” by being placed under compression prior to supporting any loads beyond its own dead weight.

Reinforced concrete: A concrete member with reinforcing steel embedded inside to resist tensile forces.

Span: The distance between abutments or intermediate supports.

Steel: Refined iron that contains virtually no impurities.

Strain: The elongation (lengthening) or contraction (shortening) of a material per unit length of the material.

Stress: Applied load divided by the material area it is acting on.

Tensile strength: The amount of tensile stress that a material can resist before failing.

Some vocabulary obtained from:
https://www.teachengineering.org/lessons/view/cub_brid_lesson04
https://www.encyclopedia.com/earth-and-environment/minerals-mining-and-metallurgy/metallurgy-and-mining-terms-and-concepts/

Procedure:

1. Pre-Lesson Assessment: Before showing the PowerPoint presentation, engage in a brief discussion.

2. Brainstorming: As a class, have students engage in an open discussion. Remind students that no idea or suggestion is “silly” when brainstorming. All ideas should be respectfully heard. Take an open position, encourage wild ideas, and discourage the criticism of ideas. Have them raise their hands to respond. Write their ideas on the board. Ask the students:

    - What things must be considered when selecting materials to be used in constructing a bridge?
      As they answer, review the following with them: As you know, bridges are basically constructed for the purpose of creating a crossing from one point to another. This includes connecting people to other places; shortening trip distances; accessing commercial areas, ports, and industries; and enabling other types of commerce. In fact, every one of us has, at some time or another, constructed bridges of our own.

    - Have you ever placed a board across a ditch or over a muddy patch of the yard? What materials did you use?
      (Ask students to share their experiences when they used available materials to create a bridge between two places. Scouts often make rope bridges.)

    - Have you ever looked at a bridge and wondered what it was made of and where the materials came from?
      Imagine our example of a wooden board spanning a small stream in the powerpoint. Did you notice how the board bent downward when the elephant walked on it? Would this same material be good for a really long bridge over a large body of water? Maybe not. The materials used for even simple bridges, such as crossing a stream, show us how learning about materials is crucial to the design and construction of bridges.

Activities obtained from: https://www.teachengineering.org/lessons/view/cub_brid_lesson04_activity1

Procedure continued:

Main Activity – *open discussion in classroom*

1. When designing bridges, engineers must really understand the properties of the materials they have available. Also, many things must be considered when selecting the materials for bridge construction. What are some of these things? (Take ideas from students, write them on the board, and discuss each.) Supplement the students' answers with the following thought: The strength of the material is usually the first thing engineers consider. They also think about the cost, availability, and suitability of that material for that particular bridge. In some cases, the speed of construction is a factor that can vary depending on the materials chosen.

2. What materials are commonly used in bridge construction? (Take ideas from students and write them on the board.) Steel and concrete are the most popular choices for modern bridge construction. Other materials include wood, iron (a different type of steel), plastic, and stone. Before the availability of steel and concrete, most bridges were made of wood, rope, and/or stone. Stone is only useful in handling compression forces and is therefore most often used in arch bridges. Wood was often used to make bridges that required shorter spans, such as crossing streams or ravines. Wood was also used with rope to cross wider rivers and canyons.

3. Why don't engineers build bridges out of diamonds? Diamonds are the strongest material. Diamonds are very strong, but also incredibly expensive, and building a bridge out of diamonds would be very difficult. Engineers must think about how much a material costs when they are using it as well as how easy it is to work with the material.

4. Discuss the advantages and disadvantages of commonly used materials used to build bridges – concrete and steel.
   (Answer: Steel has high strength in both compression and tension. Steel can be bent or shaped easily into different forms. Concrete can be shaped easily with the use of forms [much like molds]. Concrete is also extremely strong in compression.)
   How about a disadvantage to steel and concrete? (Answer: Steel is expensive and corrodes or rusts, so it must be protected. Concrete is very weak in tension.)

Activity Two

Arrange to have the Pensacola Bay Bridge staff bring examples of tested materials for "show and tell" in your classroom. Ask if the university tests steel, concrete, wood, plastic, and/or composite materials.

Activity Three

Show students an online interactive tool to visually illustrate the properties of wood, plastic, aluminum, brick, concrete, reinforced concrete, cast iron, and steel. Use a fun mouse-controlled slider to drag, stretch, or squeeze materials to failure. *See WGBH's Building Big: Materials Lab website at http://www.pbs.org/wgbh/buildingbig/lab/materials.html*

TEACHER BACKGROUND INFORMATION

Essential Materials:

Pedestrians and vehicles use bridges to bypass obstacles. By spanning canyons, rivers, and roads and providing a more direct route, they can often dramatically cut travel times. Bridges are complex, carefully engineered structures made of materials that are light enough to be practical but are also strong and long lasting.

Traditional building materials for bridges were stone, timber, and steel and have more recently included reinforced and pre-stressed concrete. Some types of plastics, aluminum, and aluminum alloys are also used for special elements. These materials differ in strength, workability, durability, and corrosion resistance as well as in structure, texture, color, and surface treatments. The shape, environmental compatibility, technical quality, and costs are necessary to create the best bridge design and determine what materials to use.

Stone

The Etruscans, Romans, Fratres Pontifices from the Middle Ages (ca. 1100), and later master builders built the great old bridges of stone masonry. When their foundations were constructed with hard stone on firm ground, their arches and piers lasted thousands of years. Stone bridges can be beautiful and durable with spans of up to 150 meters.

Regrettably, stone bridges are now very expensive to build. Over an extended period, however, a well-designed and constructed stone bridge could ultimately be the cheapest option, enduring centuries with almost no maintenance—unless attacked by extreme air pollution.

Nowadays, stone is confined to surfaces, being preset or fixed facing on arches, abutments, and piers. Sound weather-resistant stone is the most suitable, especially fundamental rock, such as crystallized limestone, diabase, gneiss, granite, or porphyry. There must be harmony between the structure's size, abutments, piers, and the size and surface roughness of the stone blocks used.

Modern bridges are most commonly constructed using two basic materials: steel and concrete. The typical material properties of these are particularly valuable in the design and engineering of a bridge.

Steel

Steel has the most favorable strength qualities among the common bridge-construction materials. Therefore, it is most suitable for the longest, most daring spans. With a compressive and tensile strength of 36,000 pounds per square inch, normal building steel has ten times the compressive strength and a hundred times the tensile strength of medium concrete. Steel's special merit is its ductility. Before it breaks, it deforms considerably, yielding above a certain level of stress. Steel's yield strength is the first term in standard quality.

TEACHER BACKGROUND INFORMATION CONTINUED

For bridges, high-strength steel is often preferable. For building purposes, steel is fabricated in plate form (1/4 to 3 1/4 inches thick), which is formed by rolling when red hot. Cast steel is used for bearings and other items. Special steels with strengths of 270,000 pounds per square inch for ropes, cables, and members under tension are processed in different ways to allow the building of bold cable-stayed or suspension bridges.

Steel's high strength allows beams or girders to have small cross-sections, contributing to the structures' low dead loads.

Concrete

Two materials, cement and aggregate, combine to create concrete. Cement is composed of various materials (usually limestone and certain types of clay) in powder form. When mixed with water, cement undergoes a chemical reaction called hydration, which causes it to harden. Meanwhile, aggregate is a mixture including fine material (typically sand) and coarse material (typically gravel rock). When water, aggregate, and cement are mixed and allowed to cure, the result is a hardened mass called concrete.

Wood

Wood should only be used for relatively simple structures, as it is not as reliable as other materials. However, it is affordable and easy to work with, even using rudimentary equipment and tools. Using construction material chosen primarily for natural beauty, wood bridges are used for light vehicle access or pedestrian traffic. When exposed to moisture, wood swells and rots; thus, wood bridges protected by chemical treatments against rain will last longer.

ASSESSMENT
UNIT 6

Homework Worksheet: Assess students' understanding of the lesson by assigning the attached Strength of Materials Worksheet as homework. The worksheet includes a matching activity to reinforce vocabulary and definitions.

(Homework) Observation: Assess students' understanding of the lesson by having them observe a bridge as they travel home and then determine what types of materials the bridge is made of.

HOMEWORK WORKSHEET

Strength of Materials Vocabulary

Directions: Match the vocabulary word with the definition by drawing a line from the vocabulary term to the corresponding definition.

VOCABULARY TERM	DEFINITION
Tensile strength •	• The amount of compressive stress that a material can resist before failing.
Ductile •	• The elongation or contraction of a material per unit length of the material.
Strain •	• A rock that contains a high concentration of iron.
Modulus of elasticity •	• Iron that is refined to contain virtually no impurities.
Compressive strength •	• A concrete member with steel embedded inside to resist tensile forces.
Brittle •	• The amount of tensile stress that a material can resist before failing.
Stress •	• A combination of cement and aggregate into one solid mass.
Steel •	• Indicates the stiffness of a material.
Cement •	• The ability of a material to be subjected to large strains before it ruptures or fails.
Iron ore •	• Applied load divided by the material area it is acting on.
Concrete •	• The ability of a material to show little or no yielding before failure.
Reinforced concrete •	• A powder made of a variety of materials that hardens when mixed with water.

HOMEWORK WORKSHEET

ANSWER KEY

VOCABULARY TERM	DEFINITION
Tensile strength	The amount of compressive stress that a material can resist before failing.
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LESSON CLOSURE

Think of bridges around your home and along the roadways, bike paths, or walking paths that you use. What do the bridges look like? What types of materials were used to construct them? Many types of materials, including concrete, steel, wood, iron, plastic, and stone, have been used to create modern bridges.

Today, we learned that concrete and steel are the most commonly used materials in large modern bridges. What is an advantage to using steel or concrete? (Answer: Steel has high strength in both compression and tension. Steel can be bent or shaped easily into different forms. Concrete can be shaped easily with the use of forms [much like molds]. Concrete is also extremely strong in compression.)
How about a disadvantage to steel or concrete? (Answer: Steel is expensive and corrodes or rusts. Concrete is very weak in tension.)

Engineers consider all the advantages and disadvantages of materials when deciding which material to incorporate into their bridge designs. What are other things that engineers must consider when selecting materials for the construction of a bridge? (Answer: The strength of the material is usually the most important factor engineers consider. They also think about the cost, availability, speed of construction, and suitability of that material for that particular bridge.)

** Additional Multimedia Support

Show students a blast furnace animation at the How Stuff Works website:
https://www.youtube.com/watch?v=9l7JqonyoKA&t=12s

Citation:
https://www.teachengineering.org/lessons/view/cub_brid_lesson04
http://www.aboutcivil.org/Materials%20used%20in%20bridges.html