Unit: Structures
Lesson: Bridges

Objectives

After this lesson students will:

- Know the three main bridge styles along with others talked about in class.
- Understand the terms associated with bridges.
- Know the uses, spans, and limitations of each of the bridges talked about in class.
- Know the materials that make up bridges
- Understand the forces that affect a bridges stability and longevity.
- Be able to create a scale bridge of their choice to be tested for strength in competition with the other bridges in class.

Content Outline

I. Beam Bridges

A. Uses

1. Span streams
2. Rivers
3. Small Valleys
4. Roads.

B. Design

1. A beam or "girder" bridge is the simplest and most inexpensive kind of bridge.
2. In its most basic form, a beam bridge consists of a horizontal beam that is supported at each end by piers. The weight of the beam pushes straight down on the piers.
3. The beam itself must be strong so that it doesn't bend under its own weight and the added weight of crossing traffic. When a load pushes down on the beam, the beam's top edge is pushed together (compression) while the bottom edge is stretched (tension).

C. Materials

1. Pre-stressed concrete is an ideal material for beam bridge construction; the concrete withstands the forces of compression well and the steel rods imbedded within resist the forces of tension. Pre-stressed concrete also tends to be one of the least expensive materials in construction. But even the best materials can't compensate for the beam bridge's biggest limitation: its length.

D. Span

1. Beam bridges rarely span more than **250 feet**
2. To span greater distances, they can be chained together, called a "continuous span." The limitation is that there is no room for large boats or ships to pass underneath.

E. Limitations

1. Short span

II. Arch Bridges

A. Uses

1. For spans where towers are not feasible. (Ex. A 1,000 foot deep canyon)

B. Design

1. Instead of pushing straight down, the weight of an arch bridge is carried outward along the curve of the arch to the supports at each end. These supports, called the abutments, carry the load and keep the ends of the bridge from spreading out.

C. Materials

1. Today materials like steel and pre-stressed concrete have made it possible to build longer and more elegant arches

D. Span

1. Typically, modern arch bridges span between **200-800 feet**
2. But there is a 1700 foot span in New River Gorge, West Virginia.

E. Limitations

1. Constructing an arch bridge can be tricky, since the structure is completely unstable until the two spans meet in the middle.

III. Suspension Bridges

A. Uses

1. Span bays, wide rivers, etc. The towers enable the main cables to be draped over long distances, allowing it to span the longest of any type of bridge.

B. Design

1. True to its name, a suspension bridge **suspends** the roadway from huge main cables, which extend from one end of the bridge to the other. These cables rest on top of high towers and are secured at each end by anchorages.
2. Most of the weight of the bridge is carried by the cables to the anchorages, which are imbedded in either solid rock or massive

concrete blocks. Inside the anchorages, the cables are spread over a large area to evenly distribute the load and to prevent the cables from

C. **Materials**

1. Some of the earliest suspension bridge cables were made from twisted grass. In the early nineteenth century, suspension bridges used iron chains for cables.
2. Today, the cables are made of thousands of individual steel wires bound tightly together. Steel, which is very strong under tension, is an ideal material for cables; a single steel wire, only 0.1 inch thick, can support over half a ton without breaking.

D. **Span**

1. Suspension bridges can span distances from **2,000 to 7,000 feet** -- far longer than any other kind of bridge.

E. **Limitations**

1. They tend to be the most expensive to build.

IV. Cable-Stayed Bridges

A. **Uses**

1. For medium length spans cable-stayeds are fast becoming the bridge of choice.

B. **Design**

1. Compared to suspension bridges, cable-stayeds require less cable, can be constructed out of identical pre-cast concrete sections, and are faster to build.
2. On cable-stayed bridges the weight is held by the towers, unlike suspension bridges where it's held at the anchorages.
3. The cables can be attached to the roadway in a variety of ways, on the outside of the bridge or in-between the lanes.
4. In a radial pattern, cables extend from several points on the road to a single point at the top of the tower. In a parallel pattern, cables are attached at different heights along the tower, running parallel to one other.

C. **Materials**

1. Same as Suspension.

D. **Span**

1. Bridges between **500 and 2,800 feet**

E. **Limitations**

1. Some say it has less stability (hasn't been popular in U.S. until recently - may only be because of looks!)

Procedures

Day 1:

- Lecture on content

Day 2:

- Go over the following questions with the students-

1. What are some of the primary factors that engineers must consider as they design a bridge?
Some of the numerous factors that engineers consider as they design bridges are the purpose of the bridge, available materials, accessibility by contractors, traffic flow and load, soil composition, and water depth.

2. What are the three primary families of bridges?
The three primary families of bridges are suspension, beam, and arch bridges.
More: Cable-Stayed, Cantilever, Truss and Pontoon

3. The collapse of the Tacoma Narrows Bridge was a catastrophic yet educational event. What were the unique environmental factors that engineers overlooked as they designed this bridge?
During the design and construction of the Tacoma Narrows Bridge, engineers failed to account for the aerodynamics of the bridge. This was vitally important due to the simple fact that the bridge was subject to a constant 40 mile an hour wind. The collapse of the bridge was not due to the brute force of the wind but to a resonance between the natural frequency of oscillation of the bridge and the frequency of wind-generated vortices that pushed and pulled alternately on the bridge structure.

4. How can the use of fiber optics be helpful in monitoring the structural integrity of bridges?
Engineers have begun to use fiber optics to monitor changes in structural integrity of bridges. As the bridge develops a weakening in its structure, fiber optic sensors then recognize this weakening and send a signal to a monitoring station. Technicians can then repair any damage that may have occurred or prevent major structural failures. This technology is very important because these sensors can recognize damage not visible to the human eye.

5. Describe how bridges have impacted communities both economically and socially.

6. Bridges and highways are built to support great loads. Discuss why weigh stations are necessary along highways and bridges.

7. Discuss the three primary families of bridges. Describe how their structures distribute the load the bridge must support.

8. Define force and equilibrium. Describe the forces that act on a bridge. Discuss

why it is important for the forces acting on a bridge to be in a state of equilibrium.
Tension or Tensile Stress, Compression

9. Discuss why suspension bridges have enabled engineers to design and construct bridges that span great lengths and why the arch and beam bridges were not feasible technologies for long-spanning bridges?

10. Earthquakes cause a great deal of damage to bridges. Describe some modifications you would make to bridges to minimize damage. (Any idea is acceptable as long as you can support it with a logical rationale.)

- Start learning activity

Learning Activities

- Worksheet on "which bridge would work best with each situation."
- In pairs, students will create a scale bridge of their choice to be tested for strength in competition with the other bridges in class.
- Can choose between
    - Beam
    - Arch
    - Suspension
    - Truss
    - Cable-Stayed
    - Cantilever

Assessment (Next Page)

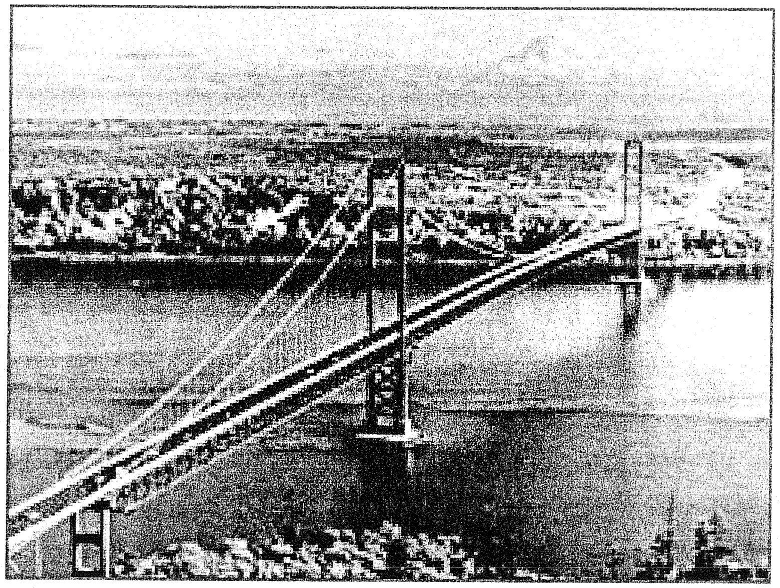
- 25 Points Total

5 Points	Design/ Problem Solving Process
15 Points	Bridge Strength (use Bridge Weight/Weight Held ratio) - no units
5 Points	Use of Work-time

Resources

Technology Interactions Textbook
http://www.pbs.org/wgbh/nova/bridge/meetcable.html
Craft Sticks or 1/8" to 1/4" square Balsa Wood (limit the amount they can use)
Glue (White or Hot Glue)
String (For use with Suspension and Cable-Stayed Bridges)
Rope (" " "...)
Scissors

Suspension



Uses

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Design

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Span

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Limitations

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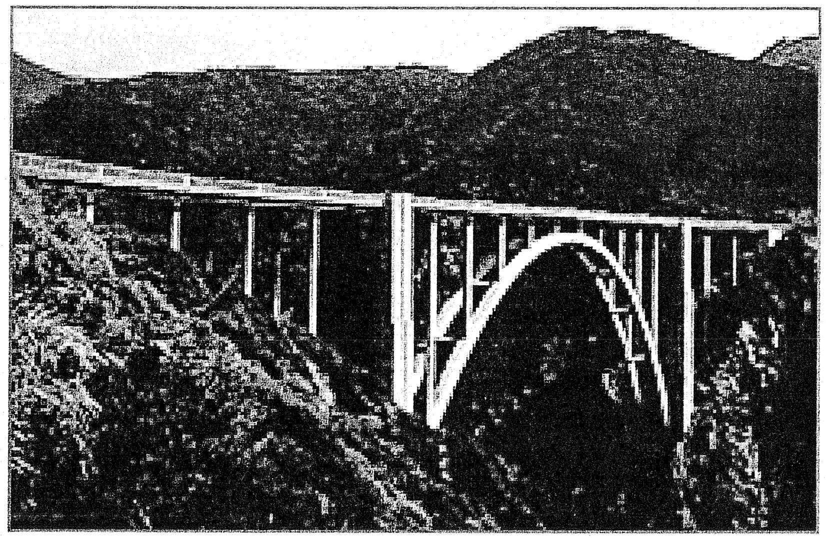
Arch Bridges



Uses

- For spans where towers are not feasible. (ex. A 1,000 foot deep canyon)

Design

- Instead of pushing straight down, the weight of an arch bridge is carried outward along the curve of the arch to the supports at each end. These supports, called the abutments, carry the load and keep the ends of the bridge from spreading out.

Materials

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Span

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- But there is a 1700 foot span in New River Gorge, West Virginia.

Limitations

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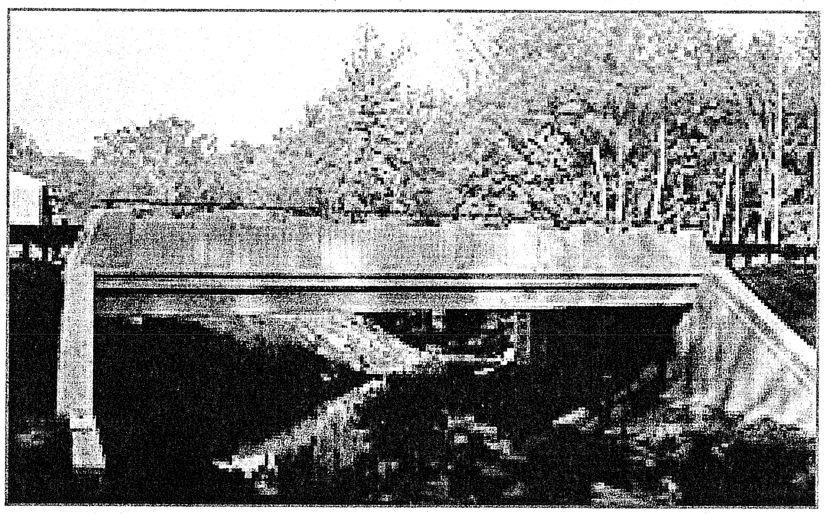
Beam Bridges



Uses

- Span streams, rivers, small valleys, roads.

Design

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Span

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Limitations

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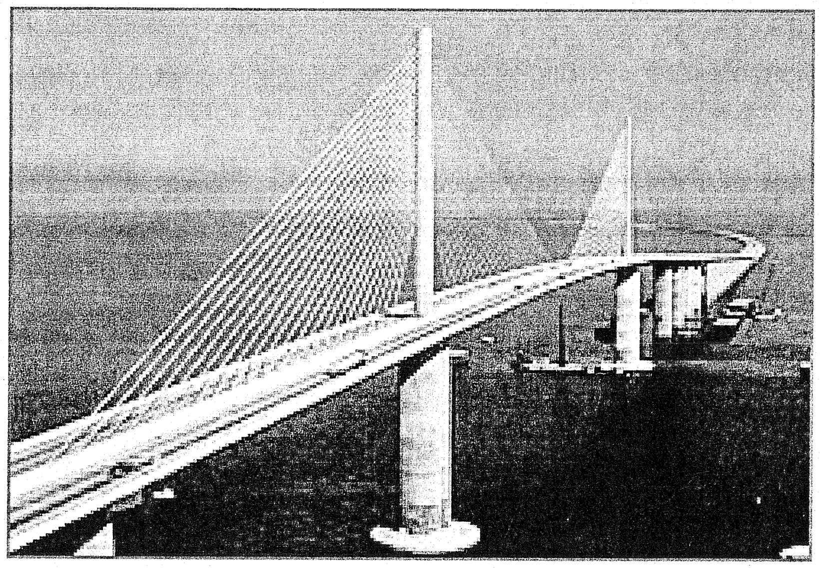
Cable-Stayed Bridges



Uses

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Design

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Materials

- Same as Suspension.

Span

- Bridges between 500 and 2,800 feet

Limitations

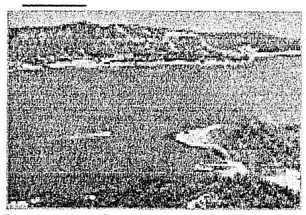
- Some say it has less stability (hasn't been popular in U.S. until recently- may only be because of looks!)

Name______________________

Bridges Worksheet

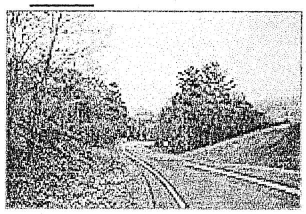
Match the following situation on the left with the bridge that would work the best:

1.____



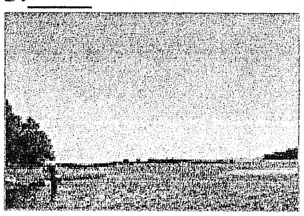
A 5,000-foot span across an ocean bay where huge ships come and go.

2.____



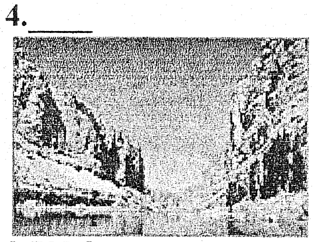
A 120-foot span across a reeway.

3.____



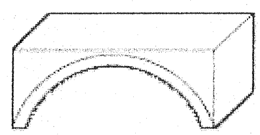
A 1,000-foot span across a river busy with barge traffic.

4.____

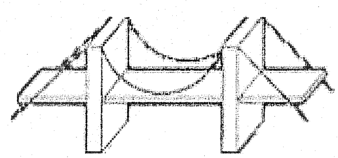


A 700-foot span across a deep canyon gorge.

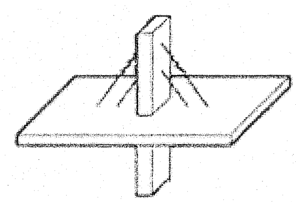
A. Arch Bridge



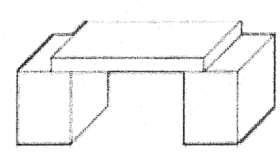
B. Suspension Bridge



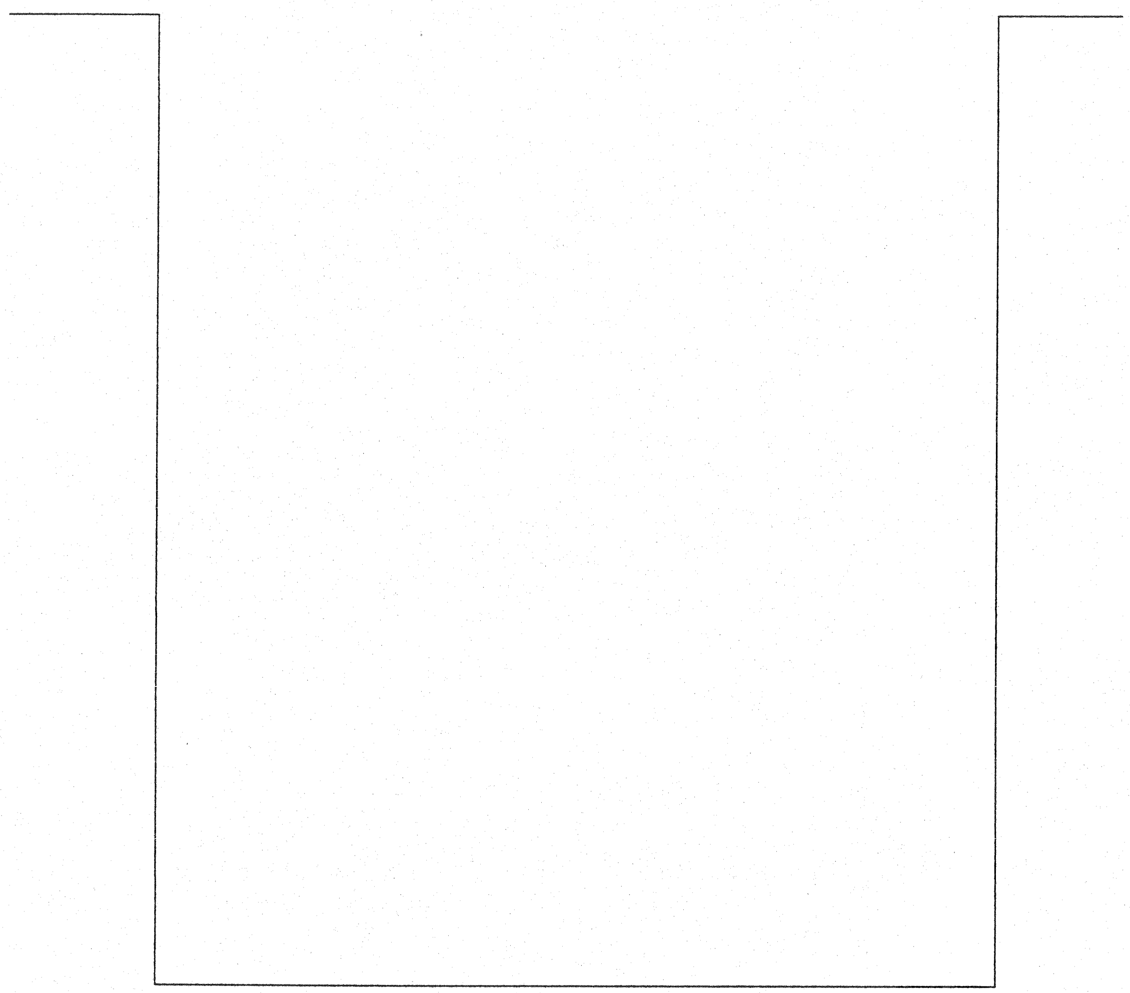
C. Cable-Stayed Bridge



D. Beam Bridge



5. **Sketch an arch bridge spanning between the to sides of the canyon below:**



Using the 6 Step Problem Solving Process

First, list the six step problem solving method in the space provided below. **Second,** use the process to solve the problem and write your answers in the same space.

STEP 1
____
Solve____________________________________
____

STEP 2
____
Solve____________________________________
____

STEP 3
____
Solve____________________________________
____

STEP 4
____
Solve____________________________________
____

STEP 5
____
Solve____________________________________
____

STEP 6
____
Solve____________________________________
____

Sketch four different bridge designs you might use:

1.

2.

3.

4.

Sketch the final bridge design you will use: