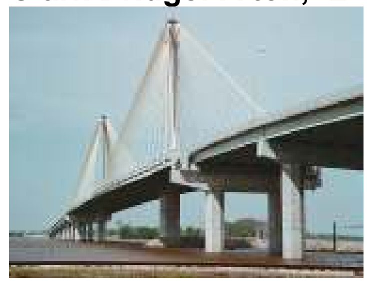
Activity # 9 (Part 1 of 5)

Building Bridges: The Basics

Clark Bridge: Alton, IL



There are three major types of bridges:

- The beam bridge
- The arch bridge
- The suspension bridge

The biggest difference between the three is the distances they can cross in a single **span**. A span is the distance between two bridge supports, whether they are columns, towers or the wall of a canyon. A modern beam bridge, for instance, is likely to span a distance of up to 200 feet (60 meters), while a modern arch can safely span up to 800 or 1,000 feet (240 to 300 m). A suspension bridge, the pinnacle of bridge technology, is capable of spanning up to 7,000 feet (2,100 m).

What allows an arch bridge to span greater distances than a beam bridge, or a suspension bridge to span a distance seven times that of an arch bridge? The answer lies in how each bridge type deals with two important forces called **compression** and **tension**.

> **Compression** is a force that acts to compress or shorten the thing it is acting on.
>
> **Tension** is a force that acts to expand or lengthen the thing it is acting on.

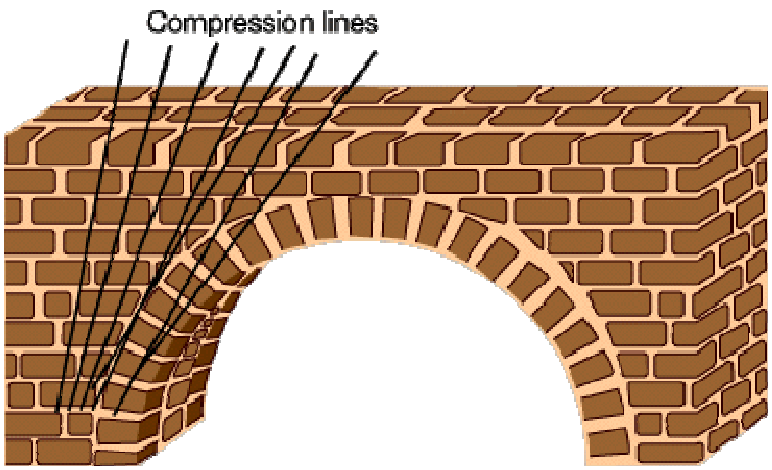
A simple, everyday example of compression and tension is a spring. When we press down, or push the two ends of the spring together, we compress it. The force of compression shortens the spring. When we pull up, or pull apart the two ends, we create tension in the spring. The force of tension lengthens the spring. Compression and tension are present in all bridges, and it's the job of the bridge design to handle these forces without buckling or snapping. **Buckling** is what happens when the force of compression overcomes an object's ability to handle compression, and **snapping** is what happens when the force of tension overcomes an object's ability to handle tension. The best way to deal with these forces is to either dissipate them or transfer them. To **dissipate** force is to spread it out over a greater area, so that no one spot has to bear the brunt of the concentrated force. To **transfer** force is to move it from an area of weakness to an area of strength, an area designed to handle the force. An arch bridge is a good example of dissipation, while a suspension bridge is a good example of transference.

Activity # 9 (Part 2 of 5)

The Arch Bridge

An arch bridge is a semicircular structure with abutments on each end. The design of the arch, the semicircle, naturally diverts the weight from the bridge deck to the abutments.

Compression
Arch bridges are always under compression. The force of compression is pushed outward along the curve of the arch toward the abutments.



Tension
The tension in an arch is negligible. The natural curve of the arch and its ability to dissipate the force outward greatly reduces the effects of tension on the underside of the arch. The greater the degree of curvature (the larger the semicircle of the arch), however, the greater the effects of tension on the underside.

As just mentioned, the shape of the arch itself is all that is needed to effectively dissipate the weight from the center of the deck to the abutments. As with the beam bridge, the limits of size will eventually overtake the natural strength of the arch.

The Beam Bridge

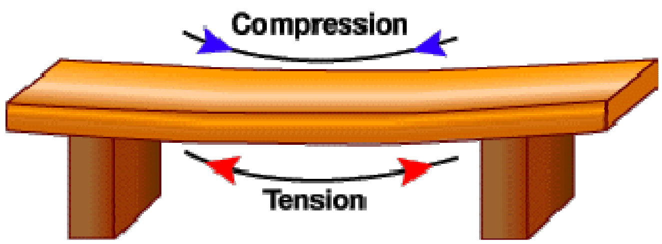
A beam bridge is basically a rigid horizontal structure that is resting on two piers, one at each end. The weight of the bridge and any traffic on it is directly supported by the piers. The weight is traveling directly downward.

Compression
The force of compression manifests itself on the top side of the beam bridge's deck (or roadway). This causes the upper portion of the deck to shorten.

Activity # 9 (Part 3 of 5)

Tension
The result of the compression on the upper portion of the deck causes tension in the lower portion of the deck. This tension causes the lower portion of the beam to lengthen.

Example
Take a two-by-four and place it on top of two empty milk crates -- you've just created a crude beam bridge. Now place a 50-pound weight in the middle of it. Notice how the two-by-four bends. The top side is under compression and the bottom side is under tension. If you keep adding weight, eventually the two-by-four will break. Actually, the top side will buckle and the bottom side will snap.



Dissipation
Many beam bridges that you find on highway overpasses use concrete or steel beams to handle the load. The size of the beam, and in particular the height of the beam, controls the distance that the beam can span. By increasing the height of the beam, the beam has more material to dissipate the tension. To create very tall beams, bridge designers add supporting lattice work, or a **truss**, to the bridge's beam. This support truss adds rigidity to the existing beam, greatly increasing its ability to dissipate the compression and tension. Once the beam begins to compress, the force is dissipated through the truss.

Despite the ingenious addition of a truss, the beam bridge is still limited in the distance it can span. As the distance increases, the size of the truss must also increase, until it reaches a point where the bridge's own weight is so large that the truss cannot support it.

Truss Strength
A single beam spanning any distance experiences compression and tension. The very top of the beam experiences the most compression, and the very bottom of the beam experiences the most tension. The middle of the beam experiences very little compression or tension. If the beam were designed so that there was more material on the top and bottom, and less in the middle, it would be better able to handle the forces of compression and tension. (For this reason, I-beams are more rigid than simple rectangular beams.)

A truss system takes this concept one step further. Think of one side of a truss bridge as a single beam. The center of the beam is made up of the diagonal members of the truss, while the top and bottom of the truss represent the top and bottom of the beam. Looking at a truss in this way, we can see that the top and bottom of the beam contain more material than its center (corrugated cardboard is very stiff for this reason).

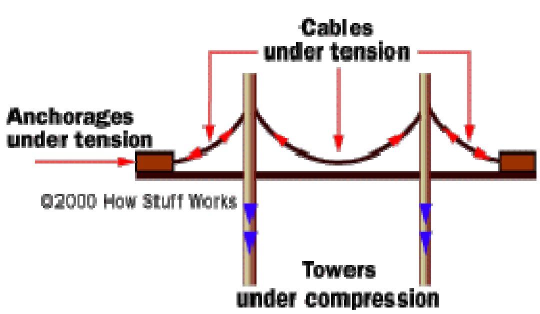
In addition to the above-mentioned effect of a truss system, there is another reason why a truss is more rigid than a single beam: A truss has the ability to dissipate a load through the truss work. The design of a truss, which is usually a variant of a triangle, creates both a very rigid structure and one that transfers the load from a single point to a considerably wider area.

The Suspension Bridge

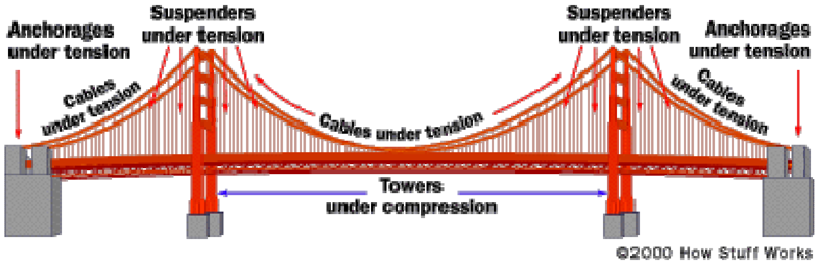
A suspension bridge is one where cables (or ropes or chains) are strung across the river (or whatever the obstacle happens to be) and the deck is suspended from these cables. Modern suspension bridges have two tall towers through which the cables are strung. Thus, the towers are supporting the majority of the roadway's weight.

Compression
The force of compression pushes down on the suspension bridge's deck, but because it is a suspended roadway, the cables transfer the compression to the towers, which dissipate the compression directly into the earth where they are firmly entrenched.

Tension
The supporting cables, running between the two anchorages, are the lucky recipients of the tension forces. The cables are literally stretched from the weight of the bridge and its traffic as they run from anchorage to anchorage. The anchorages are also under tension, but since they, like the towers, are held firmly to the earth, the tension they experience is dissipated.



Activity # 9 (Part 5 of 5)



Almost all suspension bridges have, in addition to the cables, a supporting truss system beneath the bridge deck (a **deck truss**). This helps to stiffen the deck and reduce the tendency of the roadway to sway and ripple.

A classic suspension bridge in New York City

Resources: http://science.howstuffworks.com/bridge7.htm