BRIDGE DESIGN

Can you believe people built bridges before they built houses? **It's true...** Because our prehistoric relatives wandered around looking for food, they didn't even think about building houses. However, to wander very far, they did need to build bridges across rivers and streams.

Nature provided the first bridges. Trees that had fallen across streams, rock stepping stones, and hanging vines were among the choices of materials.

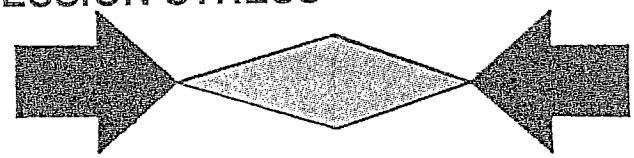
Every bridge ever constructed had the same 4 stresses to overcome:

Tensile Stress
Compression Stress
Shear Stress
Torsion Stress

TENSILE STRESS

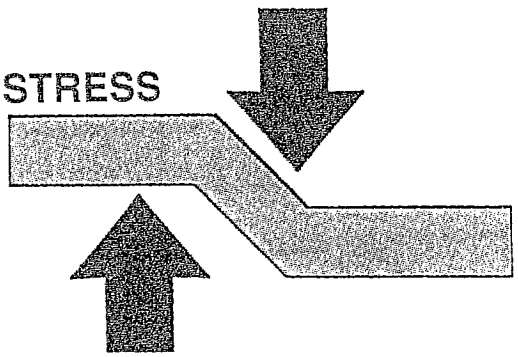
Forces that try to stretch material and pull it apart.

COMPRESSION STRESS



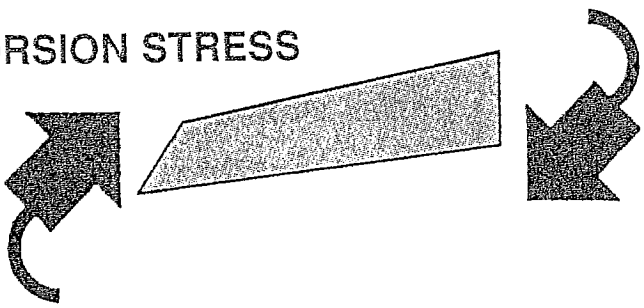
Forces that try to push or squeeze material together.

SHEAR STRESS



Forces that try to make materials tear and slide by each other.

TORSION STRESS



Forces that try to twist and bend material.

BRIDGE PROBLEMS

Many problems must be looked at before a good bridge can be designed.

Even professional bridge builders make mistakes. Those mistakes can cost human lives and great amounts of dollars.

In 1940, a suspension bridge that had been built across the Tacoma Narrows in Washington State blew down in a wind storm. The bridge had been called "Galloping Gertie" because it moved and twisted so much in the wind.

Many lives were lost in Kansas City when an indoor walkway collapsed and fell on people below.

All of these disasters happened because designers used wrong materials and failed to look at all the stresses on the bridges.

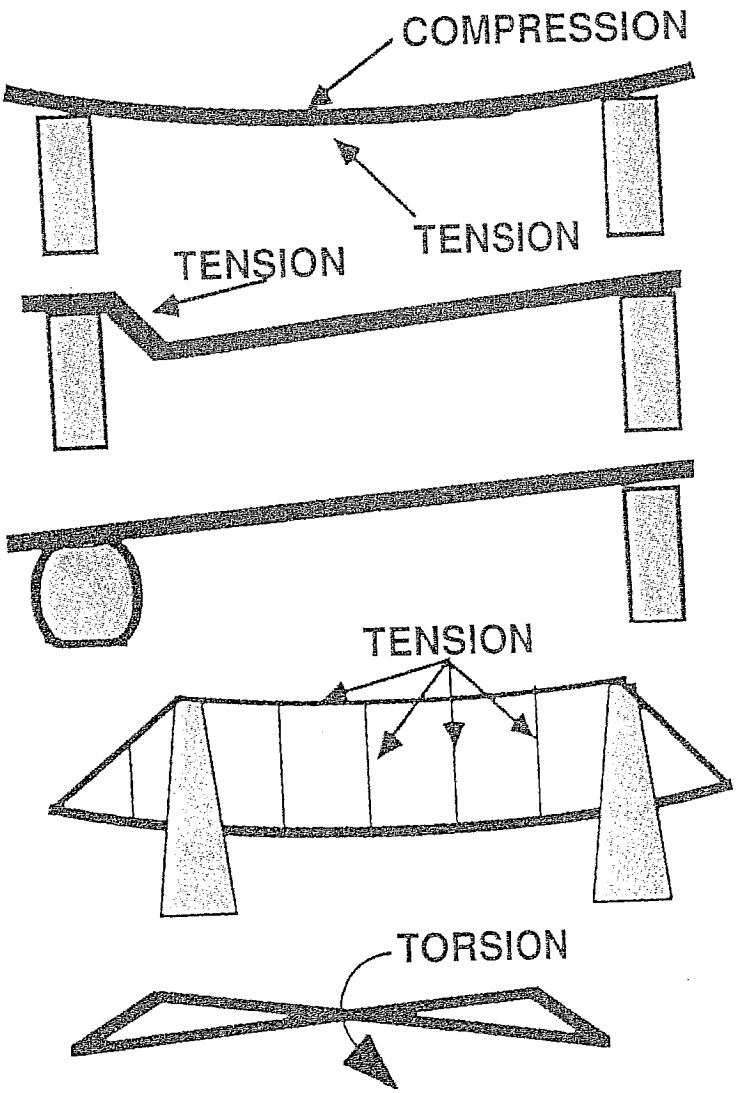
BENDING
The weight of the bridge and the load on the bridge caused it to sag. The materials on top of the bridge compress. Tension forces act on the bottom.

SHEAR
The weight and load of the bridge make the materials slide by each other. Eventually they tear apart.

COMPRESSION
Bridge piers may buckle under the weight.

STRETCHING
Bridges that use cables sag when the cables stretch.

TWISTING
Some bridges will twist when traffic weights are not the same on both sides. The wind will also cause twisting. Torsion forces act on the point being twisted.



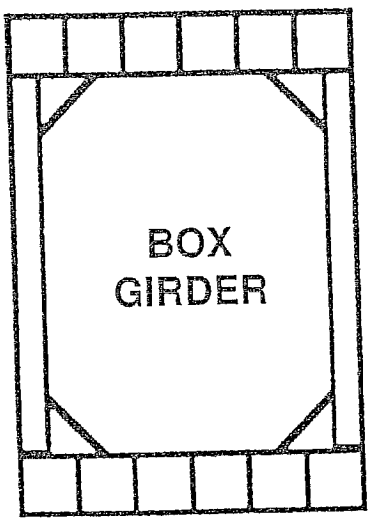
BRIDGE MATERIALS

Early wood or vine bridges would eventually rot, and stones could not span large spaces.

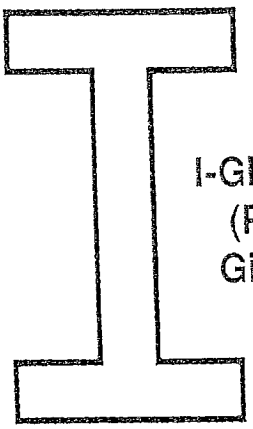
Selection of materials is very important in bridge construction. Early suspension bridges could be destroyed by the movement of traffic or animals. One bridge in the U.S. was destroyed by the movement of sheep walking across.

Modern bridges often use steel in the form of cables or girders, or concrete as construction materials.

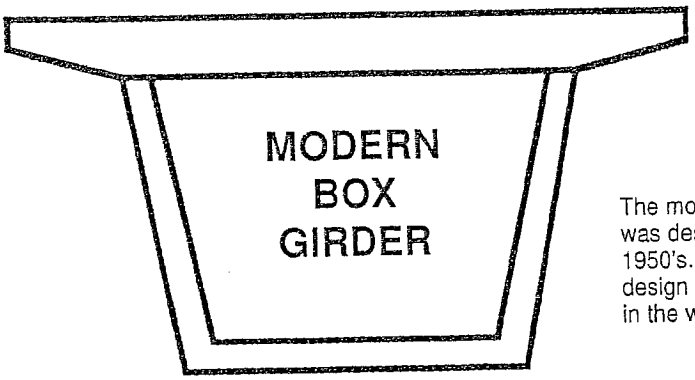
STEEL TUBES, GIRDERS, BEAMS, ETC.



Rectangular tubes were designed to be rigid. Traffic could pass on top of the "box girder" as well as through the inside.



I-Girders were made from steel. They made it possible to support heavy loads over great distances.

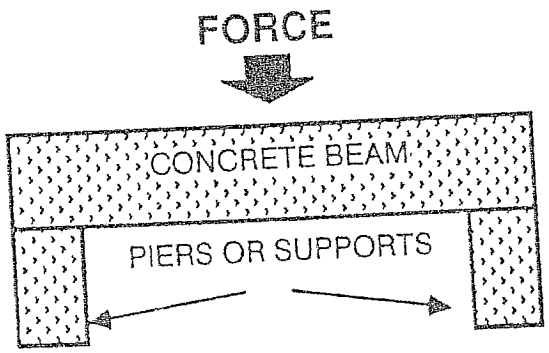


The modern box girder was designed in the 1950's. Its wide, flat design kept it stable in the wind.

CONCRETE

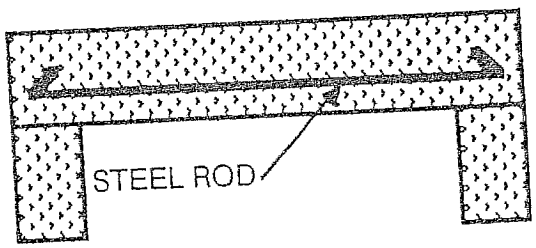
Concrete is a mixture of sand, stone, cement, and water. When the water dries, the concrete remains in a hard, dry form. Concrete can be poured into a mold and be shaped into beams or other forms.

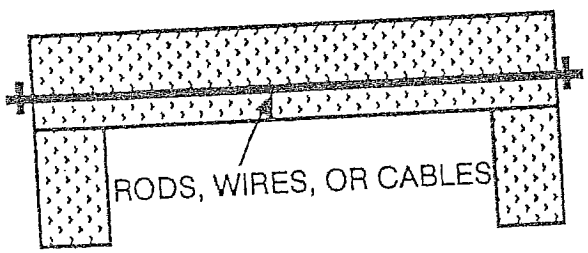
Concrete has good compression properties, but not so good under tension. However, when steel mesh or rods are put into the wet concrete it can be made into reinforced concrete.



When using concrete beams, the stress is greatest at the center. Compressive forces are on top of the beam, and tension forces on the bottom.

In the late 1800's an American lawyer named Thaddeus Hyatt discovered that steel rods made concrete beams stronger. The rods were put near the bottom of drying concrete beams. The end of the rods were bent up at an angle where the beam rested on the supports.





In the early 1900's, a French engineer discovered how to pre-stress concrete. Concrete is again poured around the rods, wires, or cables. As the concrete dries, the rods, wires, or cables are tightened. When the concrete is dry, the rods are kept under tension by the dried concrete. Not only is pre-stressed concrete better able to deal with the bridge stresses, but it is cheaper and easier to use.

TYPES OF BRIDGES

Although there are many different kinds of bridges, they usually fall into one of three types:

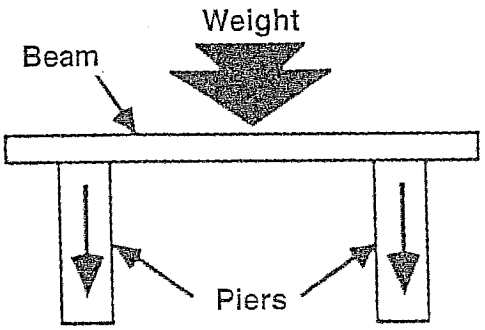
BEAM
The oldest type of bridge. A tree, plank, or girder system supported between two piers of ground.

ARCH
Very old designs. Used by Roman engineers to build stone aqueducts. The arch lets the weight be carried out to the sides through curving paths. Abutments are the points where the arch meets the ground.

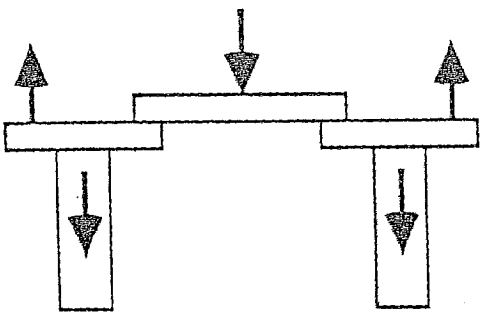
SUSPENSION
Jungle vines have been replaced by steel cables. The cables are supported from towers. Suspension bridges are used for spanning long distances.

BEAM BRIDGES

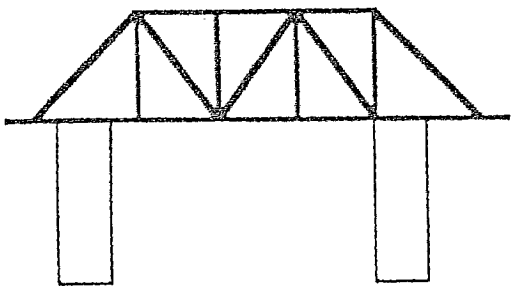
Beam bridges are the least expensive, and easiest to build. The weight is spread between the two piers. There are several different kinds of beams.



GIRDER
Box-girder or I-girders laid between two piers.



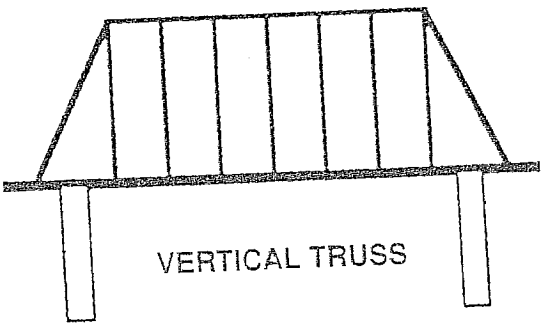
CANTILEVER
Cantilever beam bridges are built so that the middle beam is supported by the two outside beams. The arrows show how the forces are acting on the different parts of the bridge.



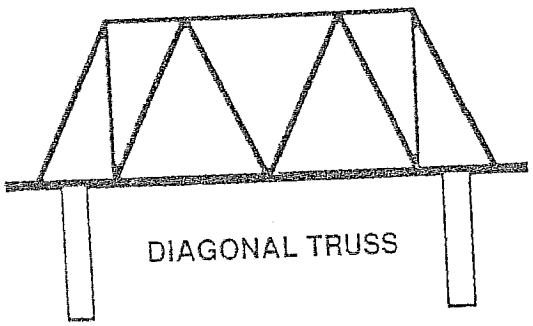
TRUSS
The truss beam bridge uses a series of triangular shapes to distribute the weight across the beam to the piers.

TYPES OF TRUSS BEAM BRIDGES

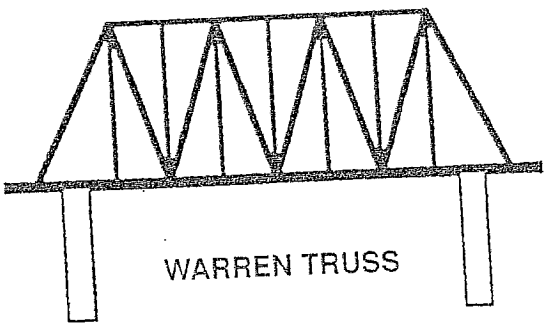
There are many different types of designs used in the truss beam bridge. Every design uses a series of triangular shapes to help distribute the load.



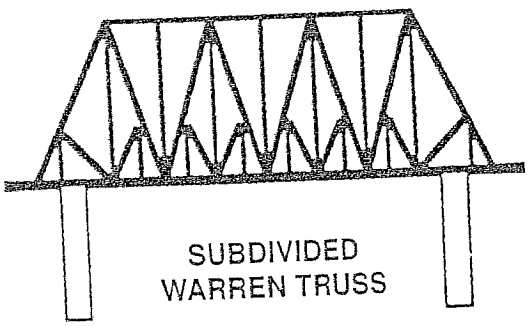
VERTICAL TRUSS



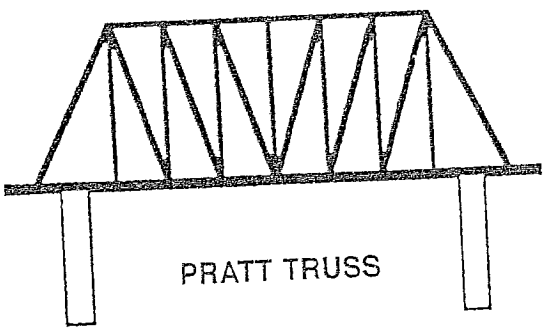
DIAGONAL TRUSS



WARREN TRUSS



SUBDIVIDED WARREN TRUSS



PRATT TRUSS

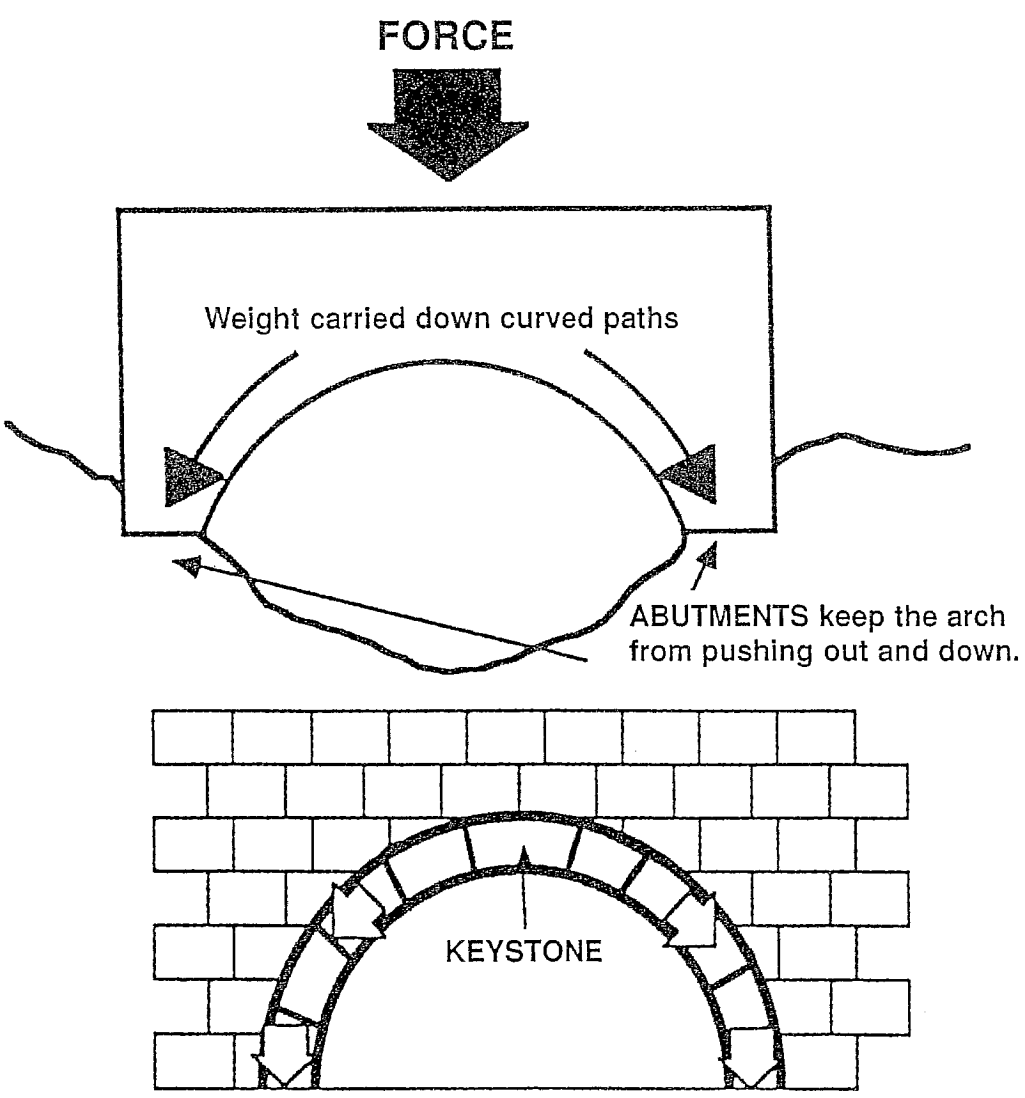
ARCH BRIDGES

The arch bridge is another type of bridge design. The arch is curved and distributes the load to the abutments or ends of the bridge.

In 312 B.C. the Romans began building aqueducts: **a man-made channel carrying water.**

Although most of the aqueducts were built underground, the parts that needed to be above were held in place with arches. The tops were covered to shield the water from the sun and make it harder to contaminate the water.

There were several different types of arches used for the tops.



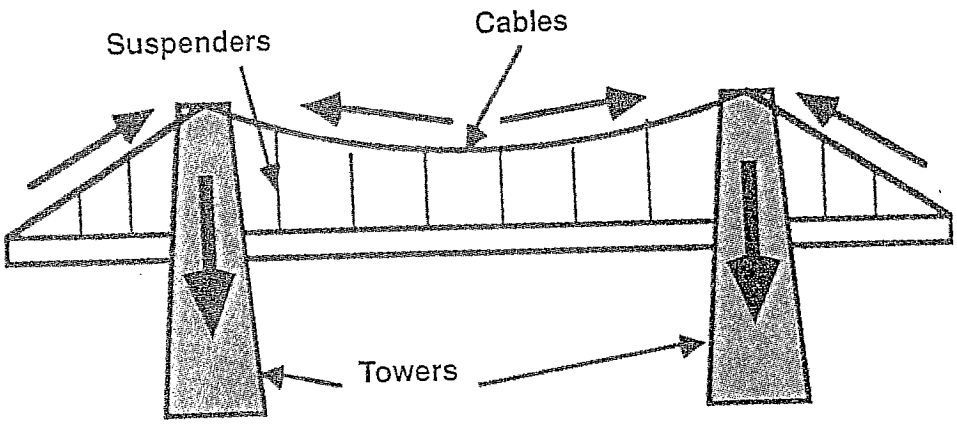
SUSPENSION BRIDGES

In a suspension bridge, the road surface is held from steel cables. The cables are hung from towers and are anchored at the ends of the bridge. Modern cables are made from thousands of strands of wire that are woven together into one cable.

Suspension bridges are used to cover long distances. Steel trusses are often used to keep the road surface stiff.

The cable-stayed bridge is a form of suspension bridge. German engineers first used it in Sweden in 1956. Single towers are used to suspend the road surface. This design uses fewer piers than the beam type, and works better than regular suspension types for short distances.

TRADITIONAL SUSPENSION BRIDGE



CABLE-STAYED BRIDGE