A bridge is a structure built to span a valley, road, body of water, or other physical obstacle, for the purpose of providing passage over the obstacle.
History of Bridge Development

Natural Bridges

- Clapper Bridge
  - Tree trunk
  - Stone

- Roman Arch Bridge
  - The Arch
  - Natural Cement

700 A.D. Asia

- Great Stone Bridge in China
  - Low Bridge
  - Shallow Arch

100 B.C. Romans

1300 A.D. Renaissance

- Strength of Materials
- Mathematical Theories
- Development of Metal
History of Bridge Development

1800 A.D.
First Cast-Iron Bridge
Coalbrookdale, England

Truss Bridges
✓ Mechanics of Design

1900 A.D.
Britannia Tubular Bridge
✓ Wrought Iron

Suspension Bridges
✓ Use of Steel for the suspending cables

1920 A.D.
✓ Prestressed Concrete
✓ Cable Stayed

2000 A.D.

Every passing vehicle shakes the bridge up and down, making waves that can travel at hundreds of kilometers per hour. Luckily the bridge is designed to damp them out, just as it is designed to ignore the efforts of the wind to turn it into a giant harp. A bridge is not a dead mass of metal and concrete: it has a life of its own, and understanding its movements is as important as understanding the static forces.
**Compression** - a force which acts to compress or shorten the thing it is acting on.

**Tension** - a force which acts to expand or lengthen the thing it is acting on.

**Span** - the distance between two bridge supports, whether they are columns, towers or the wall of a canyon.

**Force** - any action that tends to maintain or alter the position of a structure.
**Basic Concepts**

**Beam** - a rigid, usually horizontal, structural element

![Beam Diagram](image)

**Pier** - a vertical supporting structure, such as a pillar

**Cantilever** - a projecting structure supported only at one end, like a shelf bracket or a diving board

**Load** - weight distribution throughout a structure
**Basic Concepts**

**Truss** - a rigid frame composed of short, straight pieces joined to form a series of triangles or other stable shapes.

**Stable** - (adj.) ability to resist collapse and deformation; stability (n.) characteristic of a structure that is able to carry a realistic load without collapsing or deforming significantly.

**Deform** - to change shape.
Buckling is what happens when the force of compression overcomes an object's ability to handle compression. A mode of failure characterized generally by an unstable lateral deflection due to compressive action on the structural element involved.

Snapping is what happens when tension overcomes an object's ability to handle tension.

To **dissipate** forces is to spread them out over a greater area, so that no one spot has to bear the impact of the concentrated force.

To **transfer** forces is to move the forces from an area of weakness to an area of strength, an area designed to handle the forces.
## BASIC BRIDGE TYPES

<table>
<thead>
<tr>
<th>GIRDER</th>
<th>BEAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARCH</td>
<td>TRUSS</td>
</tr>
<tr>
<td>CABLE-STAYED</td>
<td>SUSPENSION</td>
</tr>
</tbody>
</table>
The type of bridge used depends on various features of the obstacle. The main feature that controls the bridge type is the size of the obstacle. How far is it from one side to the other? This is a major factor in determining what type of bridge to use.

The biggest difference between the three is the distances they can each cross in a single span.
Types of Bridges

Girder Bridge

• Oldest and most common bridge type known. (Fallen logs were used).
• In modern girder bridges, steel I-beams are used, but they are subject to twisting and are not good for bridges with any curve to them.
• Box beams are stronger and used for curving or longer bridges.
Types of Bridges

Beam Bridge

Consists of a horizontal beam supported at each end by piers. The weight of the beam pushes straight down on the piers. The farther apart its piers, the weaker the beam becomes. This is why beam bridges rarely span more than 250 feet.
**Beam Bridge**

**Forces**

When something pushes down on the beam, the beam bends. Its top edge is pushed together, and its bottom edge is pulled apart.
Truss Bridge

Forces

Every bar in this cantilever bridge experiences either a pushing or pulling force. The bars rarely bend. This is why cantilever bridges can span farther than beam bridges.
Truss Bridge

• Because of the use of the triangular shape, trusses only sustain compression and tension forces and not bending!

• Can be built in small sections so are ideal in areas where large machinery wouldn’t have access.

• The most common type is the Warren Truss

• For longer spans and for a stronger Warren Truss, vertical members are added. Notice that the roadbed can be above or below the truss.
Arch Bridges

The arch has great natural strength. Thousands of years ago, Romans built arches out of stone. Today, most arch bridges are made of steel or concrete, and they can span up to 800 feet.
Arch Bridges

Forces

The arch is squeezed together, and this squeezing force is carried outward along the curve to the supports at each end. The supports, called abutments, push back on the arch and prevent the ends of the arch from spreading apart.
• Second oldest bridge type.
• Unlike girders, *can* be built from stone.
• Because no center pier is required, *can* be used to cross valleys and rivers without interfering with river traffic.
• Considered the most beautiful of bridge types.
• Many ancient arches are still standing today!
The cable-stayed bridge, like the suspension bridge, supports the roadway with massive steel cables, but in a different way. The cables run directly from the roadway up to a tower, forming a unique "A" shape. Cable-stayed bridges are becoming the most popular bridges for medium-length spans (between 500 and 3,000 feet).
Really just a continuous girder bridge with towers above piers.
The cables are flexible and affected by the wind.
Longer spans require very complex computations and analysis.
Suspension Bridges

This kind of bridges can span 2,000 to 7,000 feet -- way farther than any other type of bridge! Most suspension bridges have a truss system beneath the roadway to resist bending and twisting.
Forces

In all suspension bridges, the roadway hangs from massive steel cables, which are draped over two towers and secured into solid concrete blocks, called anchorages, on both ends of the bridge. The cars push down on the roadway, but because the roadway is suspended, the cables transfer the load into compression in the two towers. The two towers support most of the bridge's weight.
• Of all the types of bridges used today, the suspension allows for the longest spans.

• Similar to a cable-stayed bridge except there is one main cable that runs between the towers with hanger cables below it.

• The girder and roadbed are not resting on the piers as with other bridge types, but is hanging from the hanger cables.

• Vulnerable to wind.
Basic math and science concepts

Pythagorean Theorem

\[ c^2 = b^2 + a^2 \]

\[ \alpha + \beta + \gamma = 180^\circ \]
**Basic math and science concepts**

**Fundamentals of Statics**

\[
\sum F_x = 0
\]

\[
\sum F_y = R_1 + R_2 - P = 0
\]
Fundamentals of Mechanics of Materials

Modulus of Elasticity (E):

\[ E = \frac{\text{Stress}}{\text{Strain}} = \frac{F/A}{\Delta L/L_0} \]

where:
- \( F \) = Longitudinal Force
- \( A \) = Cross-sectional Area
- \( \Delta L \) = Elongation
- \( L_0 \) = Original Length
To design a bridge like you need to take into account the many forces acting on it:

- The pull of the earth on every part
- The ground pushing up the supports
- The resistance of the ground to the pull of the cables
- The weight of every vehicle

Then there is the drag and lift produced by the wind:

- The turbulence as the air rushes past the towers
How do the following affect the structures?

- Forces
- Loads
- Materials
- Shapes

Thanks for your attention and success with your study!