

THEORY & DESIGN OF STRUCTURES IV



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UNIT V



Bridge Structures

History of Bridge Development

Natural Bridges



Clapper Bridge

- Tree trunk
- Stone

700 A.D.
Asia



Great Stone Bridge in China

- Low Bridge
- Shallow Arch



Roman Arch Bridge

- The Arch
- Natural Cement

100 B.C. Romans

- Strength of Materials
- Mathematical Theories
- Development of Metal

1300 A.D. Renaissance

History of Bridge Development

1800
A.D.



First Cast-Iron Bridge
Coalbrookdale, England

1900
A.D.



Truss Bridges
↪ Mechanics of Design

2000
A.D.



↪ Prestressed Concrete
↪ Steel



Britannia Tubular Bridge
↪ Wrought Iron

1850
A.D.



Suspension Bridges
↪ Use of Steel for the suspending cables

1920
A.D.

How Bridges Work?

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.





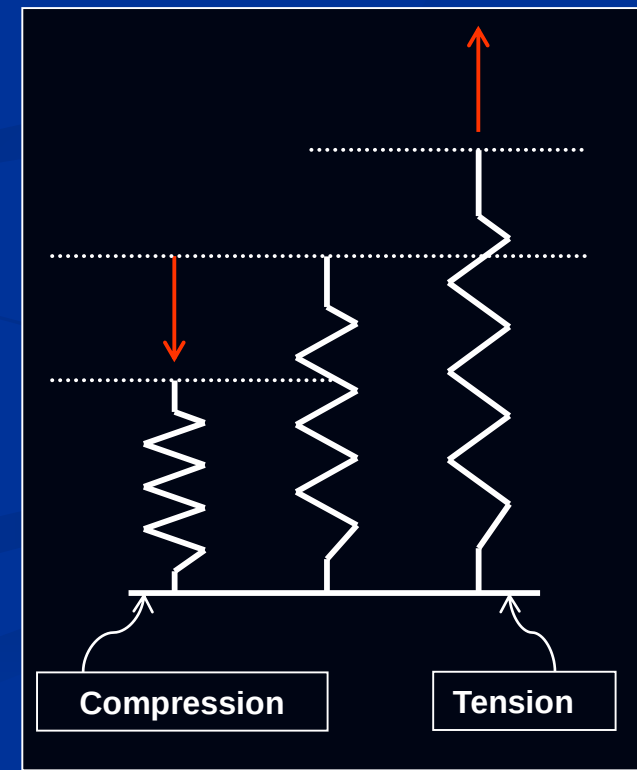
Basic Concepts

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

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.



Basic Concepts

Beam - a rigid, usually horizontal, structural element



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

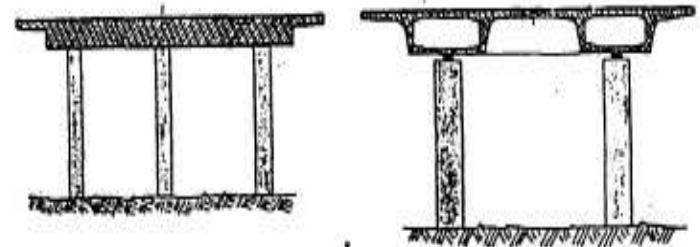
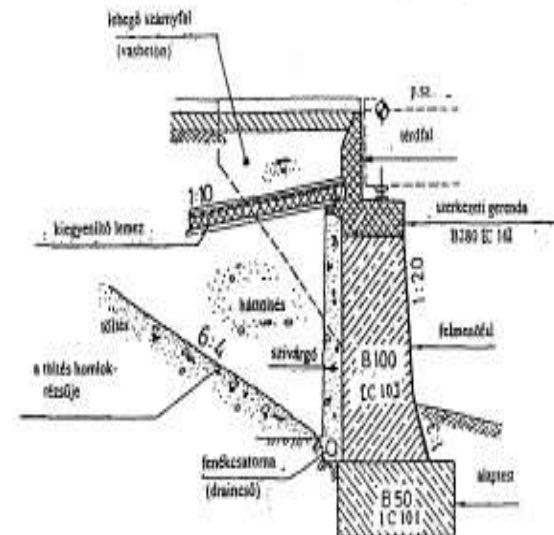
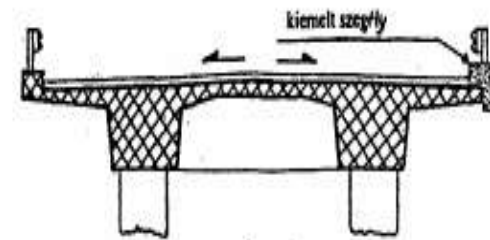
Fundamental concepts:

Superstructure:

- Girders (longitudinal, transverse)
- Deck slab

Substructure:

- Upper part (above ground)
 - Abutments (end support)
 - Piers (internal support)
- Foundation
 - shallow foundation (
 - deep foundation (piles (bored or driven), box or drilled-in caisson)
- Structural beam
- Settlement compensating plate



Basic Concepts

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 brunt 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.

Some Uses of Bridges

- Walkways
- Highways/Roads
- Railways
- Pipelines
- Connecting lands
- Crossing rivers and canyons



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

TYPES OF LOADS

Loads considered in Bridge analysis are:

1. Gravity Loads
2. Lateral Loads
3. Forces due to deformation
4. Collision Loads

GRAVITY LOADS

Gravity loads are the loads caused by the weight

of an object on the bridge and applied in a downward direction toward the center of the earth. Such loads may be:

- A. Permanent Gravity Loads
- B. Transient Gravity Loads

LATERAL LOADS

Following forces are considered under lateral loads:

- Fluid forces
- Seismic Loads
- Ice Forces

FORCES DUE TO DEFORMATION

In bridge we have to consider the following forces due to deformation:

1. Temperature
2. Creep and Shrinkage
3. Settlement

COLLISION LOADS

Collision loads include:

1. Vessel Collision load
2. Rail Collision Load
3. Vehicle Collision Load

COLLISION LOADS

Vessel Collision load:

On bridge over navigable waterways the possibility of vessel collision with the pier must be considered. Typically, this is of concern for structures that are classified as long span bridges. Vessel collision loads are classified in AASHTO [A3.14].

Rail Collision Load:

If a bridge is located near a railway, the possibility of collision of the bridge as a result of a railway derailment exists. As this possibility is remote, the bridge must be designed for collision forces using extreme limit states.

Vehicle Collision Load:

The collision force of a vehicle with the barrier, railing and parapet should be considered in bridge design.

Types of Bridges

- 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 types of bridge is the distances they can each cross in a single span

Types of Bridges

- Arch



- Truss



- Cantilever



- Cable-Stayed



- Suspension



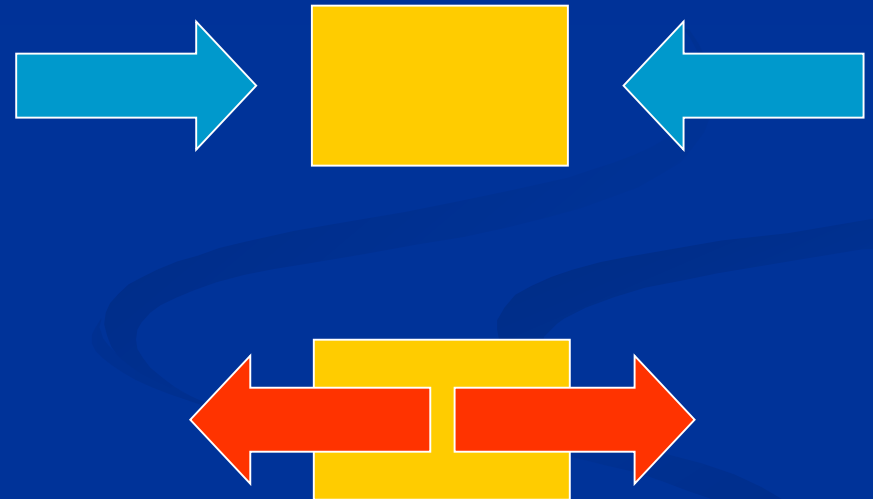
- Beam



What makes a bridge stay up?

■ Forces

- **Compression** - a pushing or squeezing force
- **Tension** - a pulling or stretching force

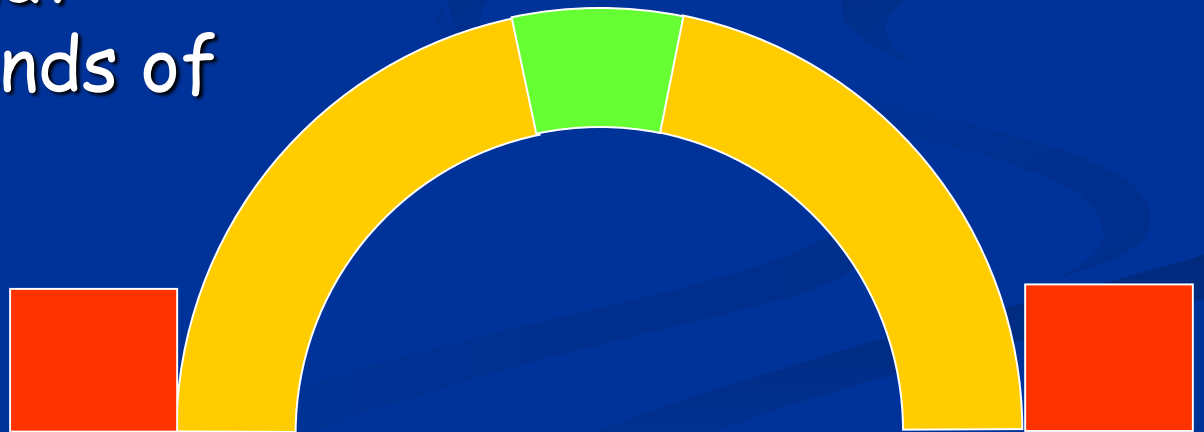


Arch Bridges

- 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.
- 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.

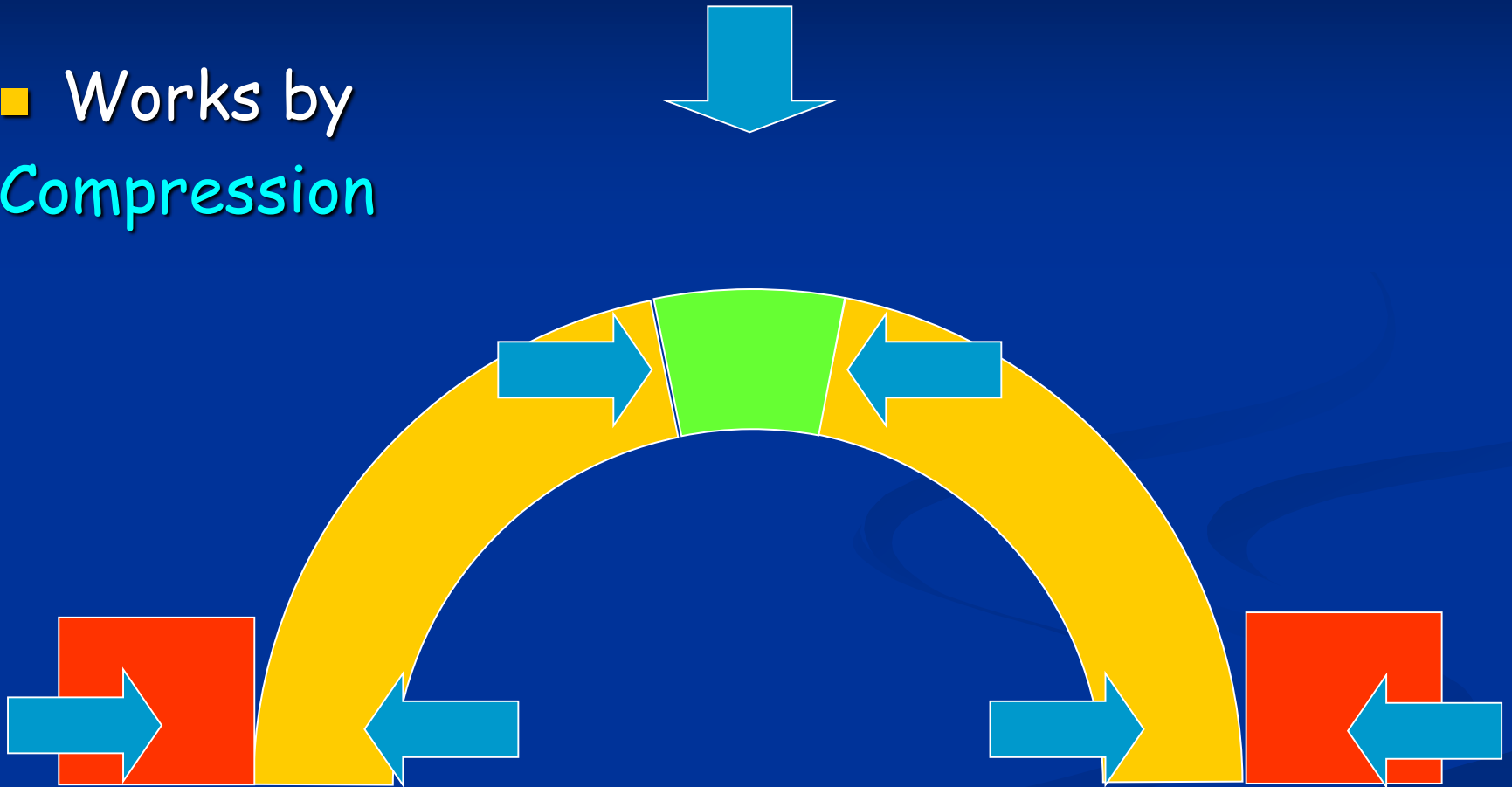
Arch Bridges

- **Keystone** - the wedge-shaped stone of an arch that locks its parts together
- **Abutments** - the structures that support the ends of the bridge



Arch Bridges

- Works by
Compression



Arch Bridges

- Where have you seen these bridges?



Cold Spring Arch Bridge, Santa Barbara, CA

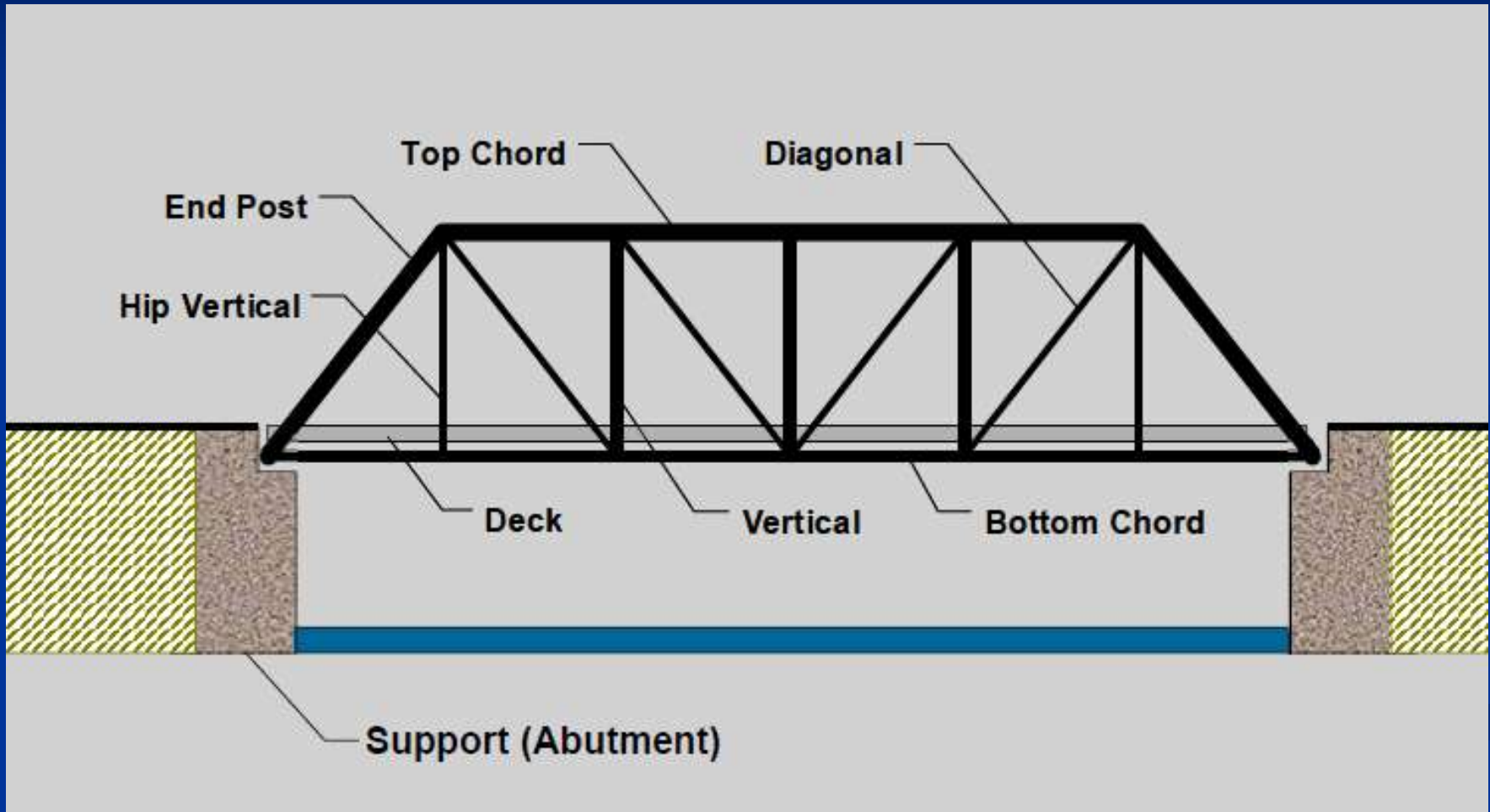


Marsh Rainbow Arch, Riverton, KS



Pont du Gard, Nimes, France

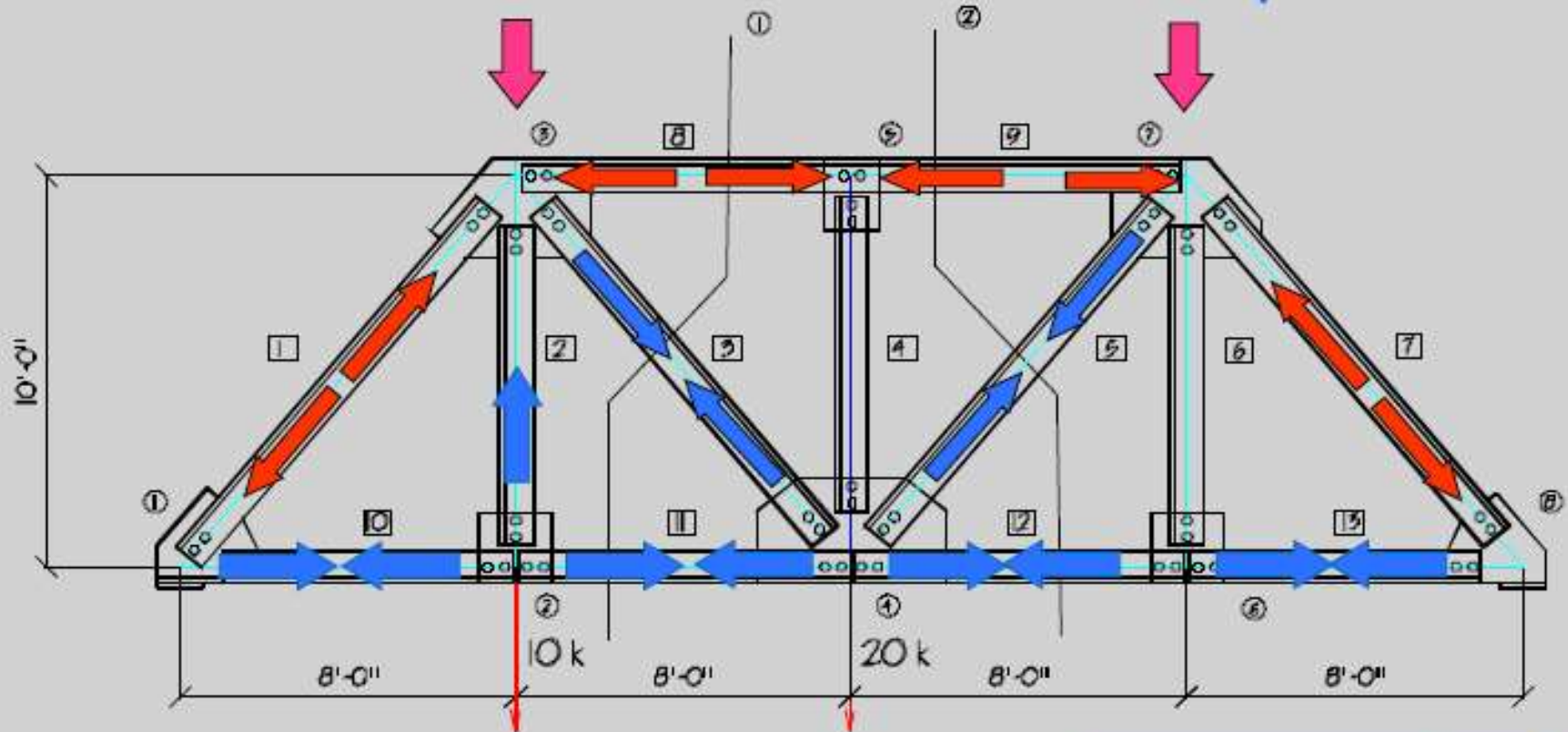
Truss Bridges



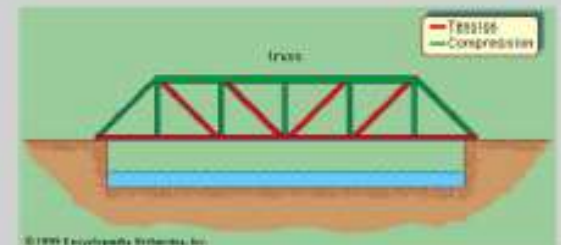
Truss Bridges

- How does Work?

Tension & Compression



PRATT TRUSS



Truss Bridges

- Where have you seen these bridges?

Truss Bridges



NY-79 Bridge
Broome County, New York
Warren



Truss Connections

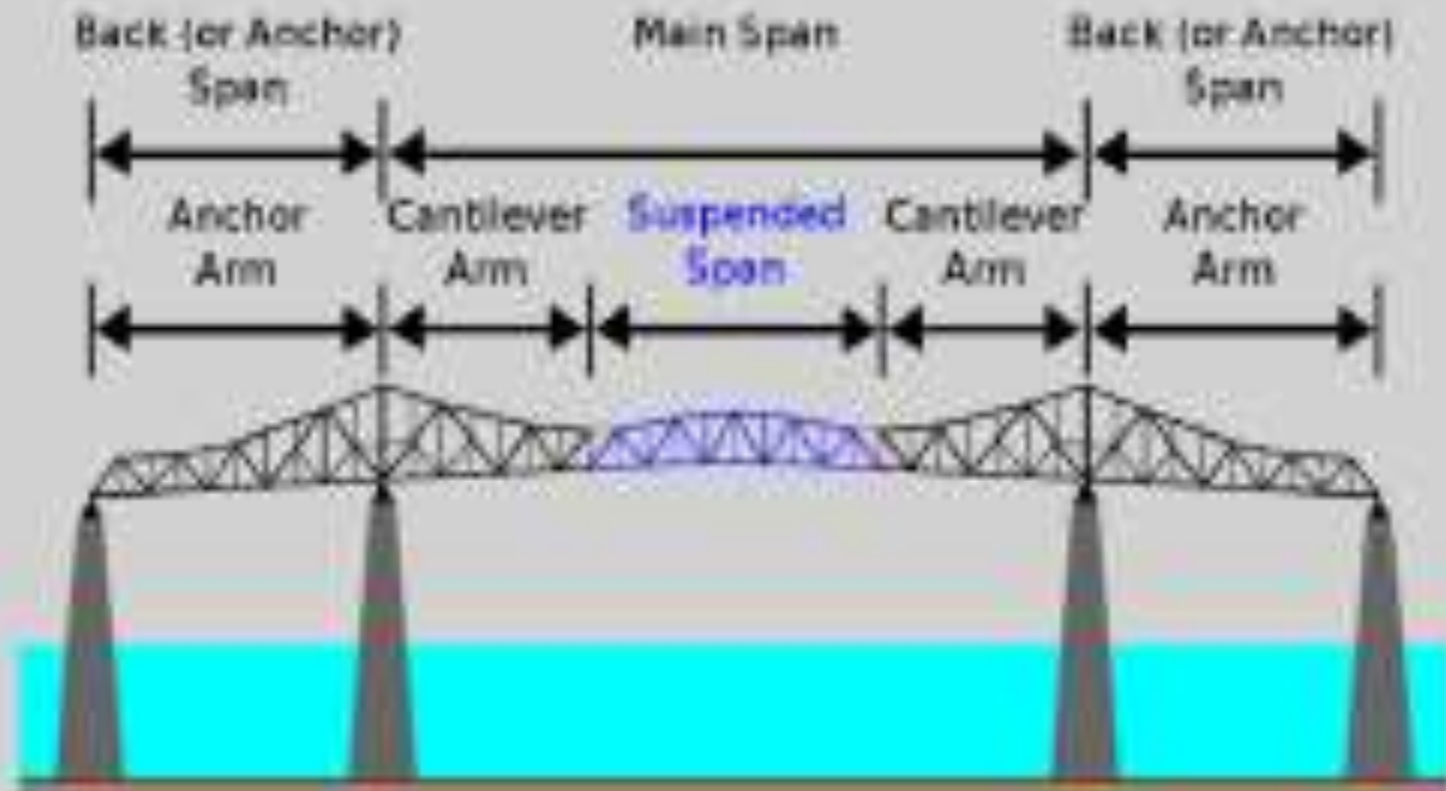
Truss Bridges



Under Truss Bridge



Cantilever Bridges



Cantilever Bridges

- Where have you seen these bridges?

Cantilever Bridges



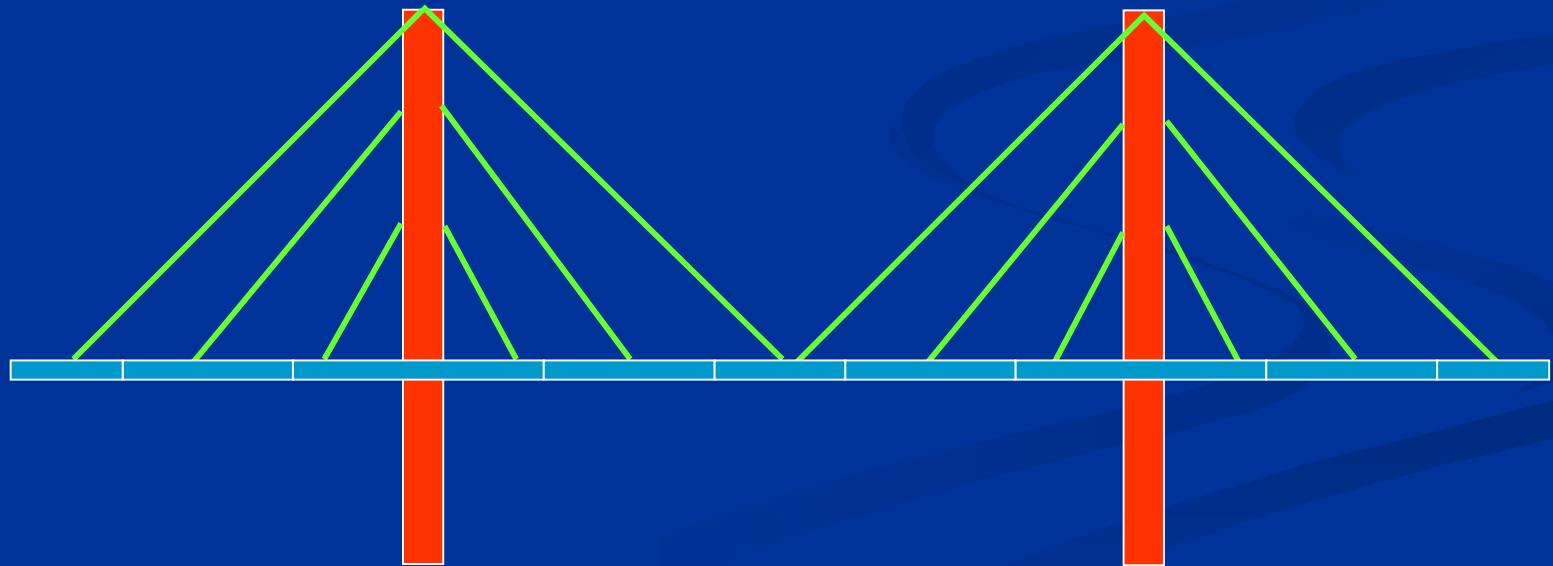
Firth of Forth-Forth Rail Bridge
Edinburgh, Scotland



Bluewater Bridge -Port Huron Michigan

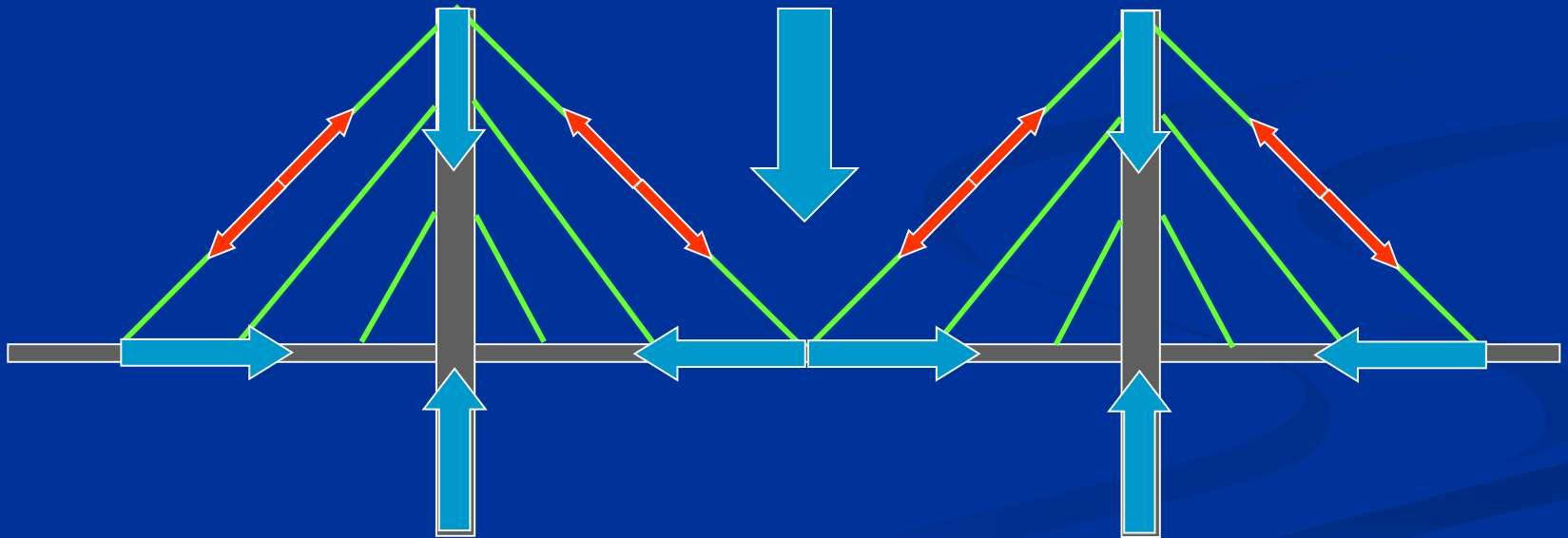
Cable-Stayed Bridges

- **Piers** - the vertical supporting structures
- **Cables** - thick steel ropes from which the decking is suspended
- **Decking** - the supported roadway on a bridge



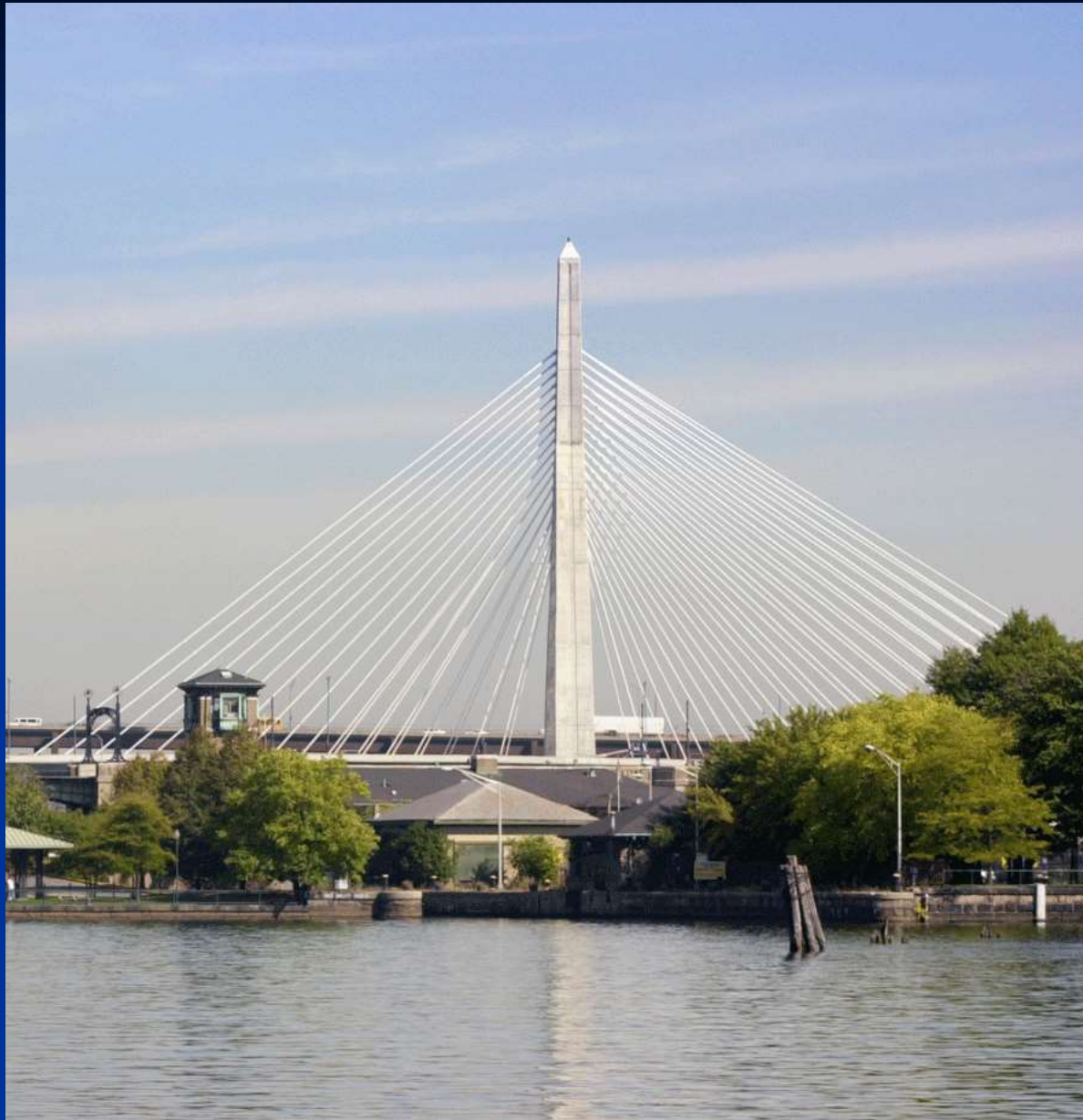
Cable-Stayed Bridges

- Works by **Tension** AND **Compression**



Cable-Stayed Bridges

- Where have you seen these bridges?



Zakim Bridge, Boston, MA



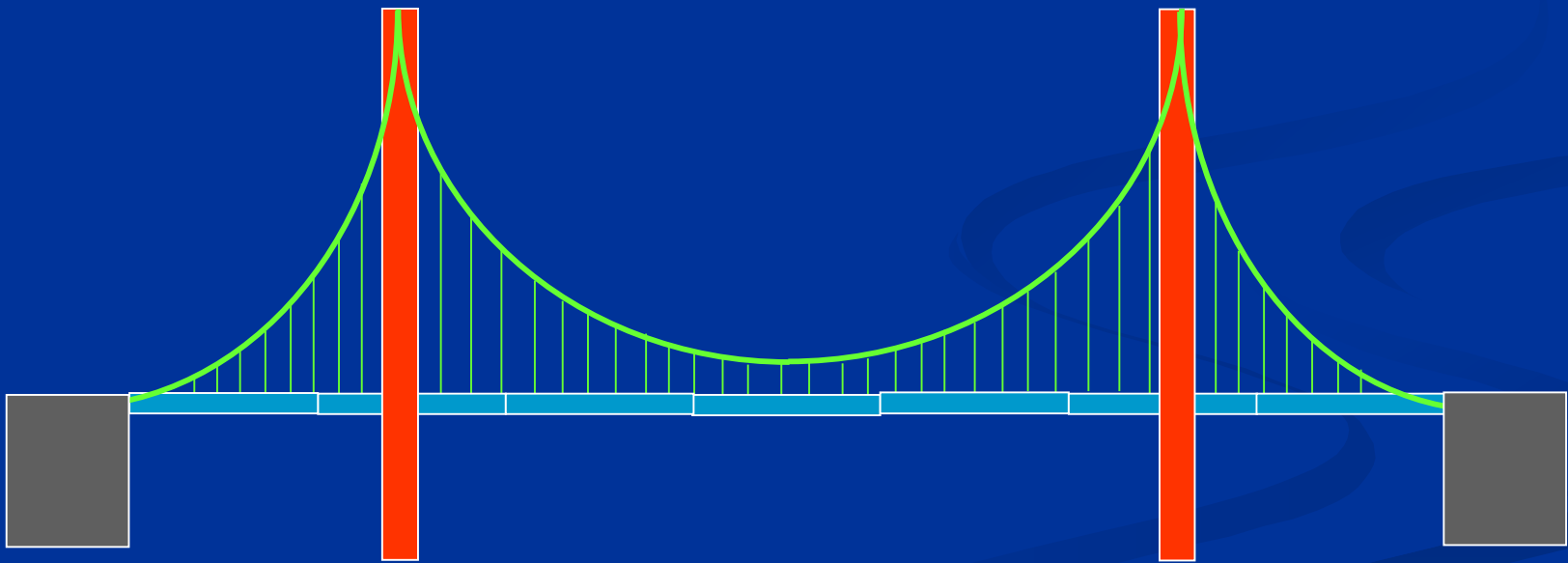
Sunshine Skyway Bridge, Tampa, FL



Sundial Bridge, Redding, CA

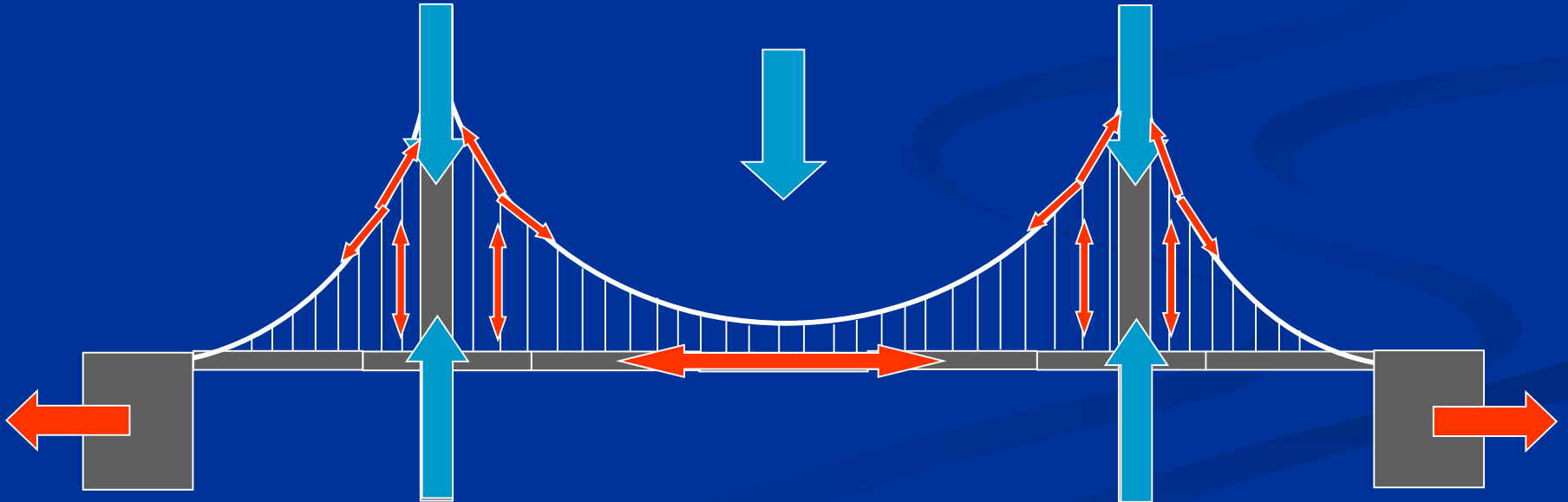
Suspension Bridges

- Similar to Cable-Stayed
- Different construction method



Suspension Bridges

- Works by **Tension** and **Compression**



Suspension Bridges

- Where have you seen these bridges?



Golden Gate Bridge, San Francisco, CA



Brooklyn Bridge, Brooklyn, NY



Verrazano-Narrows Bridge, New York, NY

Beam Bridges

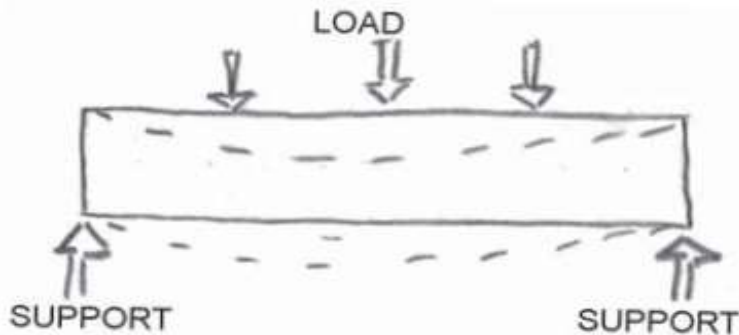
- Ancient beam bridges were made primarily of wood
- Modern beam-type bridges are made wood, iron, steel or Concrete
- How a beam operates is more complex than a cable or an arch?
- In the cable all of the material is in tension, but in a beam part of the material is in tension and part of the material is in compression

Beam Bridges

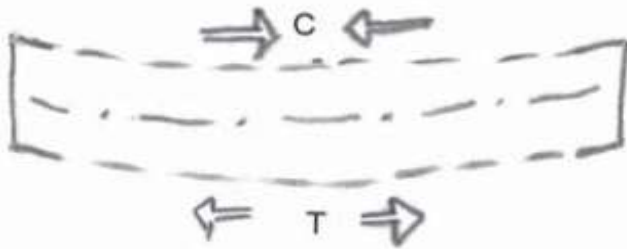
- Consists of a horizontal beam supported at each end by piers.
- The weight of the beam pushes straight down on the piers
- The farther apart its piers, the weaker the beam becomes. This is why beam bridges rarely span more than 250 feet.
- When something pushes down on the beam, the beam bends. Its top edge is pushed together, and its bottom edge is pulled apart.

Beam Bridges

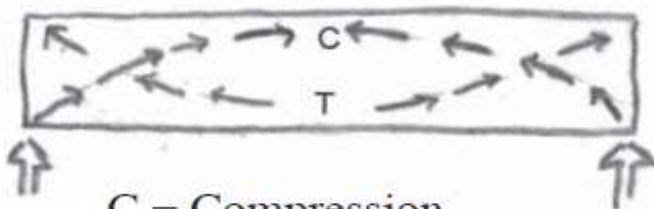
How a beam works



A beam supported at its ends and loaded in the middle deflects downward.



The top edge is in compression. The bottom edge is in tension. there is no stress in a line right through the middle.



C = Compression
T = Tension

The beam develops a compression arch across the top and a tension cable across the bottom.

The top of the beam has compression forces squeezing the material together, and the bottom of the beam has tension forces that stretch the material apart.

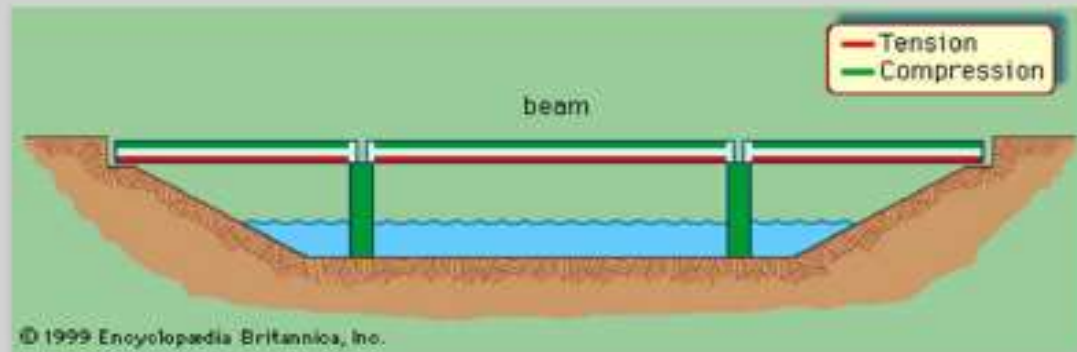
Beam Bridges

- Where have you seen these bridges?

Beam Bridges



Chesapeake Bay Bridge-Tunnel



DESIGN PROCESS, PLAN TYPES

- **Preliminary plan (study)** (basic design data, selecting design requirements, elaborating different structural solutions with minimum calculation)
- **Authorization plan** (one structural solution, approximate calculation for the verification of the main sizes and quantities)
- **Final design, detailed plan**
 - o Technical description (contains all basic design data which is not included in the structural drawings)
 - o General plan ($M=1:100$)
 - o Detailed structural analysis
 - o Structural drawings ($M=1:50$, $M=1:25$, $M=1:10$)
 - o Designer's declarations, organization plans, calculation of quantities, geotechnical report, technological plans

**FACTORS NEED TO BE
CONSIDER FOR
SELECTING
A BRIDGE TYPE**

Factors need to be consider

- Cost and strategic conditions
- Channel Section (nature of the river)
- Sub-soil conditions of the bed of the river
- Grades and alignment
- Hydraulic Data

Factors need to be consider

- Physical Features of the site
- Climatic conditions
- Navigation requirements
- Availability of workers

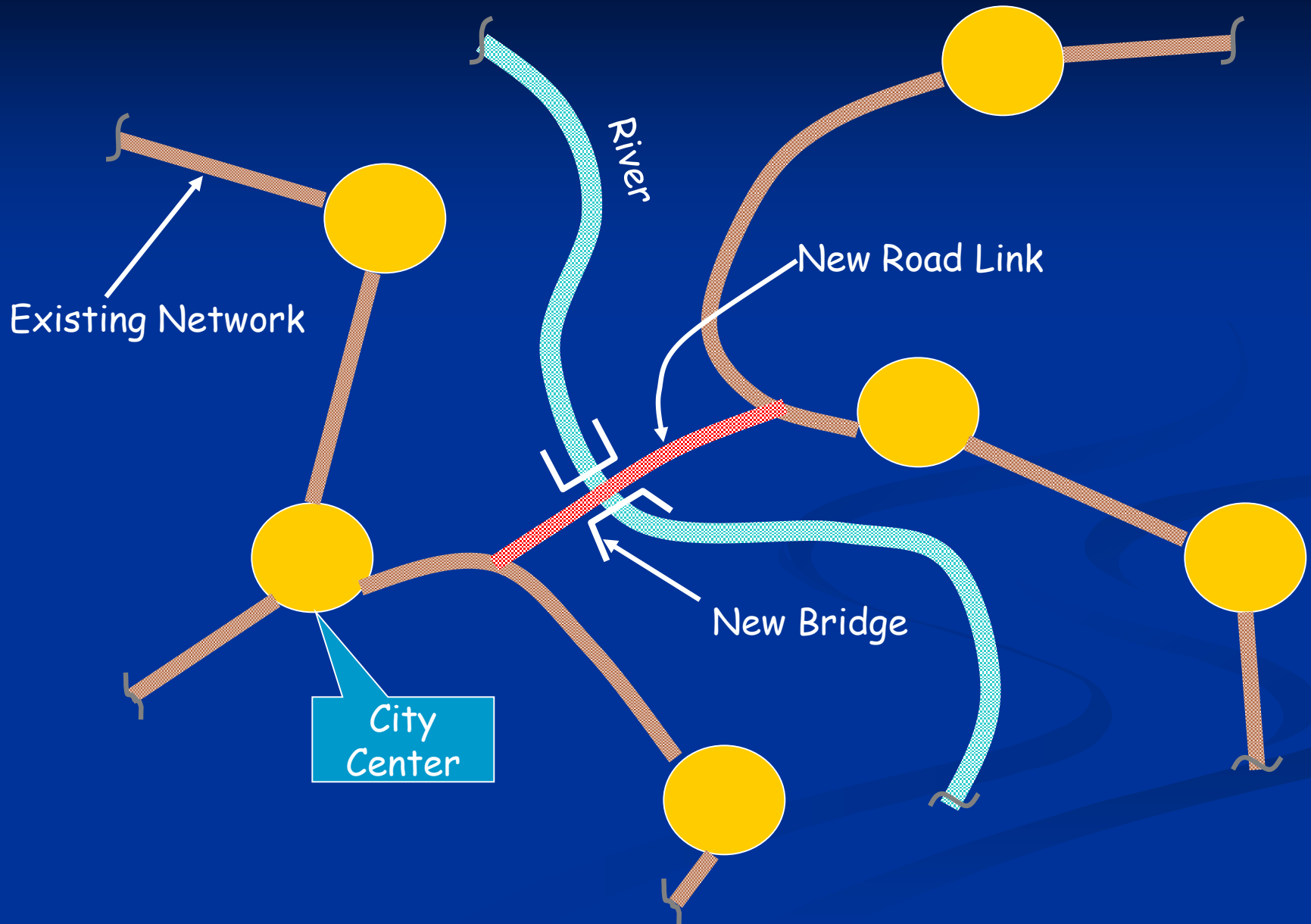
Factors need to be consider

- Time limit within which construction is to be completed
- Volume and nature of the traffic
- Economic span of the Bridge
- Level of HFL and clearance requirements
- Cost of maintenance

Factors need to be consider

- Probable life of Structure
- Foundation conditions
- Length and width of Bridge
- Live loads likely to come over the bridge

Traffic Studies



Thank you ... 