Introduction to Bridge Engineering

What is a Bridge?

- A bridge is a structure providing passage over an obstacle without closing the way beneath. The required passage may be for a road, a railway, pedestrians, a canal or a pipeline. The obstacle to be crossed may be a river, a road, railway or a valley.

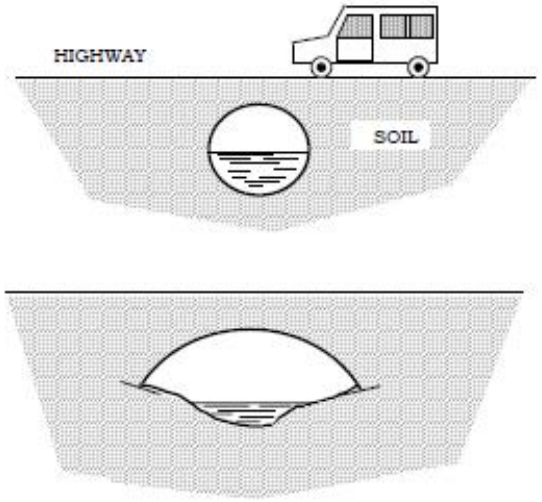
- In other words, bridge is a structure for carrying the road traffic or other moving loads over a depression or obstruction such as channel, road or railway.

- A bridge is an arrangement made to cross an obstacle in the form of a low ground or a stream or a river without closing the way beneath.

What is a bridge?

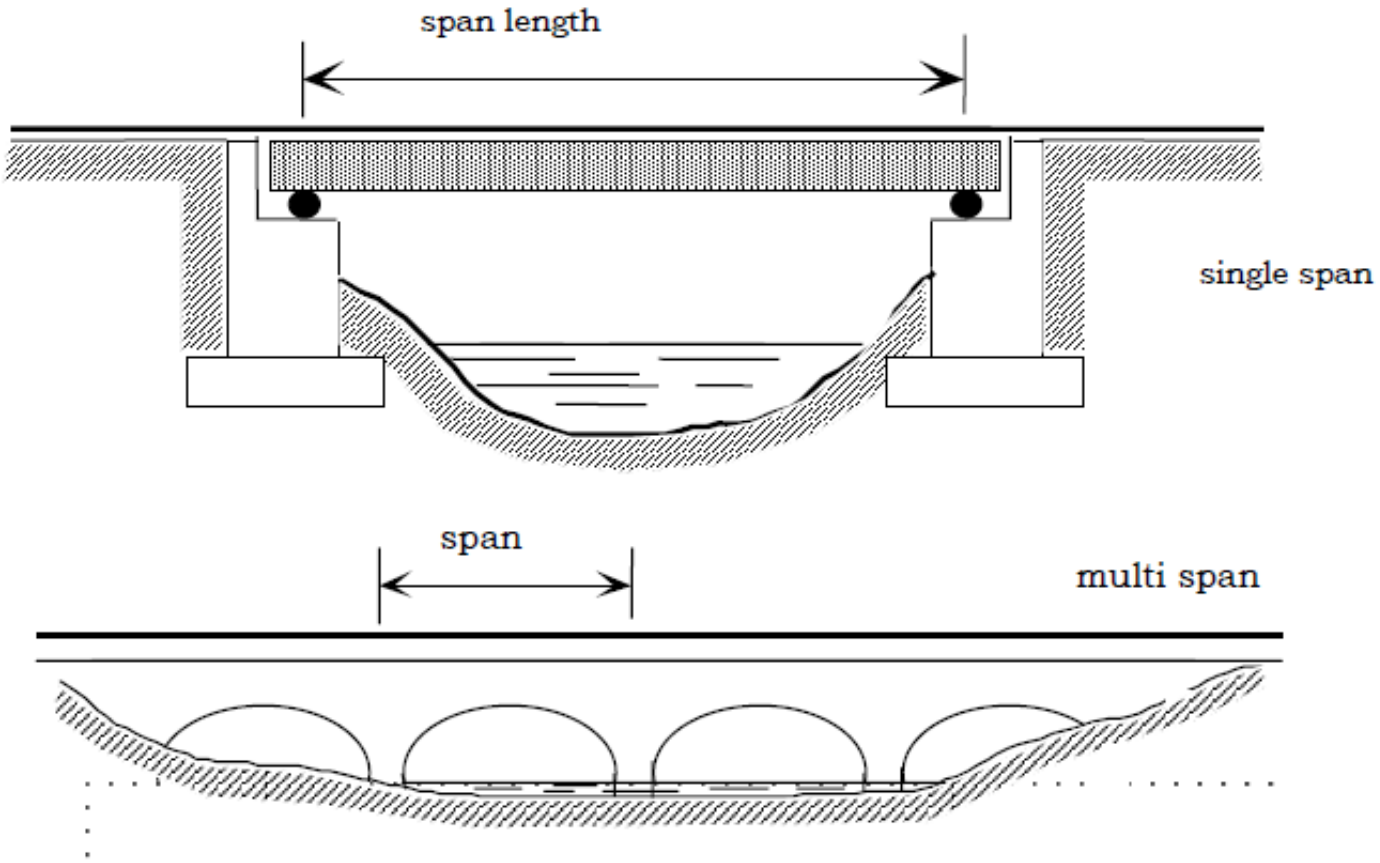
- Merriam-Webster Dictionary
  Bridge = Structure carrying a pathway or roadway over a depression or obstacle

- American Association of State Highway and Transportation Officials (AASHTO)
  Bridges = Any structure having an opening not less than 6100 mm (20ft) that forms part of a highway or that is located over or under a highway
  - Anything smaller is just a culvert



culvert

Span Length



- Span > 6 m → Bridge
- Span < 6 m → Culvert

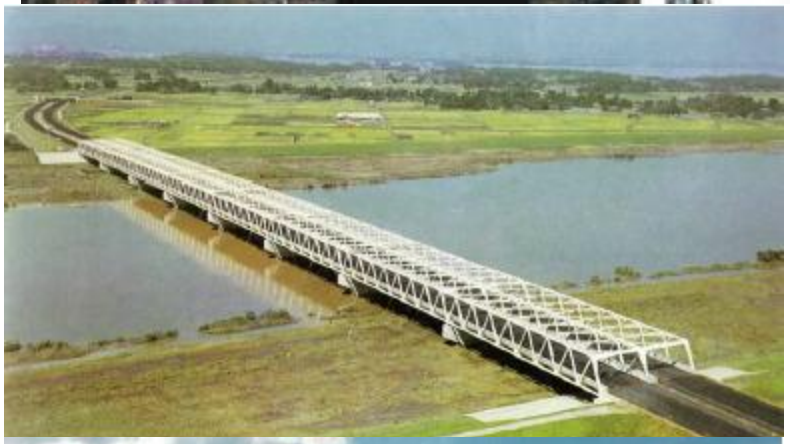
- Short span: 6-30 m
- Medium span: 30-100 m
- Long span: > 100 m

Types of Bridge by Traffic

- Highway bridge (trucks, cars)
- Pedestrian bridge (pedestrians, bicycles)
- Railway bridge (trains)
- Transit guideway (city trains, monorail)
- Other types (pipelines, utilities, industrial, aqueduct, airport structure)

Types of Bridge by Traffic Position

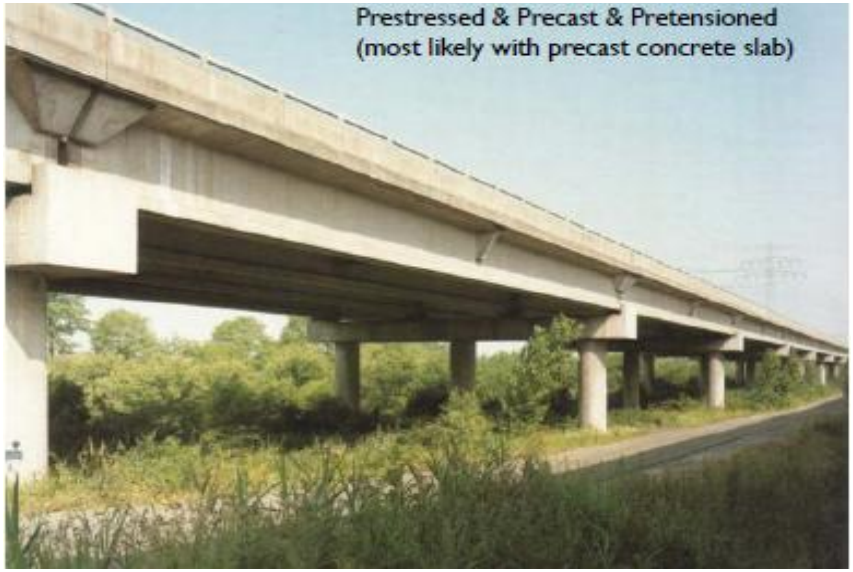
- Deck type
  - Structural components under the deck
  - Preferred by drivers (can clearly see the view)
  - Requires space under the bridge
- Through type
  - Structural components above the deck
  - Obstructed view (not a problem for railway bridges)
  - No structure under the bridge
- Half-through type



Types by Material & Fabrications

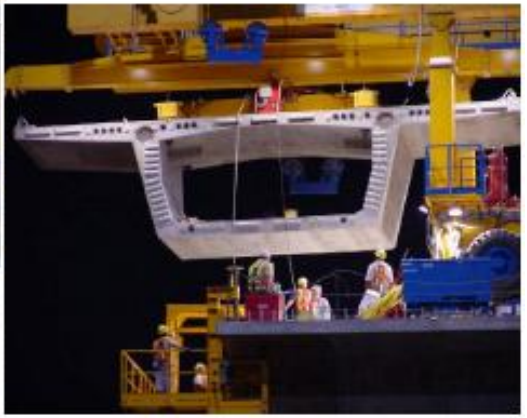
- Materials
  - Masonry (brick, rock)
  - Timber
  - Reinforced Concrete (RC)
  - Prestressed Concrete (PC)
  - Iron
  - Steel
  - Aluminum
  - Composites
  - Plastics
  - Etc…
- Fabrications
  - Precast (RC/PC)
  - Cast-in-place (RC/PC)
  - Pretensioned (PC)
  - Posttensioned (PC)
  - Prefabricated (steel)
  - Rivet (steel)
  - Bolted (steel/ timber)
  - Welded (steel)
  - Etc…

Steel
Prefabricated
(probably with precast slab)



Prestressed & Precast & Pretensioned
(most likely with precast concrete slab)

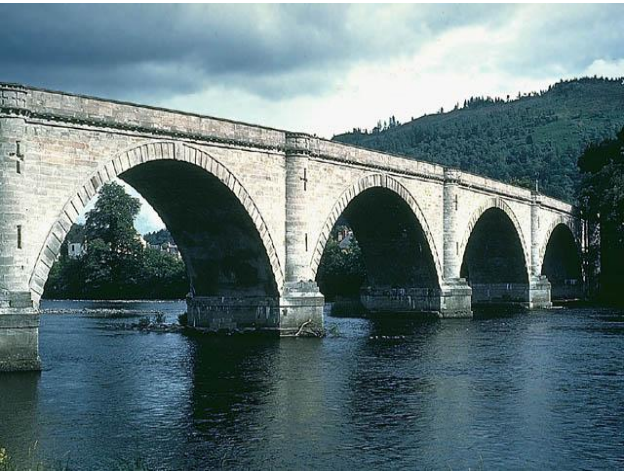
Prestressed Segmental Bridge
Precast & Post-Tensioned



Types of Bridge by Structure

Basic types based on structural form

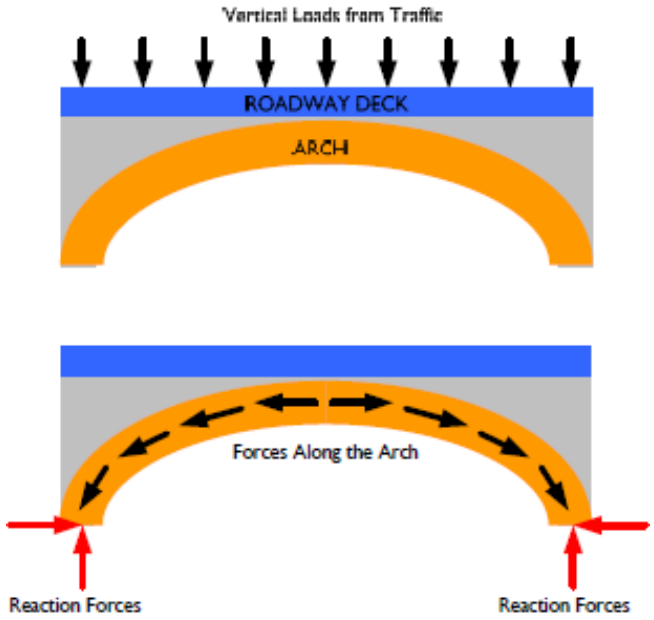
- Arch
- Beam
- Cantilever
- Cable-Stayed
- Suspension
- Others



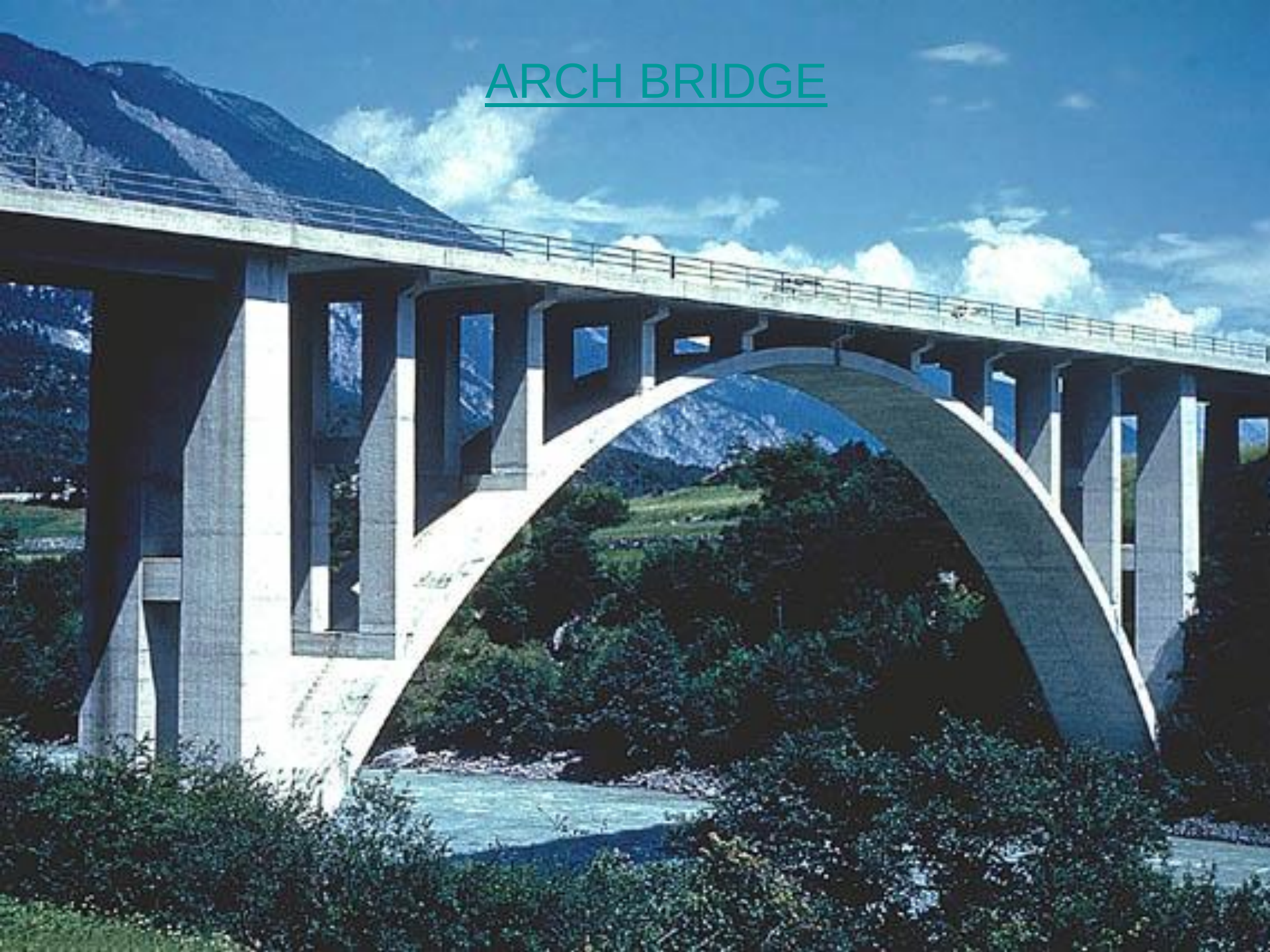
Types of Bridge by Structure

Arch Bridge

- Arch bridges are one of the oldest types of bridges and have great natural strength.
- 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.



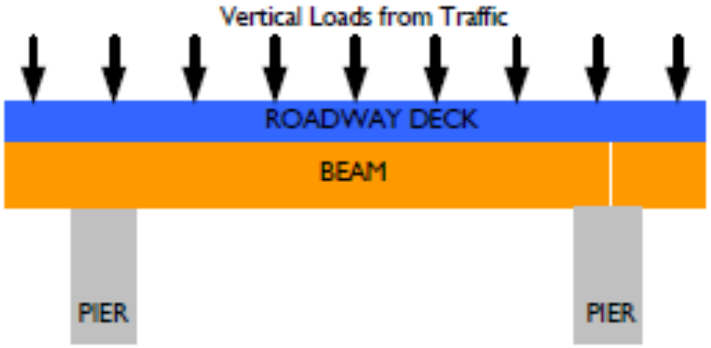
ARCH BRIDGE

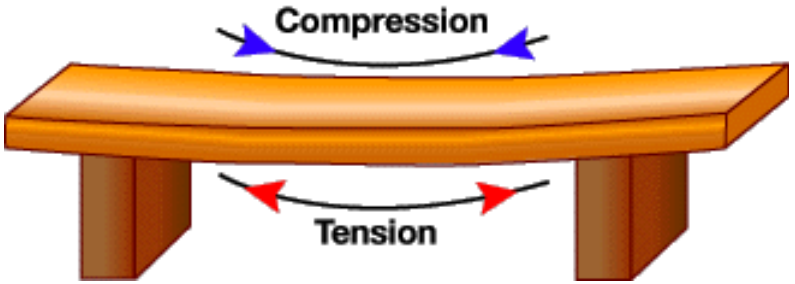


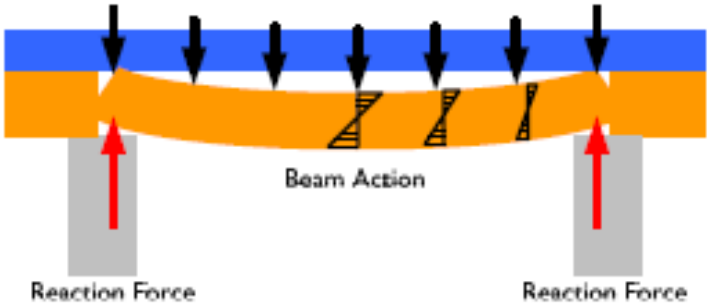
Types of Bridge by Structure

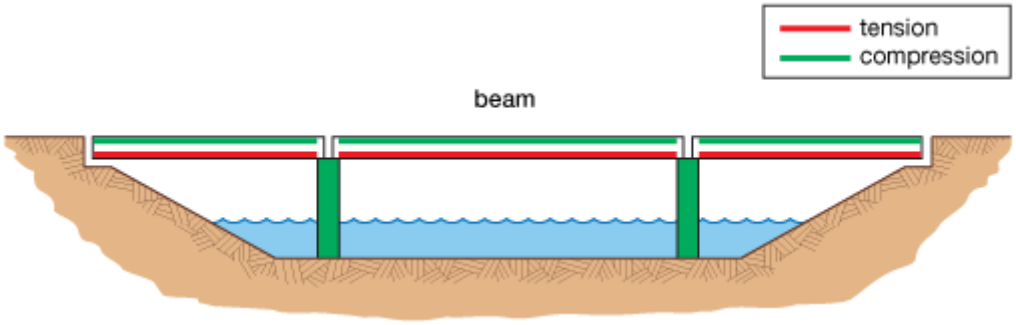
Beam/Girder Bridge

- The most basic type of bridge.
- Typically consists of a beam simply supported on each side by a support and can be made continuous later.
- Typically inexpensive to build.

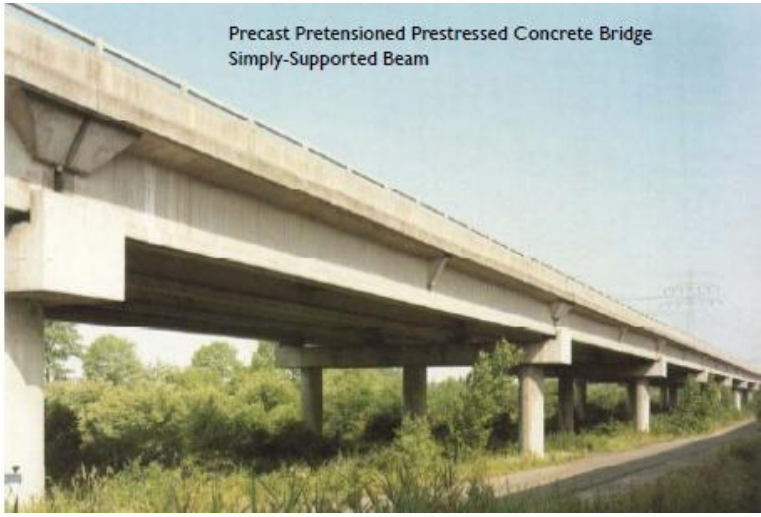






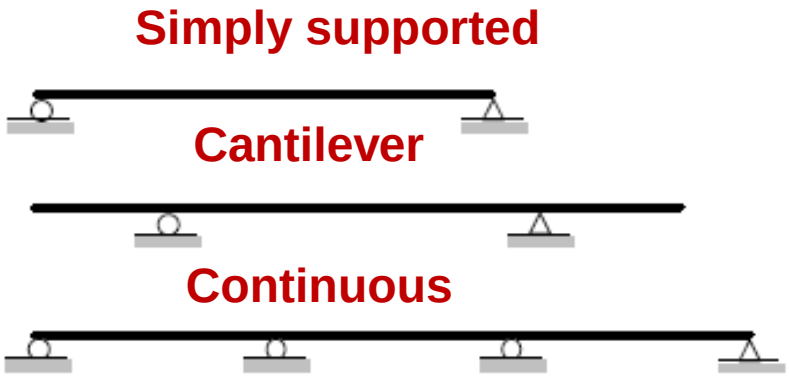


Types of Bridge by Structure

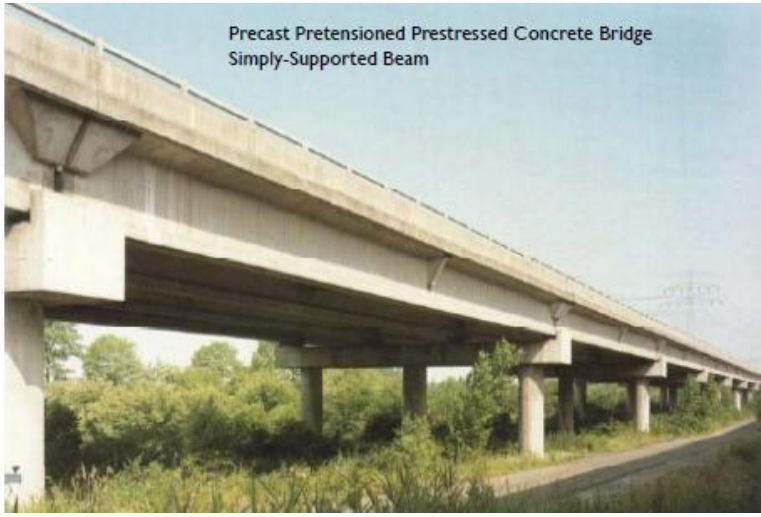


Beam/Girder Bridge

- Currently, most of the beam bridges are precast (in case of RC and PC) or prefabricated
- Most are simply-supported
- Some are made continuous on site



Types of Bridge by Structure



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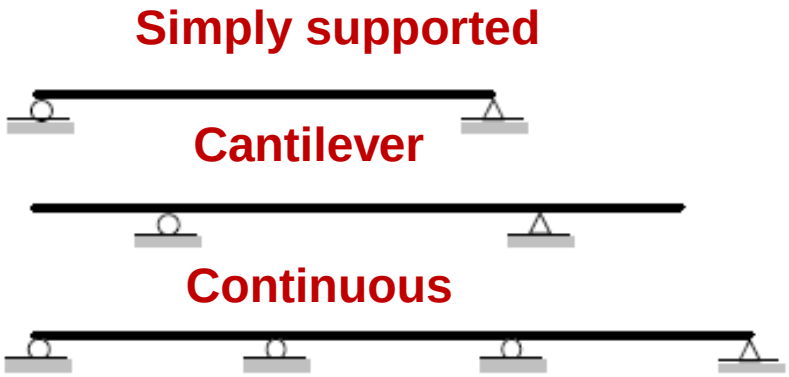


Types of Bridge by Structure

Beam/Girder Bridge

- Post-Tensioned Prestressed Concrete are often found in the form of segmentally precast members

- Segmental construction may be constructed in 2 ways
  - Cantilever Construction – construct from the pier equally on both sides
  - Span-by-Span Construction – finish one span at a time

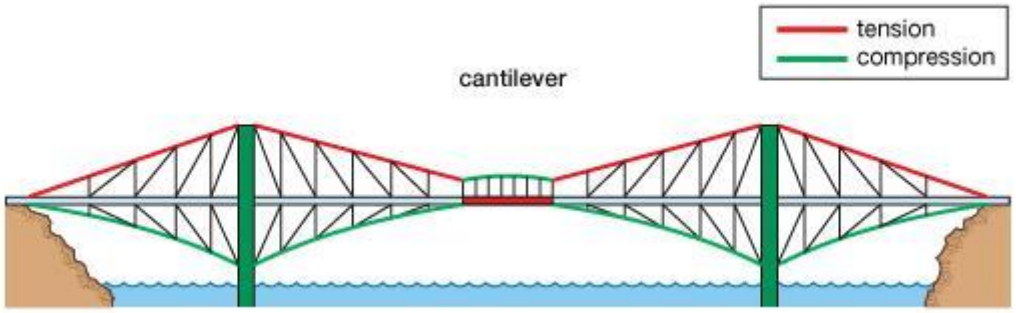
Span-by-Span

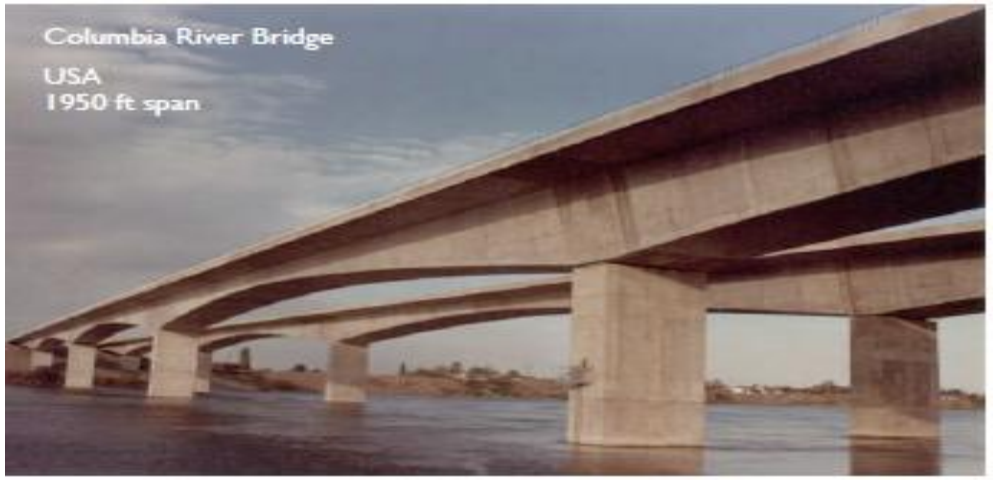
Cantilever

Types of Bridge by Structure

Cantilever Bridge

- In a cantilever bridge, the roadway is constructed out from the pier in two directions at the same time so that the weight on both sides counterbalance each other
- Notice the larger section at the support to resist the negative moments

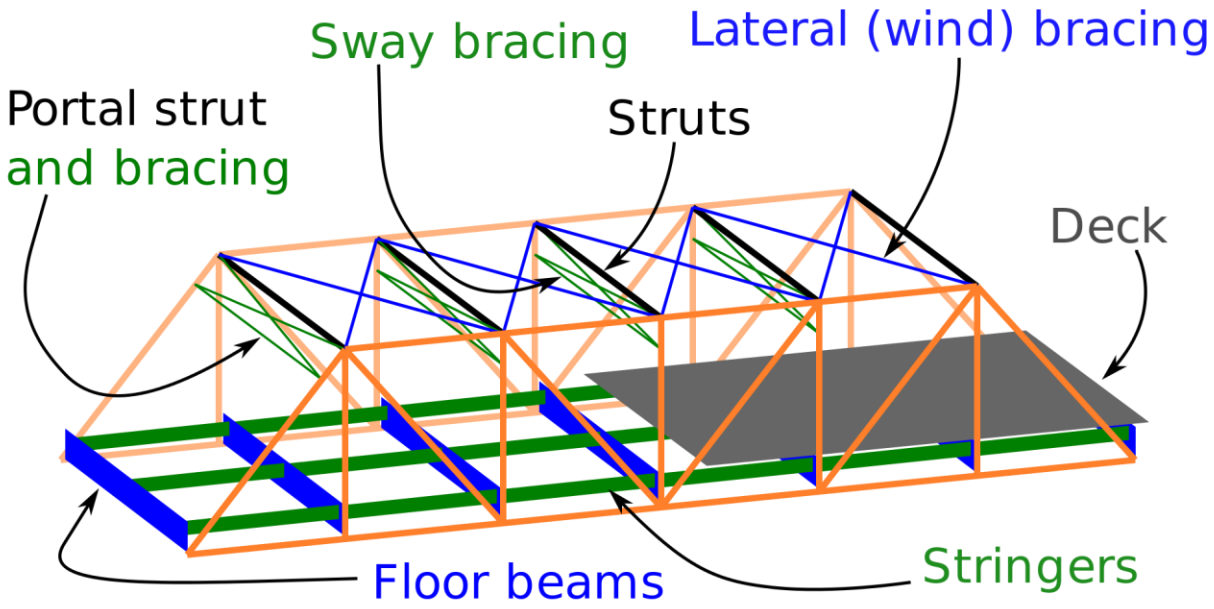




Types of Bridge by Structure

Truss Bridge

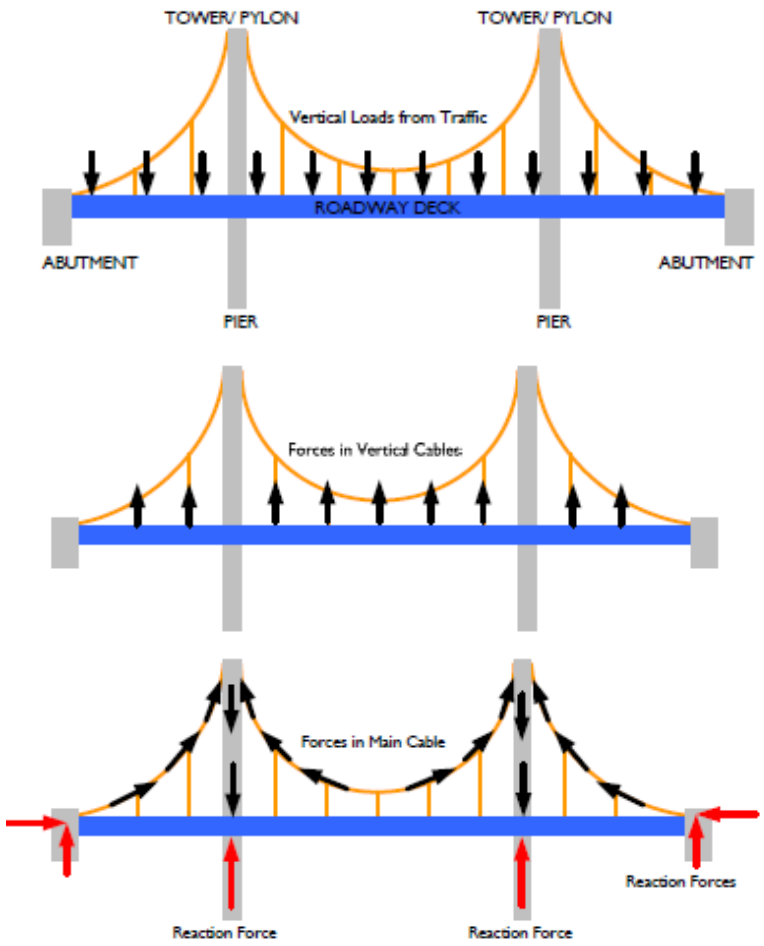
- All beams in a truss bridge are straight. Trusses are comprised of many small beams that together can support a large amount of weight and span great distances.
- Typical Span lengths: 40m-500m



Types of Bridge by Structure

Suspension Bridges

- Suspension bridge needs to have very strong main cables
- Cables are anchored at the abutment

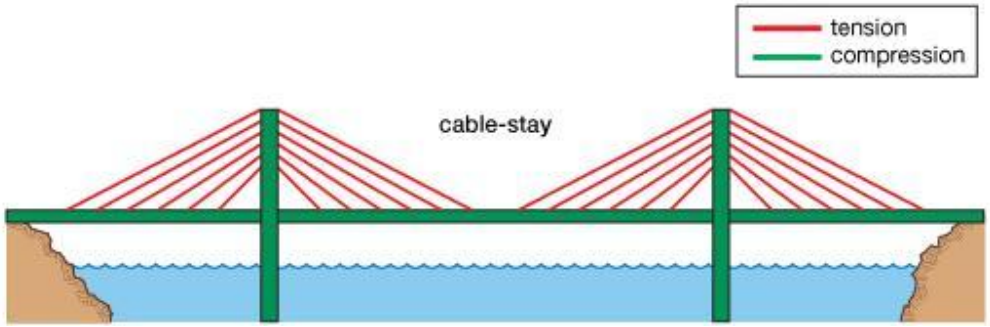


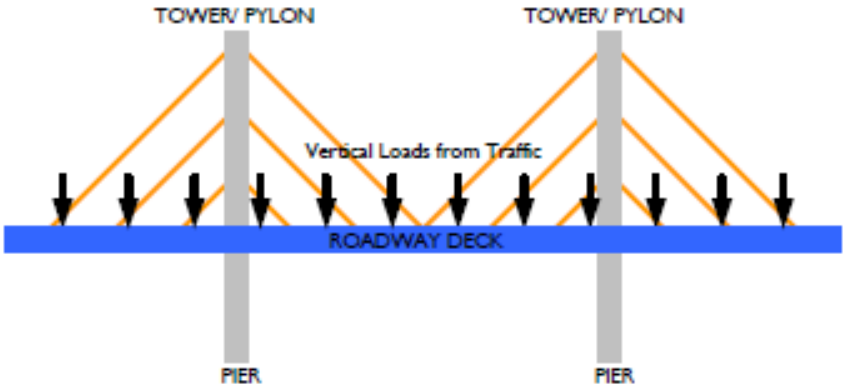
Suspension Bridge

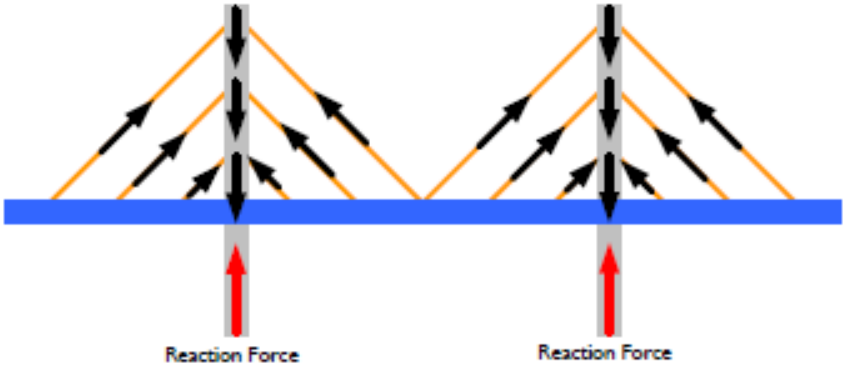
Types of Bridge by Structure

Cable-stayed Bridge

- All the forces are transferred from the deck through the cables to the pylon
- Roadway deck can be :
  1. (Prestressed) Concrete Box Deck
  2. Steel Box Deck
  3. Steel Truss Deck







Types of Bridge by Structure

Moveable Bridges

Bascule

Lift

A moveable bridge is a bridge that moves to allow passage (usually) for boats or barges.

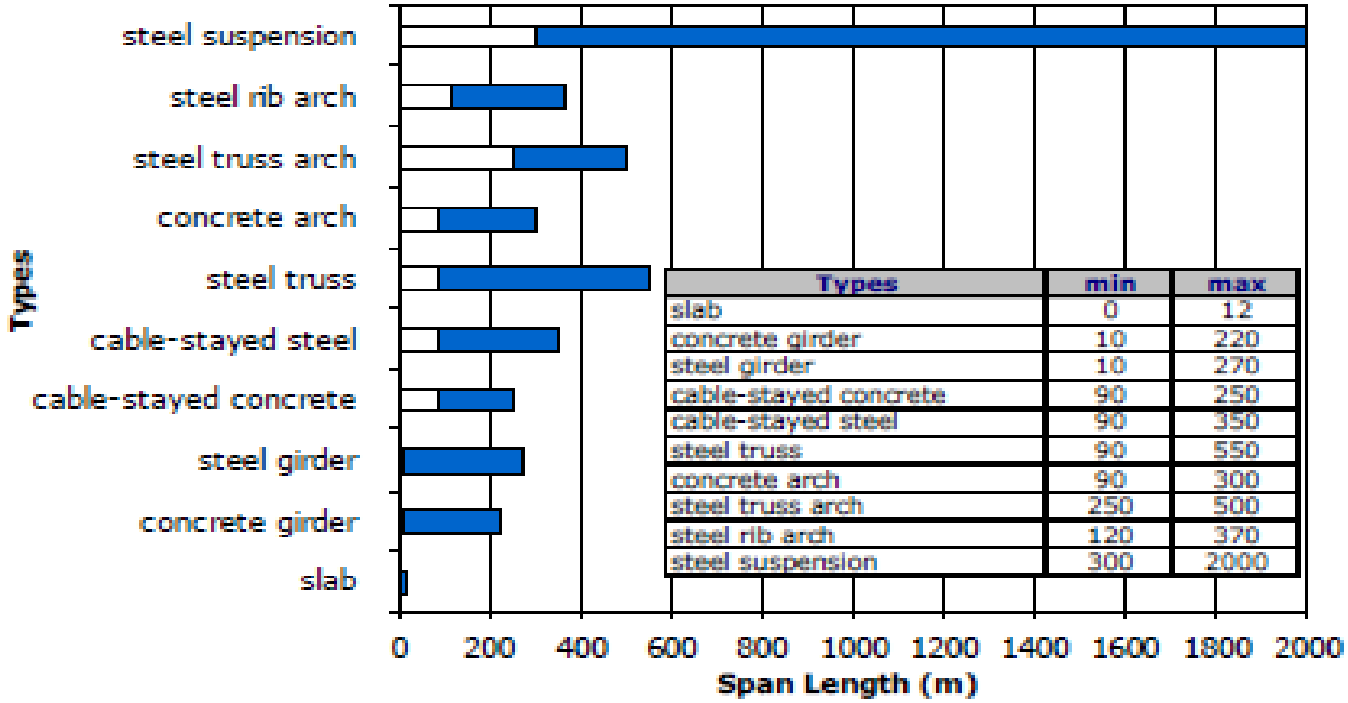
Swing

Which type should I use?

Consider the followings:

- Span length
- Bridge length
- Beam spacing
- Material available
- Site conditions (foundations, height, space constraints)
- Speed of construction
- Constructability
- Technology/ Equipment available
- Aesthetics
- Cost
- Access for maintenance

Span Length



Types	min	max
slab	0	12
concrete girder	10	220
steel girder	10	270
cable-stayed concrete	90	250
cable-stayed steel	90	350
steel truss	90	550
concrete arch	90	300
steel truss arch	250	500
steel rib arch	120	370
steel suspension	300	2000

Cost vs. Span Length

- The span length may be influenced by the cost of superstructure (cost/meter) and substructure (cost/pier)
- If the substructure cost is about 25% of total cost → shorter span is more cost-effective
- If the substructure cost is about 50% of total cost → longer spans are more economical

Cost vs. Span Length

Substructure here is expensive compared with superstructure

Access for Maintainence

- Total Cost = Initial Cost + Maintenance Cost
- Bridge should be made easy to inspect and maintain
- Maintenance cost may govern the selection of bridge
  - Steel bridge needs a lot of maintenance in coastal regions
  - Concrete bridge usually require the least maintenance

Beam Spacing

- Beam spacing determine the number of girders
- Large Spacing
  - Fewer girder (faster to erect)
  - Deeper and heavier girder (can it be transported?)
  - Reduced redundancy
  - Thicker slab
- Smaller Spacing
  - More girder
  - Smaller girder
  - More redundancy (but more beams to inspect)
  - Thinner slab

Materials

- Steel
- Concrete
  - Cast-in-place
  - Precast
- Material choice depends on the cost of material at the bridge site
- Shipping cost from fabricators

Speed of construction

- In urban areas, the construction of bridge may disrupt traffic
  - Prefabricated/ Precast member are the only choice
  - Substructure construction may disrupt traffic more than the superstructure erection → may consider longer spans

Site Requirement

- Is the bridge straight or curved
  - Precast I-Girder cannot be curved
  - Segmental prestressed can have slight curve
  - Cast-in-place
- Is shipping channel required?
- Shipping of prefabricated pieces to site
- Is the temporary falsework required? Can it be done with the site conditions?

In the Millau Aqueduct, the superstructure was completed inland and pushed into the span

Aesthetics

- An ugly bridge, however safe, serviceable, and inexpensive, is not a good bridge
- Long span bridge over a river can be a landmark; thus, aesthetics should be an important factor
- Bridge should blend with the environment
- Smooth transition between members
- Avoid unnecessary decorations
- Bridge should have an appearance of adequate strength
- Determinant of bridge's appearance (in order of importance)
  - Vertical and Horizontal geometry relative to surrounding topography and other structures
  - Superstructure type: arch, girder, etc…
  - Pier placement
  - Abutment placement
  - Superstructure shape, parapet and railing
  - Pier shape
  - Abutment shape
  - Color, surface texture, ornamentations
  - Signing, Lighting, Lanscaping

Aesthetics : What it means?

Aesthetic qualities result from the appropriate arrangement of visual design elements and are used to evaluate a visual composition. These design qualities are intangible; they are perceived qualities that arise from relationships of design elements.

The Four “C’s” of Bridge Aesthetics

- Context
- Comprehensive
- Cost
- Constructability

Aesthetics : What it means?

- **Context**

  All projects from a simple creek bridge to the longest multi span water crossing must first be considered with a view to the context in which it is located.

- **Comprehensive**

  The designs that work best are those that take aesthetics in to account right from start.

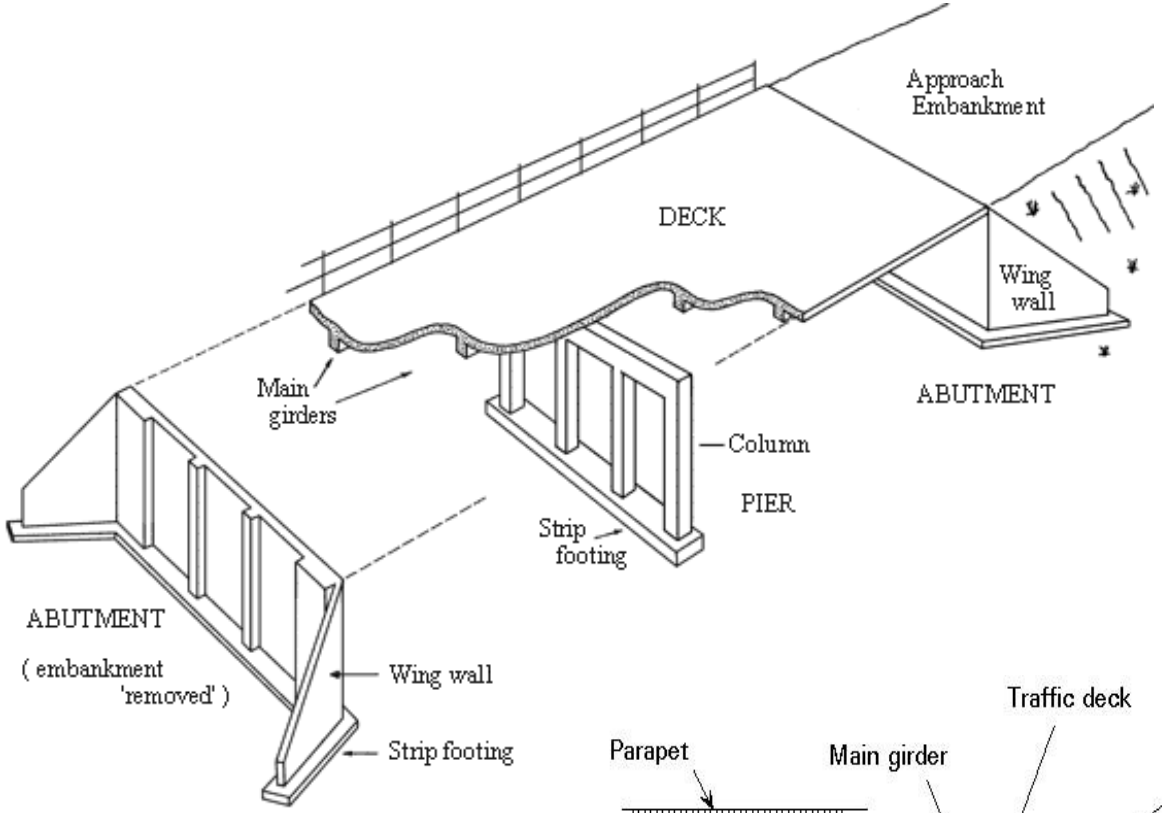
- **Cost**

  No discussion of design considerations can be conducted realistically without asking “How much is it going to cost?”.

- **Constructability**

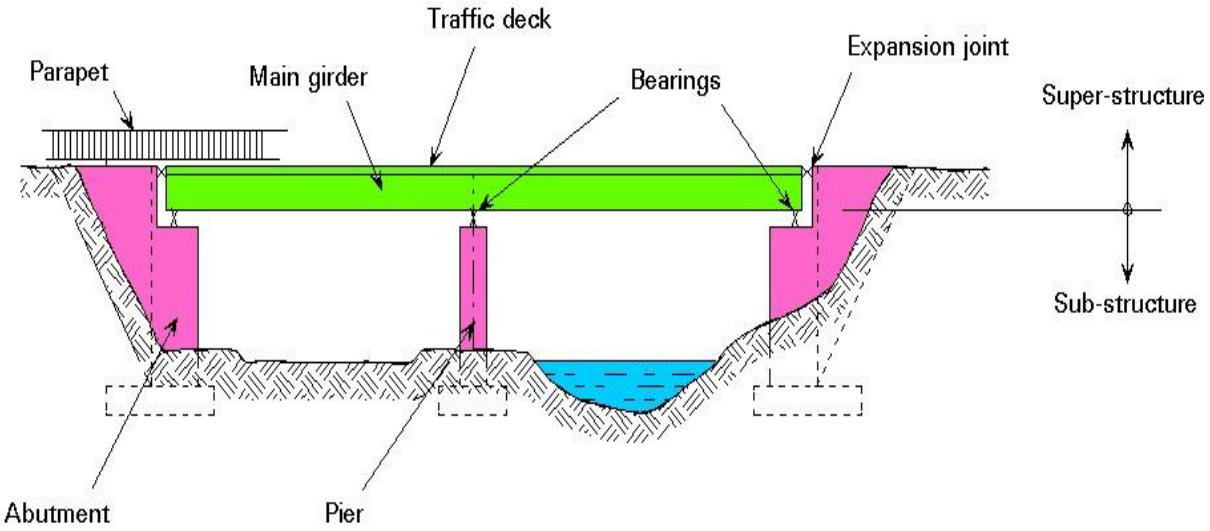
  No discussion of aesthetics is complete without considering constructability.

Bridge Terminology: Slab on Girder Bridge



Substructure - includes the piers, the abutments and the foundations.

Superstructure - comprises all the components of a bridge above the supports.



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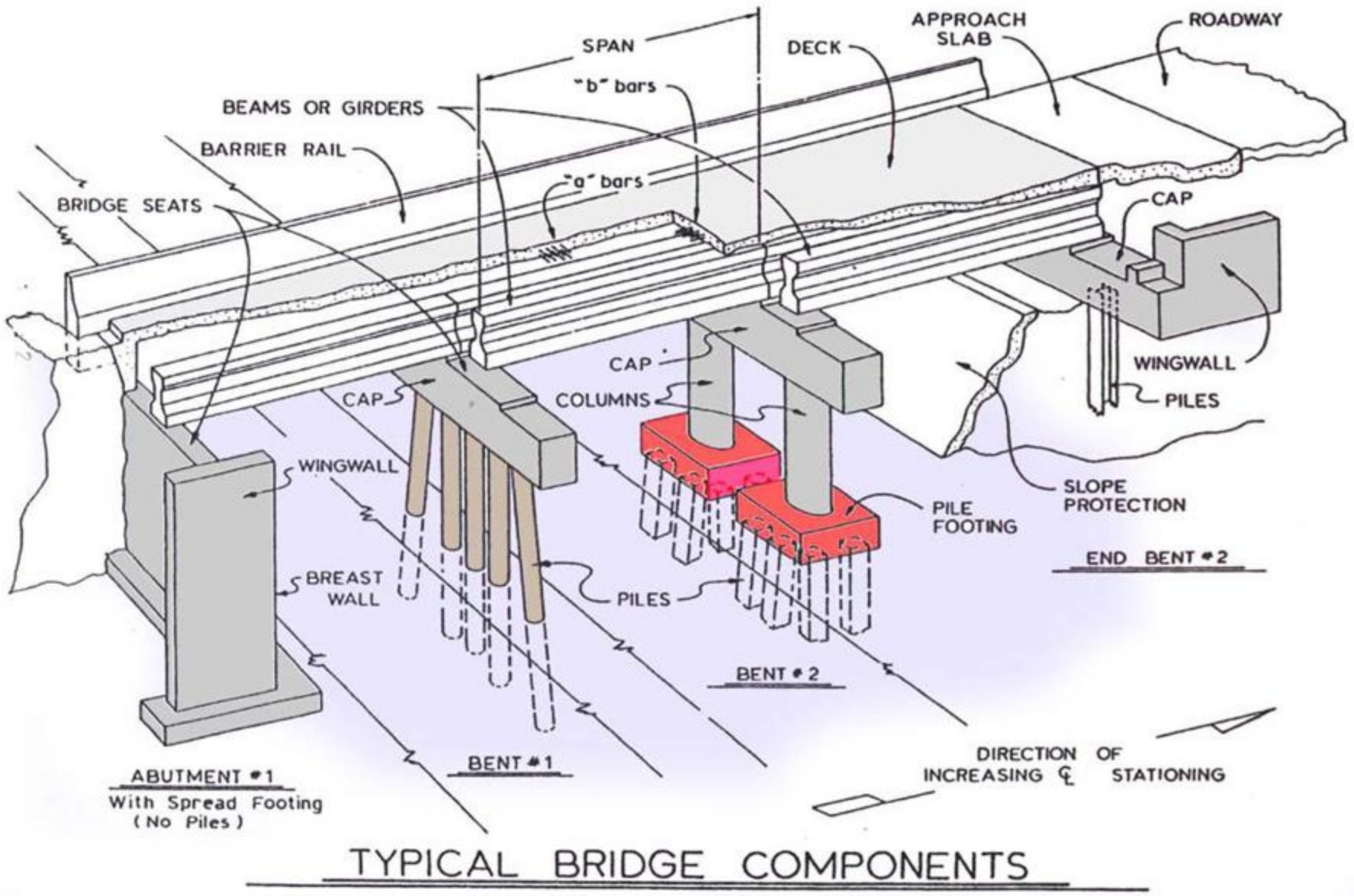

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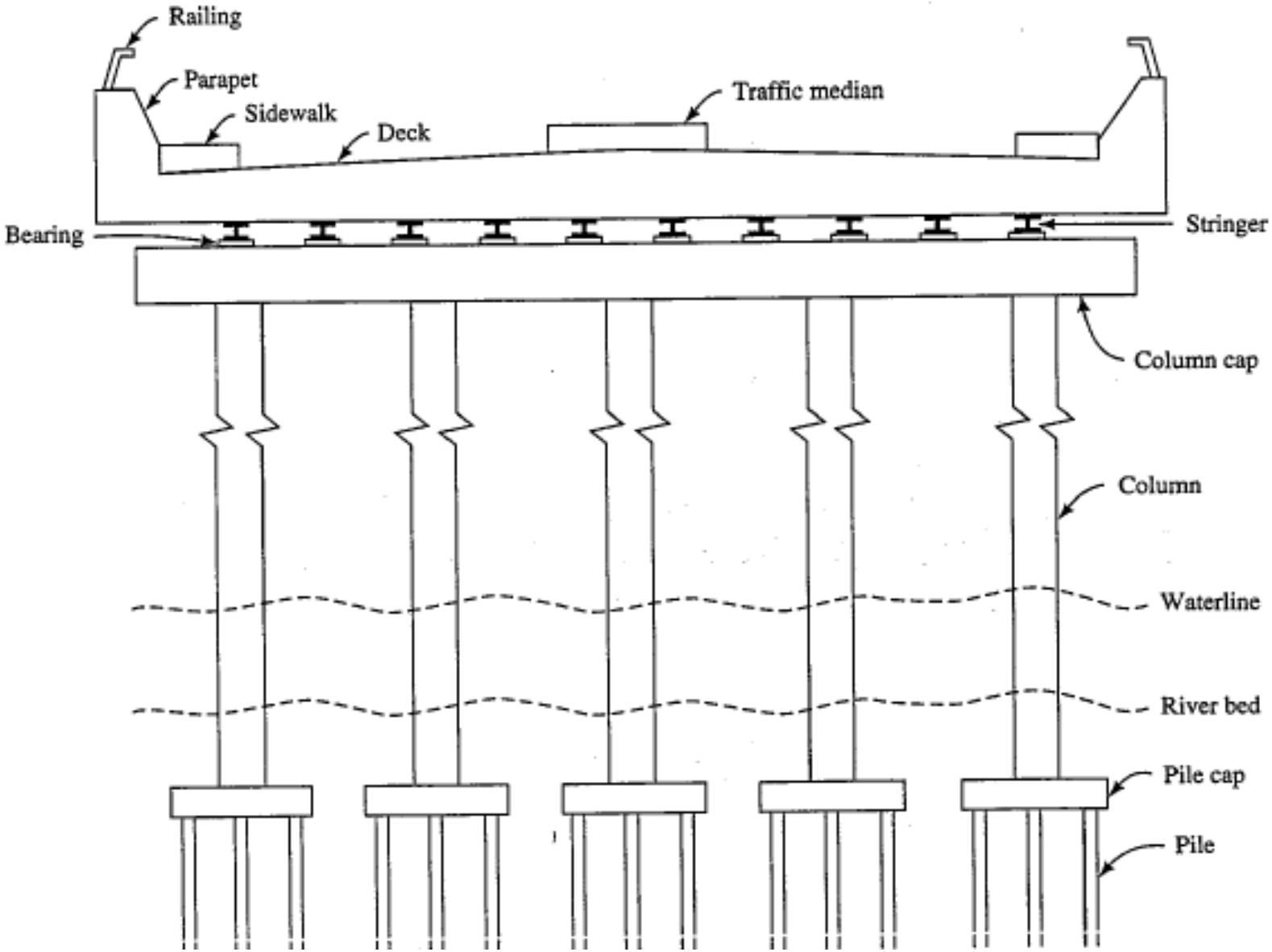

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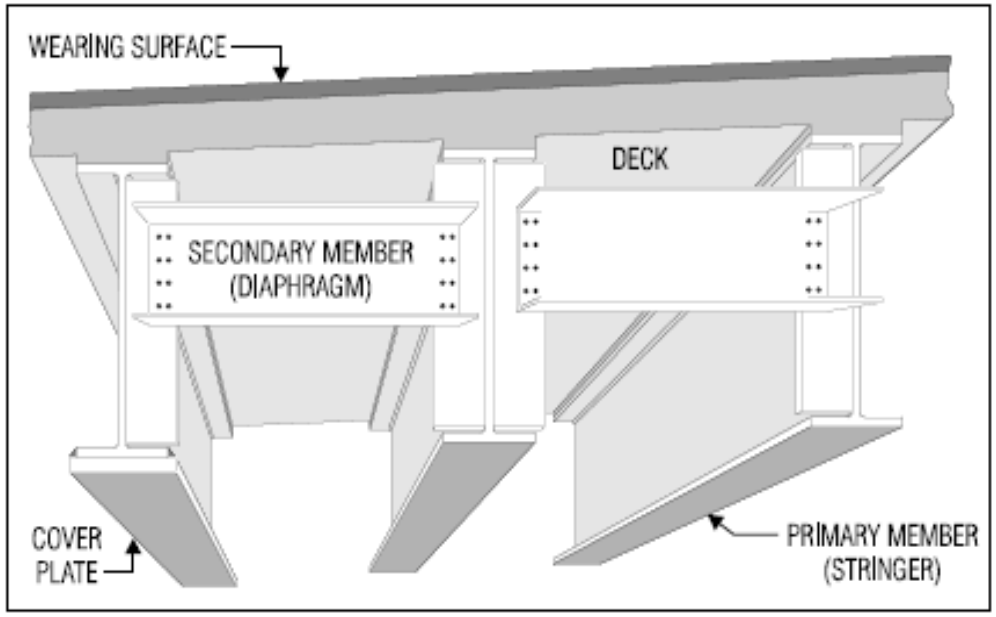


- **Primary Members.** distribute loads longitudinally and are usually designed principally to resist flexure and shear.

- **Secondary Members:** are bracing between primary members designed to resist cross-sectional deformation of the superstructure frame and help distribute part of the vertical load between stringers. They are also used for the stability of the structure during construction.

Bridge terminology: Slab on Girder Bridge

- **Wearing Surface.** The wearing surface (course) is that portion of the deck cross section which resists traffic wear. In some instances this is a separate layer made of bituminous material, while in some other cases it is a integral part of concrete deck.

- **Deck.** The *deck* is the physical extension of the roadway across the obstruction to be bridged. The main function of the deck is to distribute loads *transversely* along the bridge cross section.

- **Stringers:** Beam type primary members are also called ***stringers* or *girders*.** These stringers could be steel wide flange stringers, steel plate girders (i.e., steel plates welded together to form an I section), prestressed concrete, glued laminated timber, or some other type of beam.

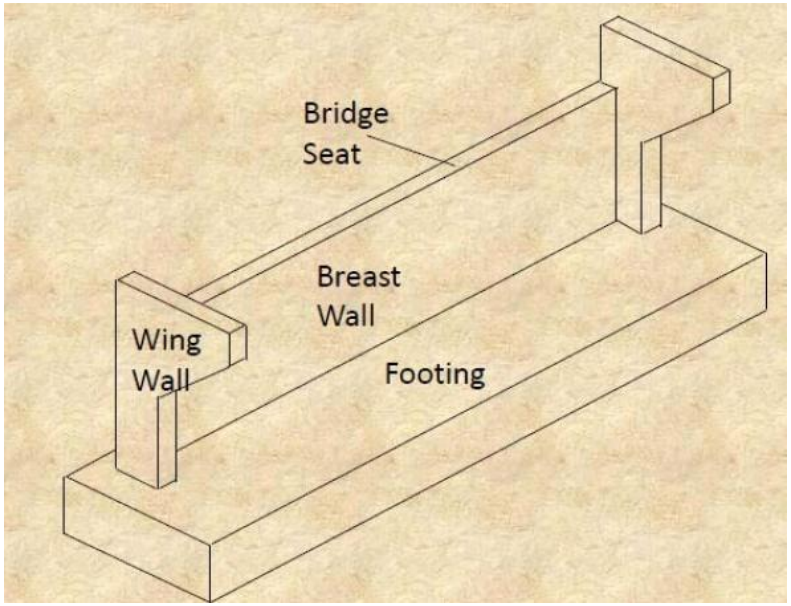
Bridge terminology: Slab on Girder Bridge

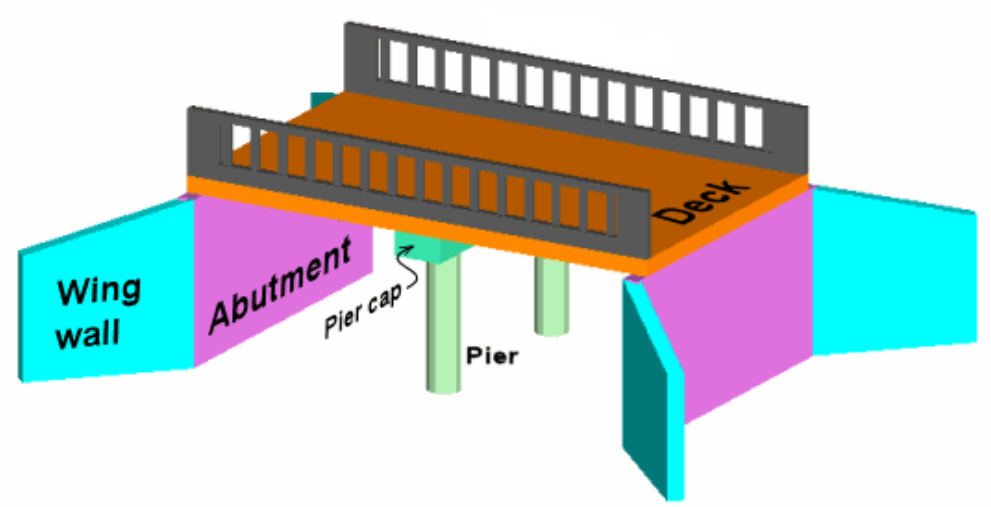
- **Abutments are earth-retaining structures which support the superstructure at the beginning and end of a bridge.**

➢ **The abutments establish the connection between the bridge superstructure and the embankments.**

➢ **They are designed to support the loads due to the superstructure which are transmitted through the bearings and to the pressures of the soil contained by the abutment.**

- **A wing wall is a side wall to the abutment back wall or stem designed to assist in confining earth behind the abutment.**

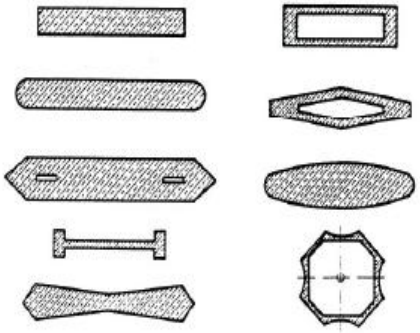




Bridge terminology: Slab on Girder Bridge

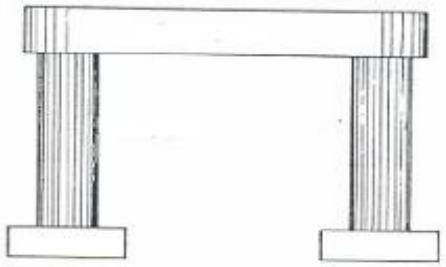
- Piers are structures which support the superstructure at intermediate points between the end supports (abutments). Like abutments, piers come in a variety of forms. From an aesthetic standpoint, piers are one of the most visible components of a bridge and can make the difference between a visually pleasing structure and an unattractive one.

Typical cross-section of piers for overcrossing and viducts on land

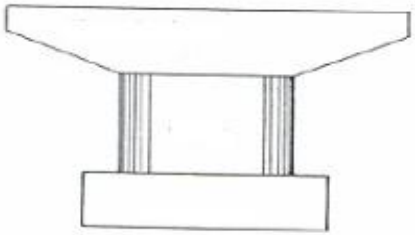


Typical cross-section of piers for river and waterway crossing

Solid Pier



Column Bent or Open Pier



Cantilever Pier or Hammered Pier

Bridge terminology: Slab on Girder Bridge

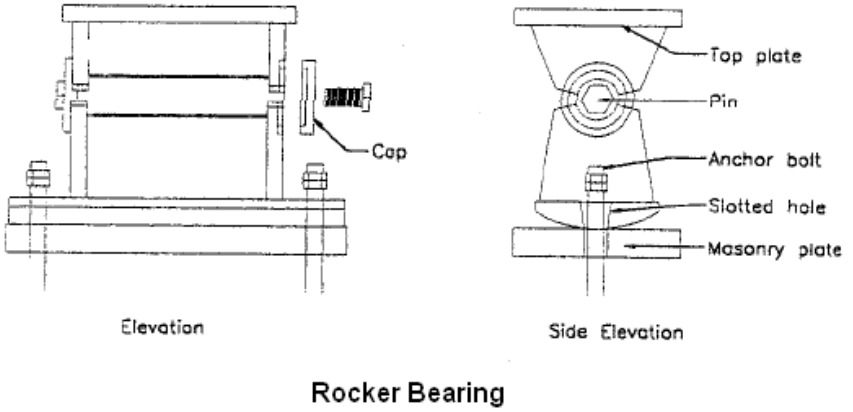
- **Bearing is a structural device positioned between bridge superstructure and substructure which transmit the vertical and horizontal loads of the superstructure to the substructure, and accommodate movements between the superstructure and the substructure**
- **Role of Bearing**
  - **To transmit load from superstructure to substructure**
  - **Accommodate relative movement between superstructure and substructure**
- **Types**
  - **Fixed Bearing**

    Rotational movement only
  - **Expansion Bearing**

    Rotational movement

    Translational movement

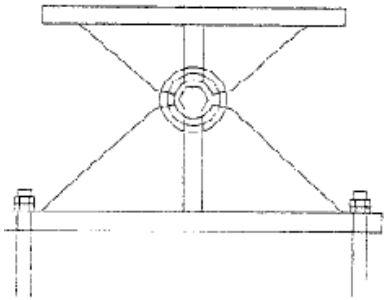
Rocker/ Pin/ Roller Bearing



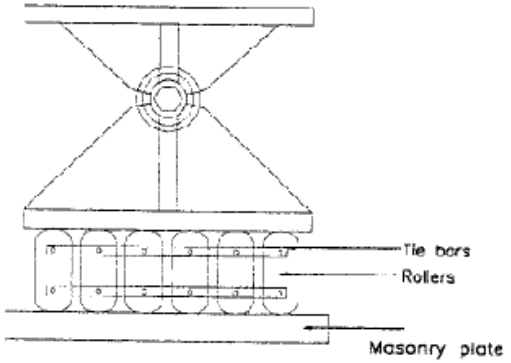
Rocker Bearing

Mostly used for steel beams

- Can carry large loads
- Requires high clearance
- Corrosion can be a Problem
- Need regular inspections
- High maintenance cost



Pin Beaing

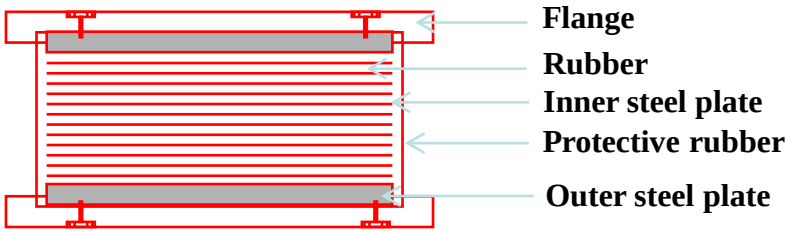


Roller Bearing

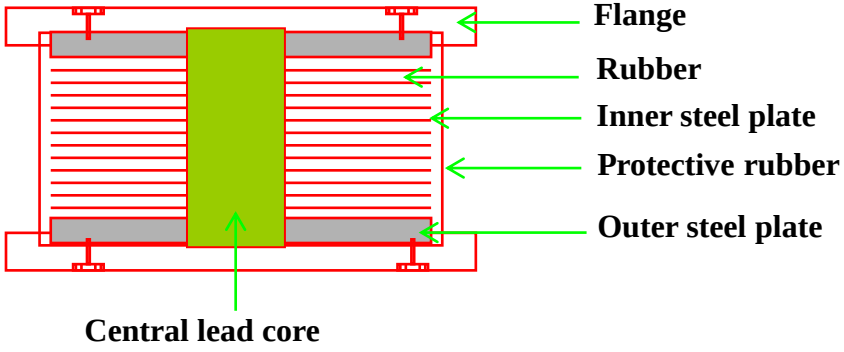
Elastomeric Bearing

- Made up of natural or synthetic rubber.
- Very flexible in shear but very stiff against volumetric change.
- Steel or fiberglass is typically used to reinforced the pad in alternate layers to prevent it from “bulging” under high load allowing it to resist higher loads.
- Can accommodate both rotational and translational movements through the deformation of pad.

Elastomeric Bridge Bearings



Elastomeric Bearing



Lead Rubber Bearing