II. Bridge Types

Components of Bridge

- **Substructure**
  - Foundation (Pile/Spread Footing)
  - Pier (Column)
  - Abutment

- **Superstructure**
  - Any structures above bearing which support the roadway
  - Wearing Surface

Components of Bridge

- Superstructure
  - Roadway Deck
  - Abutment

- Substructure
  - Pier
  - Foundation

Components of Bridge

- Superstructure
  - Roadway Deck
  - Abutment

- Substructure
  - Pier
  - Foundation

Bearing
Components of Bridge

- Pin Joint
- Cap Beam
- Bearing

Span Length

- span length
- single span
- multi span

- 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

- Types by Kinds of Traffic
- Types by Traffic Position
- Types by Material and Fabrication
- Types by Structural System
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: Highway Bridge

- Golden Gate Bridge
  - California, USA
  - 1994

- Avon Mouth Bridge
  - Bristol, UK

Types: Pedestrian Bridge

- El Alamillo Bridge
  - Seville, Spain
  - 200m span

- Japan Bridge (1994)
  - Paris, France
  - 200m span

Types: Railway Bridge

- Mountain Creek Bridge (1880)
  - Canada

- Stoney Creek Bridge (1894)
  - Canada
  - 325ft span
Types: Transit Guideway

- BTS System
  - Bangkok, Thailand

Types: Others

- Pont du Gard (Roman Aqueduct) (circa 19 BC)
  - Nimes, France

Types: Others

- Runway at the Los Angeles International Airport (LAX)
  - Los Angeles, USA

Types: Others

- Navigational Canal
  - Netherlands
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: Deck Type

- Rhone Bridge
  - France

Types: Through Type

- Henry Hudson Bridge (1936)

- Firth of Forth Bridge (1890)
  - Scotland
  - 521m span

- Tonegawa River Bridge (1972)
  - Japan
Types: Half-Through

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…

Timber Bridge probably built in place!

Leonardo Da Vinci Bridge (2001)
Norway
40 m Span
Glue-laminated Timber Bridge
Types by Material & Fabrications

- Steel
- Prefabricated
  (probably with precast slab)

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

Types of Bridge by Structure

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

Prestressed Segmental Bridge
Precast & Post-Tensioned
**Types: Arch Bridge**

- **Semi-circle** (has vertical reaction force only)
- **Flat arch** (has vertical and horizontal forces at the support)
- **Tied arch** (tie resists tension force)

**Hinge Detail at the top of an arch bridge**

Hinge changes the degree of indeterminacy in the structure
Types: Arch Bridge

- The arch construction was invented during the Roman empire

Materials:
- Masonry
- Timber
- Concrete (Reinforced/ Prestressed)
- Steel

Types: Masonry Arch Bridge

Ponte dei Salti Bridge (circa 1st century AD), Switzerland

Types: Masonry Arch Bridge

Ponte Fabricio and Ponte Cestio (65 BC), Tiberina Island, Italy

Types: Masonry Arch Bridge
**Types: Masonry Arch Bridge**

Bixby Bridge (1932)
California, USA
97.5 m span
Concrete arch

**Types: Concrete Arch Bridge**

Enz Bridge (1961)
Mülacker, Germany
46 m span
Concrete arch

Natchez Trace Parkway Bridge (1994)
Tennessee, USA
502 m span
Concrete arch

**Types: Prestressed Concrete Arch**
**Types: Steel Arch Bridge**

Sydney Harbor Bridge (1938)
Sydney, Australia
parabolic arch
503 m span

**Types: Steel Arch Bridge**

Construction of Sydney Harbor Bridge

**Types: Beam/Girder Bridges**

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

**Types: Beam/Girder Bridges**

Common Materials
- Timber Truss
- RC Beam
- Steel Plate Girder/Box Girder
- Steel Truss Girder
- Prestressed Concrete Girders
  - I-Beam, U-Beam, T-Beam
  - Segmentally Prestressed Box Beam
Types: Beam/Girder Bridges

- Simple
  ![Simple Beam/Girder Bridge](image)

- Cantilever
  ![Cantilever Beam/Girder Bridge](image)

- Continuous
  ![Continuous Beam/Girder Bridge](image)

- 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: Beam/Girder Bridges

- Hot-rolled
  ![Hot-rolled Beam/Girder Bridge](image)

- Box sections
  ![Box Beam/Girder Bridge](image)

- Plate girder
  ![Plate Girder Beam/Girder Bridge](image)

- Steel sections may be hot-rolled shapes (for short-span bridge), Box section (medium span), or Plate Girder (medium span).
Types: Beam/Girder Bridges

Upper: Steel Plate Girder Bridge
Lower: Prestressed Concrete I-Girder Bridge

Steel Plate Girder

Types: Beam/Girder Bridges

Steel Plate Girder

Typical Cross-Section of Prestressed Concrete Precast (and Pretensioned) sections are usually of I-shape

AASHTO Type IV Girder.
Types: Beam/Girder Bridges

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
Some types of truss bridges can also be considered as a “beam bridge” when looked globally.

Steel truss can be of beam type, arch type, or cantilever type depending on the primary mechanisms.
Types: Cantilever Bridges

- 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 negative moments.

Types: Cantilever Bridges

- Steel Truss Cantilever
- Prestressed Concrete Segmental Cantilever Beam

Types: Steel Truss Cantilever Bridge

Firth of Forth Bridge (1890), Scotland
521m span
### Types: Steel Truss Cantilever Bridge

![Steel Truss Cantilever Bridge Image]

### Types: Cantilever Bridges

- Prestressed Concrete Segmental Cantilever Beam
  
  **Columbia River Bridge**
  
  USA
  
  1950 ft span

### Types: Cable-Stayed Bridge

- Cable-stayed bridge uses the prestressing principles but the prestressing tendons are external of the beam
- All the forces are transferred from the deck through the cables to the pylon

### Types: Cable-Stayed Bridge

- Roadway deck can be:
  - (Prestressed) Concrete Box Deck
  - Steel Box Deck
  - Steel Truss Deck

![Cable-Stayed Bridge Diagram]
Types: Cable-Stayed Bridge

- Construction sequence
  
  Construct Pylons

Erect the deck away from the pylon in both of the pylons.

Join the cable-stayed sections with the back piers (back piers helps resist tension forces).
Types: Cable-Stayed Bridge

The concrete roadway deck is laid as the deck structure is erected.

Finally, join the two cantilevers at the midspan.

Types: Suspension Bridge

- Suspension bridge needs to have very strong main cables.
- Cables are anchored at the abutment → abutment has to be massive.

Vertical Loads from Traffic

Forces in Main Cable

Reaction Forces
Anchor of a suspension bridge

London Tower Bridge (1894)
London, UK

- 3-Hinged Suspension Bridge
- Tension member is a truss

Mackinac Bridge (1957)
Michigan, USA
1158 m span

Tacoma Narrows Bridge (1940)
Washington, USA
2800 ft span

Akashi Kaikyo Bridge (1998)
Japan
1991 m central span
Types: Suspension Bridge

Millennium Footbridge (2002) London, UK 144m span

Types: Suspension Bridge

1. Unloading crane

2. 4100t floating crane

3. Loading crane

4. Truck crane

5. Removal of loading crane

Types: Others

Pontoon (Floating) Bridge
The bridge can rotate to allow ships to go under.

Gateshead Millennium Bridge (2000)
Gateshead, UK
126m span

Charing Cross Bridge (middle - truss) and Golden Jubilee Bridges (outer – cable-stayed).

Which type should I use?

Consider the following:

- 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

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</tr>
</tbody>
</table>

0 200 400 600 800 1000 1200 1400 1600 1800 2000

Span Length (m)
Span Length

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.

Access for Maintenance

- 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 requires the least maintenance.

Substructure here is expensive compared with the superstructure.

If the water is shallow, substructure is inexpensive compared with the superstructure.
Beam Spacing

- Beam spacing determines 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
- Shipping of prefabricated pieces to site
- Is shipping channel required?
- Is the temporary falsework required? Can it be done with the site conditions?
Site Requirement

Requirement for shipping channel leads to long span bridge

Site Requirement

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

Site Requirement

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
Aesthetics

- 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