Introduction of Bridge

- A bridge is a structure which is built over some physical obstacle such as a body of water, valley, or road, and its purpose is to provide crossing over that obstacle. It is built to be strong enough to safely support its own weight as well as the weight of anything that should pass over it.

- A bridge is a structure which maintains the communication over a physical obstacle, e.g.

  – A channel/river,

  – A road,

  – A railway line or

  – A valley.

Bridge Designations

- If it carries road traffic or railway traffic or a pipe line over a channel or a valley: Bridge
- If it carries the traffic or pipe over a communication system like roads or railways: Fly-over/Over-Bridge
- Bridge (several small spans) constructed over a busy locality, a valley, dry or wetland, or forming a flyover to carry the vehicular traffic: Viaduct

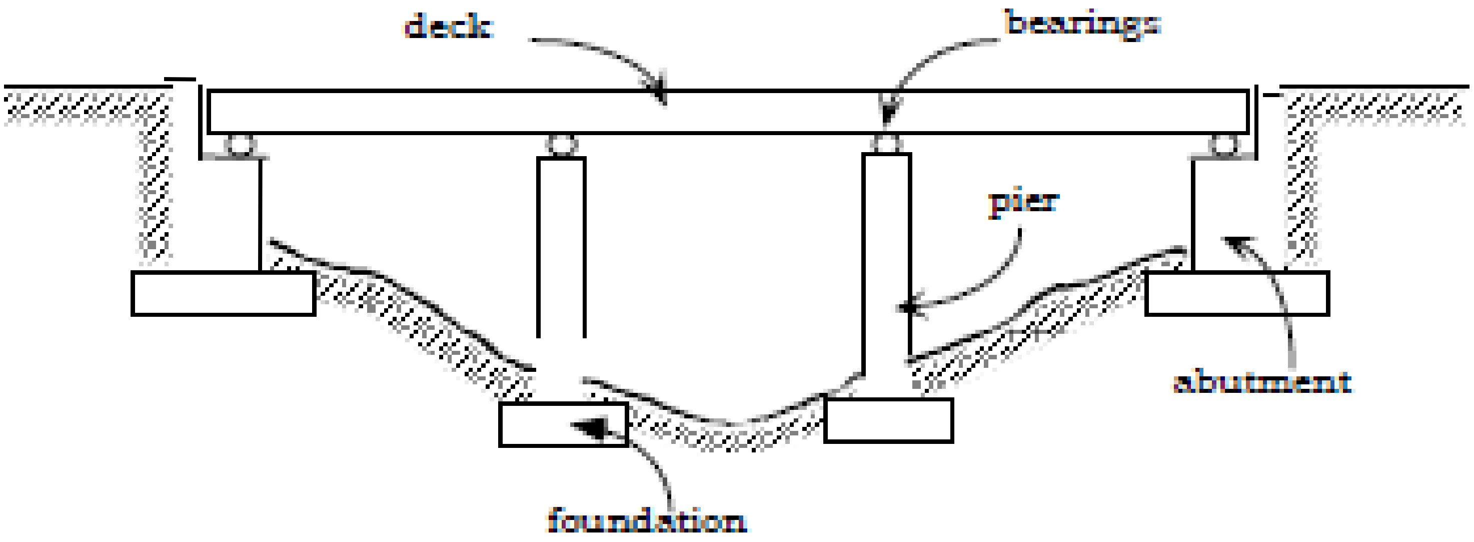
History

- History of bridges begins with a tree log accidentally fallen across water courses.
- Natural rock arches formed due to erosion beneath. (Arch Bridge)
- Climbers suspended above a deep gorge. Hanging creepers from one tree (Banyan trees) to other, by tying a bunch of long creepers with the trees situated on either side of water course.

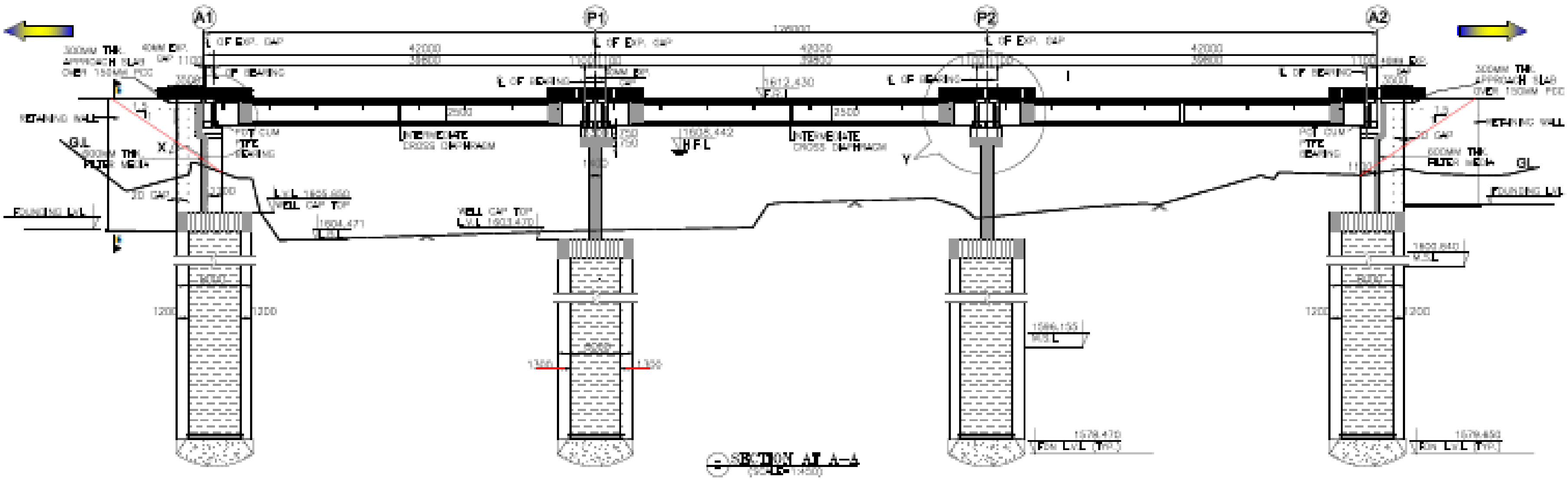



Components of Bridge

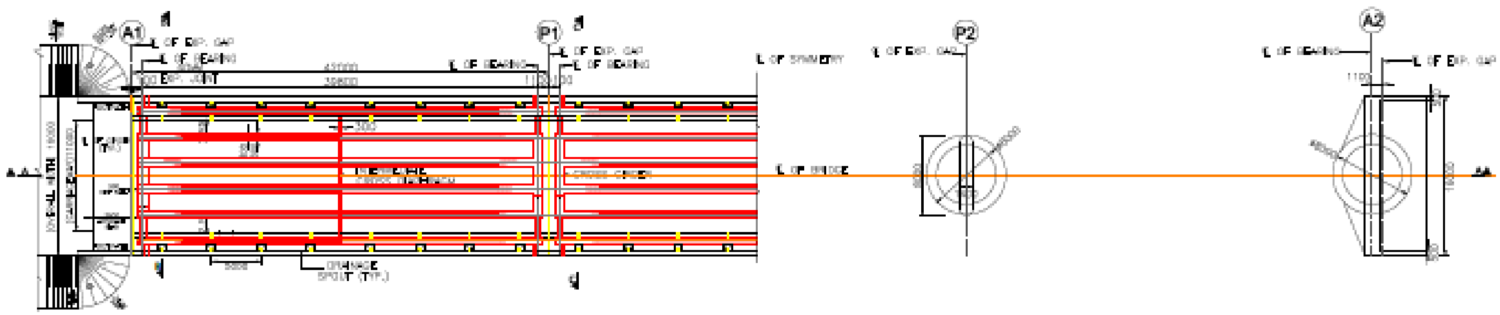
- Super-structure: Deck, Truss, Girders etc.
- Sub-structure: Piers/Abutments, Bearing and foundation.



Components of Bridge

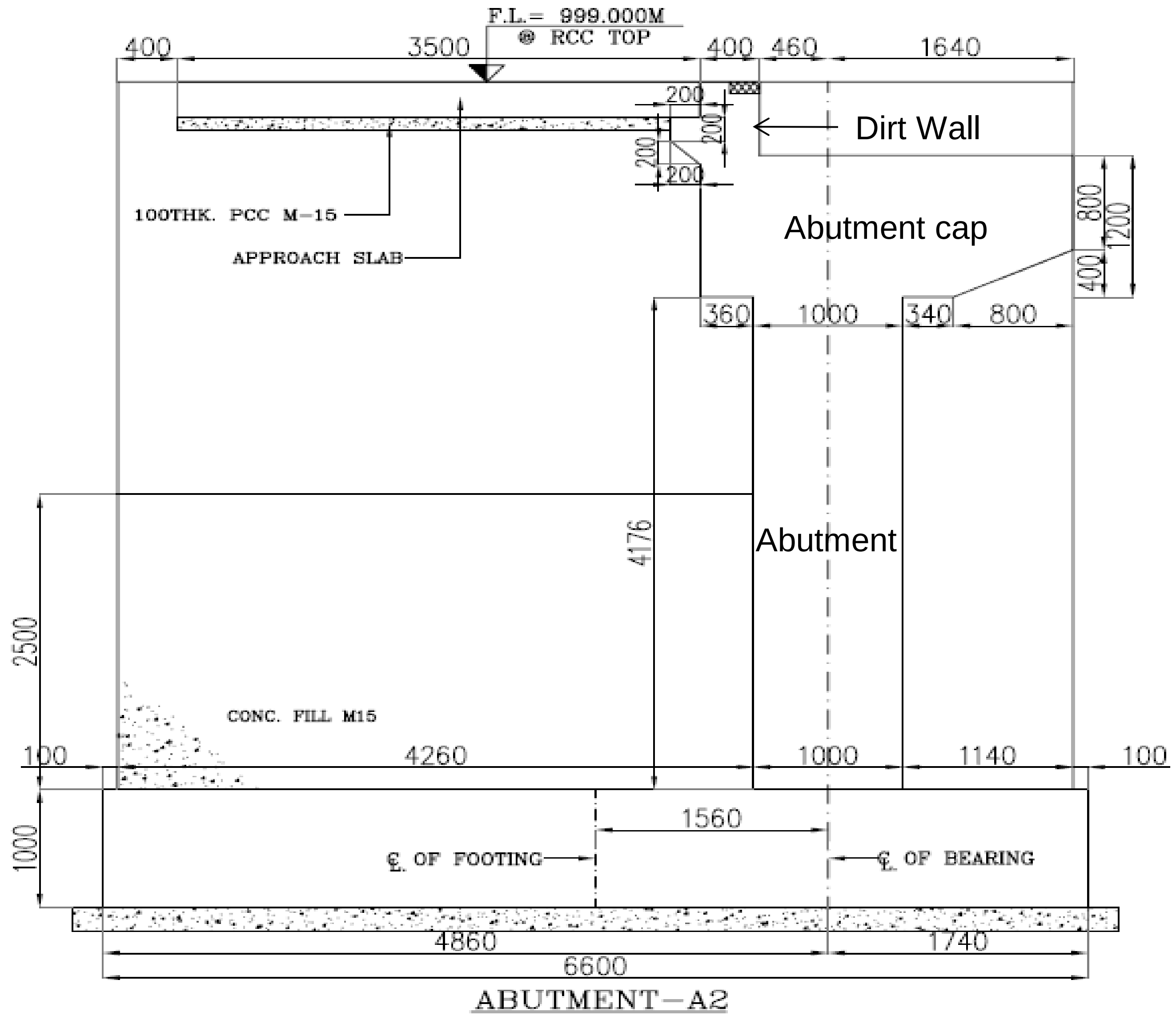


NEW ROAD LEVEL	1612.430	1612.430	1612.430	1612.430	1612.430	1612.430	1612.430	1612.430	1612.430	1612.430	1612.430	1612.430	1612.430	1612.430
GROUND LEVEL	1605.657	1605.702	1604.688	1604.862	1604.578	1604.813	1605.101	1606.771	1606.552	1605.437	1606.207	1607.177	1607.800	1607.742
CHAINAGE	8+125	8+135	8+145	8+155	8+165	8+175	8+185	8+195	8+205	8+215	8+225	8+235	8+245	8+250

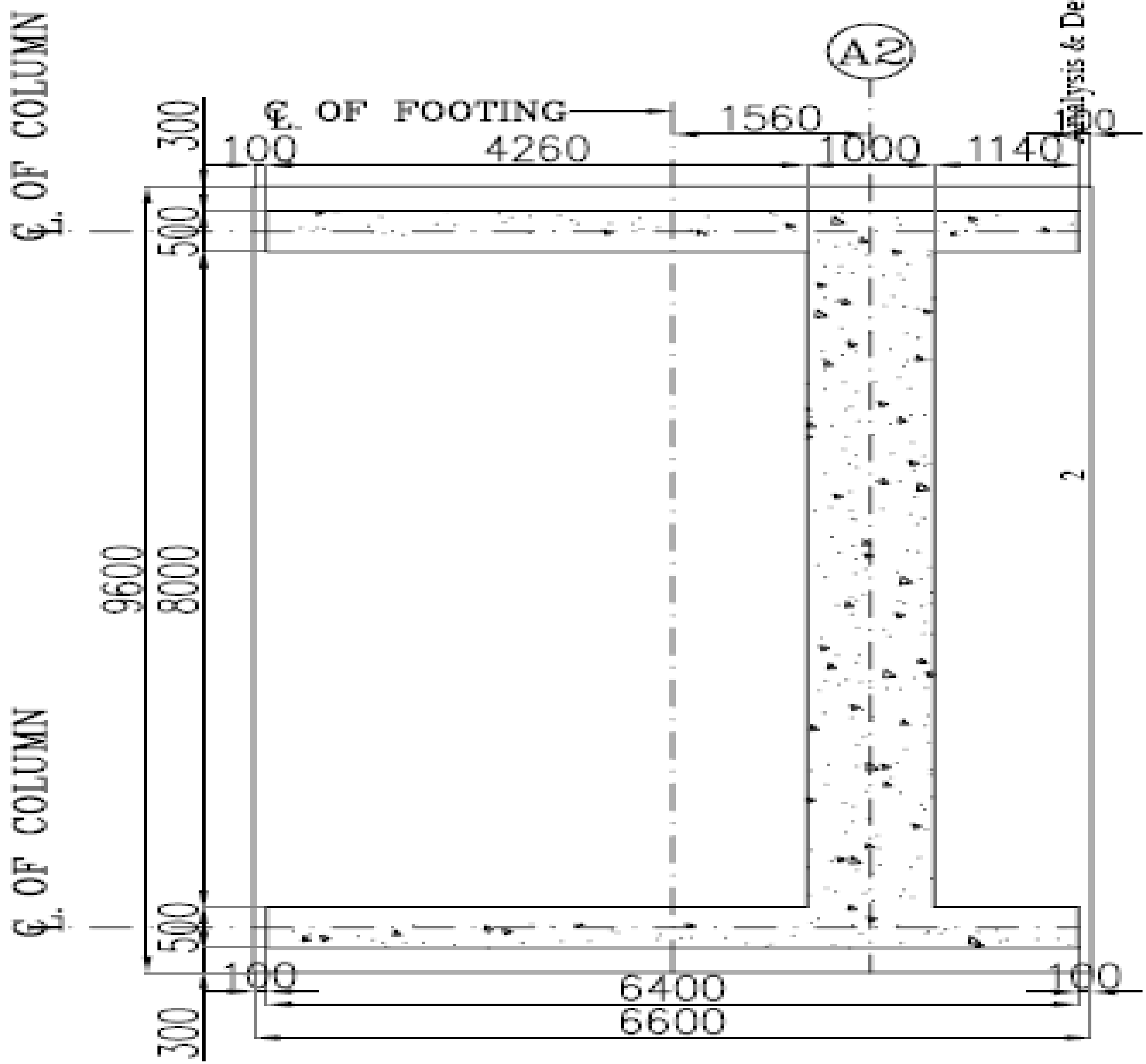


HALF PLAN AT TOP & HALF PLAN AT BOTTOM

General arrangement of Bridge



Typical details of Abutment



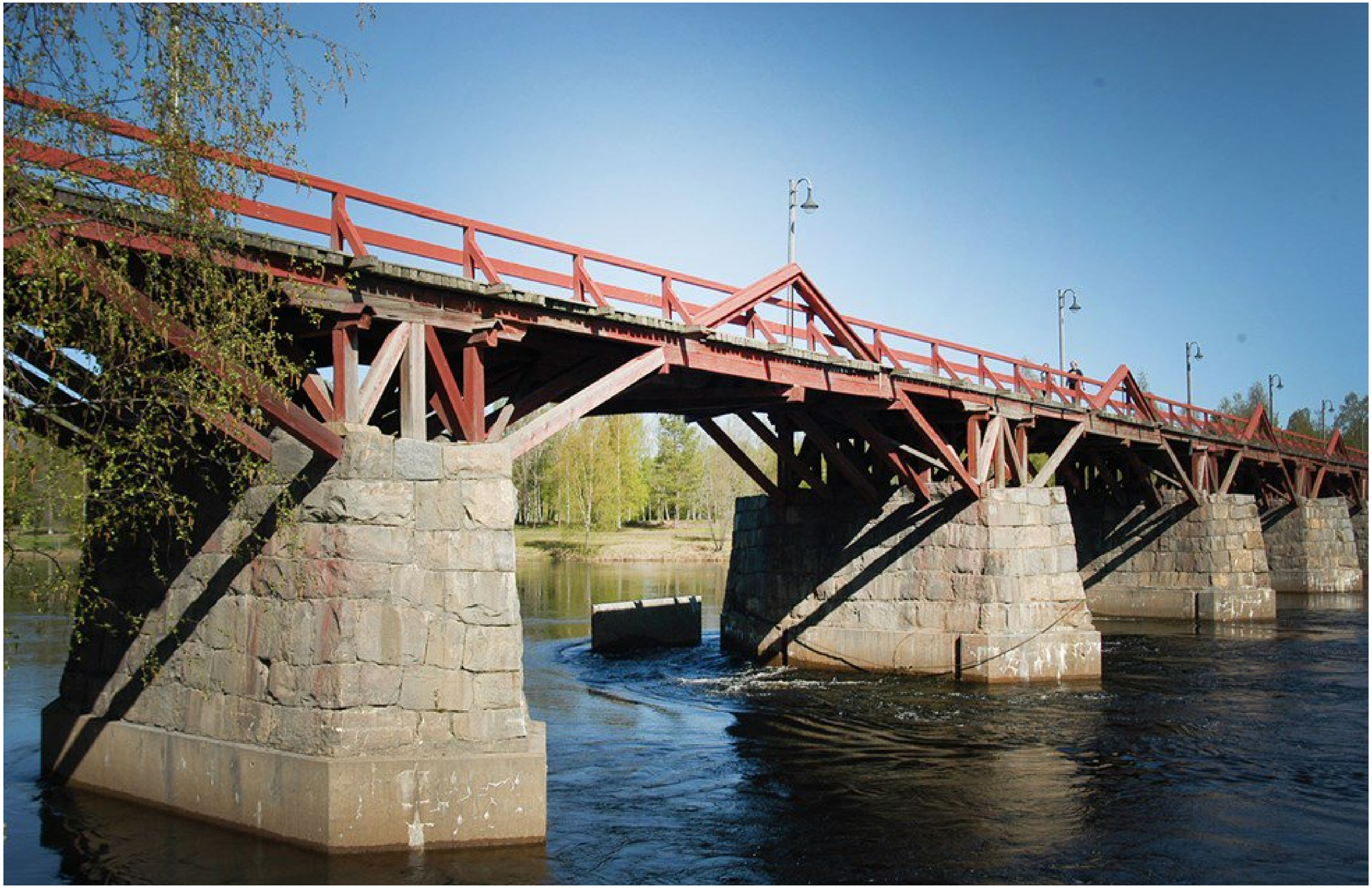
PLAN AT ABUTMENT
FOOTING TOP

Classification of Bridges

- Bridges are mainly classified according to:
  A. Materials used in their construction.
  B. Various structural forms.
  C. Construction and function.

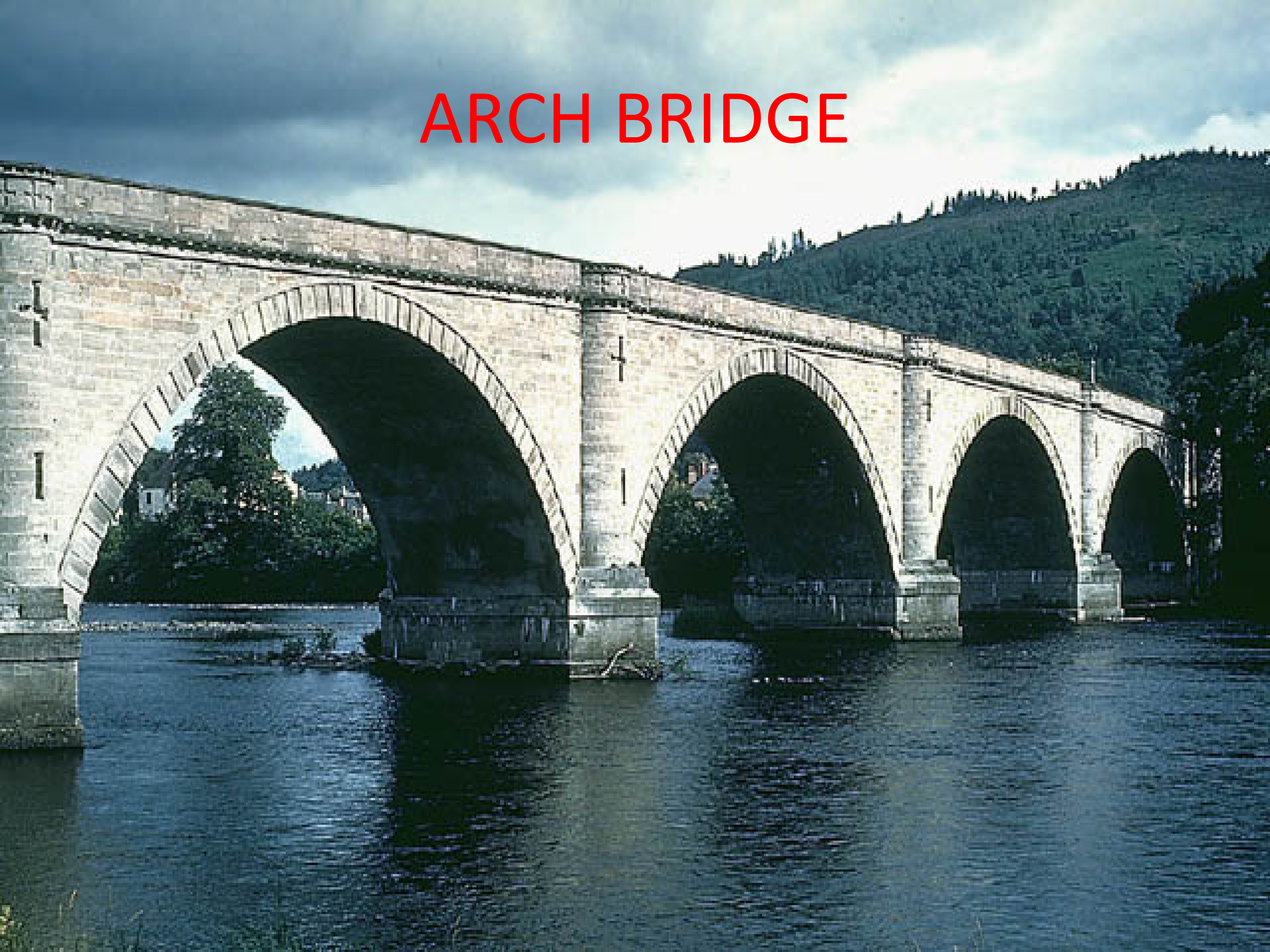
A: Classification According to Material

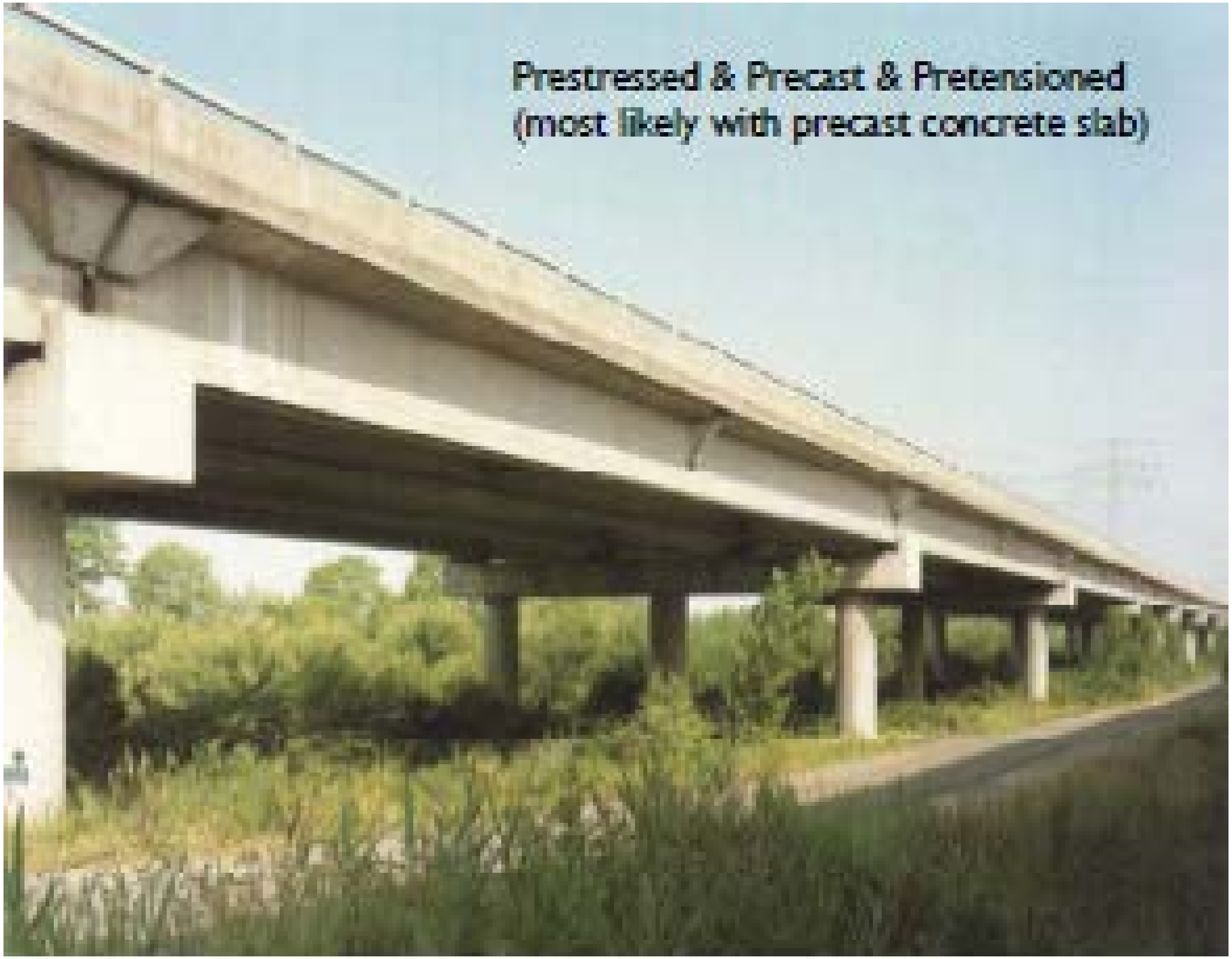
- TIMBER
- MASONARY
- CONCRETE (R.C.C or Pre-stressed)
- STEEL



[Wooden bridge - Swedish Wood]

ARCH BRIDGE




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

STEEL BRIDGE

B: According to various structural forms

- SLAB (0-12m)
- BEAM (10-30m)
- CANTILEVER/Balanced Cantilever (30-500m)
- Box-Girder (18-30m; 60-70m with Pre- stressing)
  (Cellular/Multi-celled Bridges)

(contd…..)

Contd.

• TRUSS	35- 300m
• ARCH	20-500m
• CABLE STAYED	90-350m
• SUSPENSION	300-2000m

Distinctive Features of Slab Bridges

- Usually used for Short spans
- Carry loads in Shear and Flexural bending
- Have sufficient torsional stiffness
- Bearings are not required
- Simple Shattering/formwork is required
- Becomes heavy (increase in D.L) for large spans. Hollow slabs are sometimes provided for medium spans.

Distinctive Features of Beam/Girder Bridges.

- Oldest and most common bridge type known
- Usually used for Short and Medium spans
- Carry loads in Shear and Flexural bending
- In modern girder bridges, steel I-Beams replace Concrete Beams
- Low torsional stiffness

Types: Beam/Girder Bridges

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

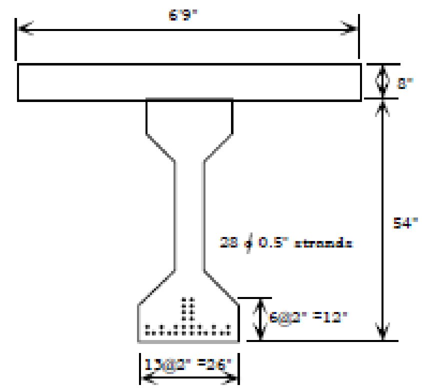
Types: Beam/Girder Bridges

Steel Plate Girder

Types: Beam/Girder Bridges

Types: Beam/Girder Bridges

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



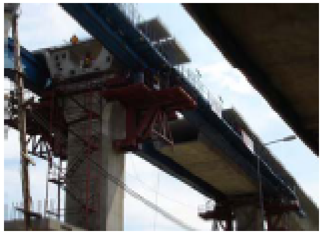
AASHTO Type IV Girder.

Typical Cross-Section of Pretensioned AASHTO Type IV girder

Distinctive Features of Box Girder Bridges

- In addition to flexural stiffness and shear resistance, these bridges have sufficient torsional stiffness
- Most suitable for curved plan and longer span bridges

Types: Beam/Girder Bridges



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

Types: Beam/Girder Bridges

- 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

Steel Box Girder Bridge

Distinctive Features of Truss Bridge

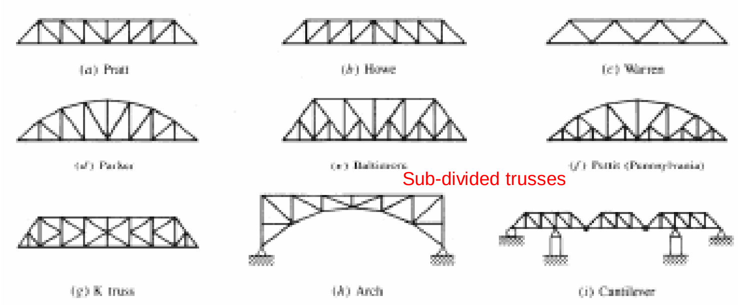
- The primary member forces are axial loads
- The open web system permits the use of a greater overall depth than for an equivalent solid web girder, hence reduced deflections and rigid structure
- Both these factors lead to economy in material and a reduced dead weight. The increased depth also leads to reduced deflections, that is, a more rigid structure.
- High maintenance and fabrication costs.
- Aesthetic appearance is debatable mainly because of complexity of elevation.
- Used economically in the span range of upto 300m.

Types: Beam/Girder Bridges

- Some types of truss bridges can also be considered as a "beam bridge" when looked globally

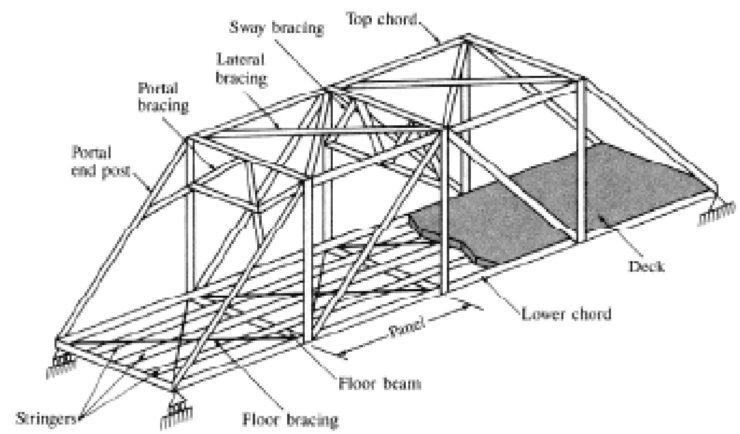
Types: Beam/Girder Bridges

Types: Beam/Girder Bridges



Steel Truss can be of beam type, arch type, or cantilever type depending on the primary mechanisms

Types: Beam/Girder Bridges



Components of Truss

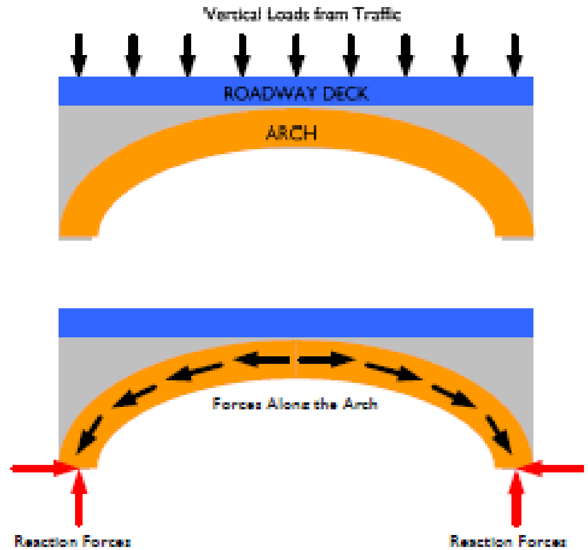
Distinctive Features of Cantilever Bridge

- Cantilever bridges can be of steel or concrete
- 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

Distinctive Features of Arch Bridge

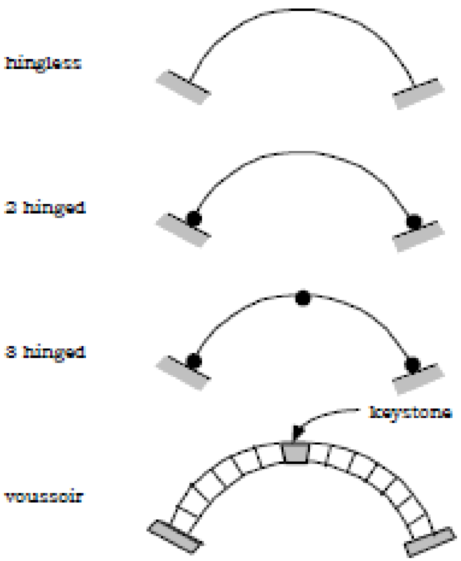
- Arch action reduces bending moments
- Economical as compared to equivalent straight simply supported Girder or Truss bridge
- Suitable; when site is a deep gorge with steep rocky banks.
- Conventional curved arch rib has high Fabrication and Erection costs.
- Unlike girders, can be built from stones
- Considered the most beautiful of bridge types
- Used in the span range of upto 250m.

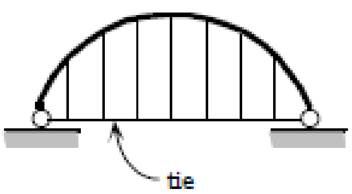
Types: Arch Bridge



Types: Arch Bridge

Hinge changes the degree of indeterminatcy in the structure





Types: Concrete Arch Bridge

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

Types: Prestressed Concrete Arch

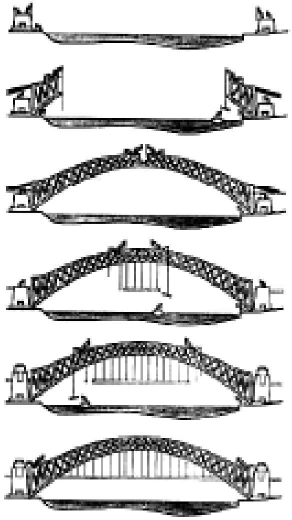
Natchez Trace Parkway Bridge (1994)
Tennessee, USA
502 m span

Types: Steel Arch Bridge

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

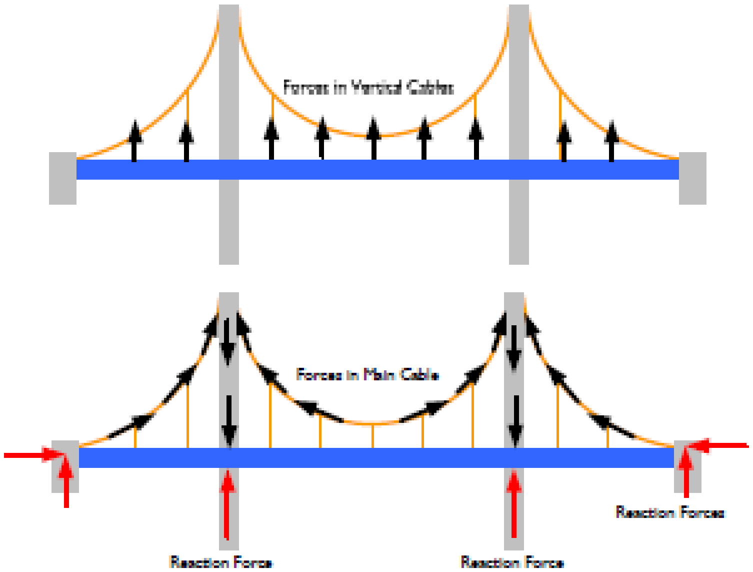
Types: Steel Arch Bridge

Construction of Sydney Harbor Bridge



Distinctive Features of Suspension Bridge

- The deck is hung from the cable by Hangers constructed of high strength ropes in tension
- Cables are anchored at the abutment, hence abutment has to be massive
- The main cable is stiffened either by a pair of stiffening trusses or by a system of girders at the deck level.
- This stiffening system serves to control the aerodynamic movements.



…contd.

- Suspension bridge needs to have very strong main cables
- The complete structure can be erected without intermediate staging from the ground
- It is the only alternative for spans over 600m, and it is generally regarded as competitive for spans down to 3000m.
- The height of the main towers can be a disadvantage in some areas; for example, within the approach road for an airport

Types: Suspension Bridge

Anchor of a suspension bridge

Types: Suspension Bridge

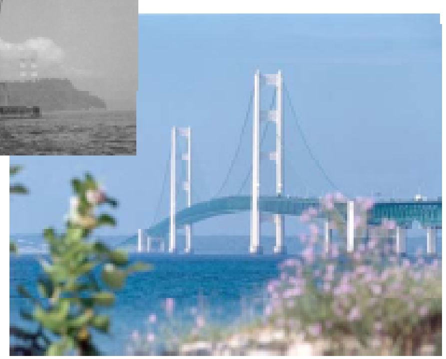
London Tower Bridge (1894)
London, UK

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

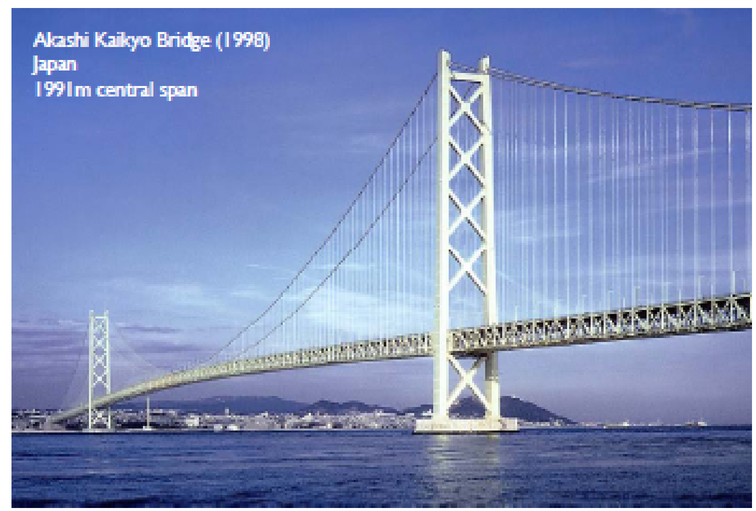
Types: Suspension Bridge

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

Mackinac Bridge (1957)
Michigan, USA
1158 m span



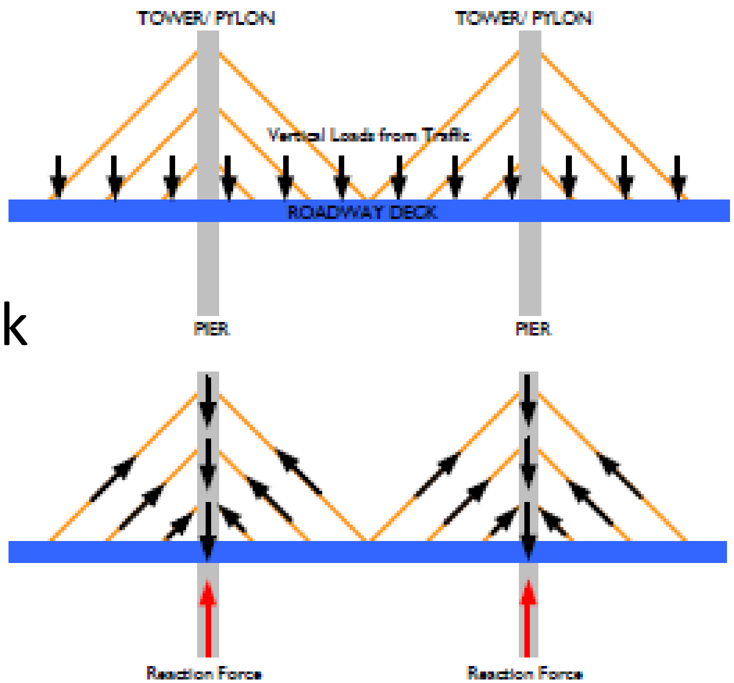
Types: Suspension Bridge



Akashi Kaikyo Bridge (1998)
Japan
1991m central span

Distinctive Features of Cable-Stayed Bridge

- Cable-stayed bridge uses the pre-stressing principles but the pre-stressing tendons are exposed/outside of the beam
- All the forces are transferred from the deck through the cables to the tower/pylon

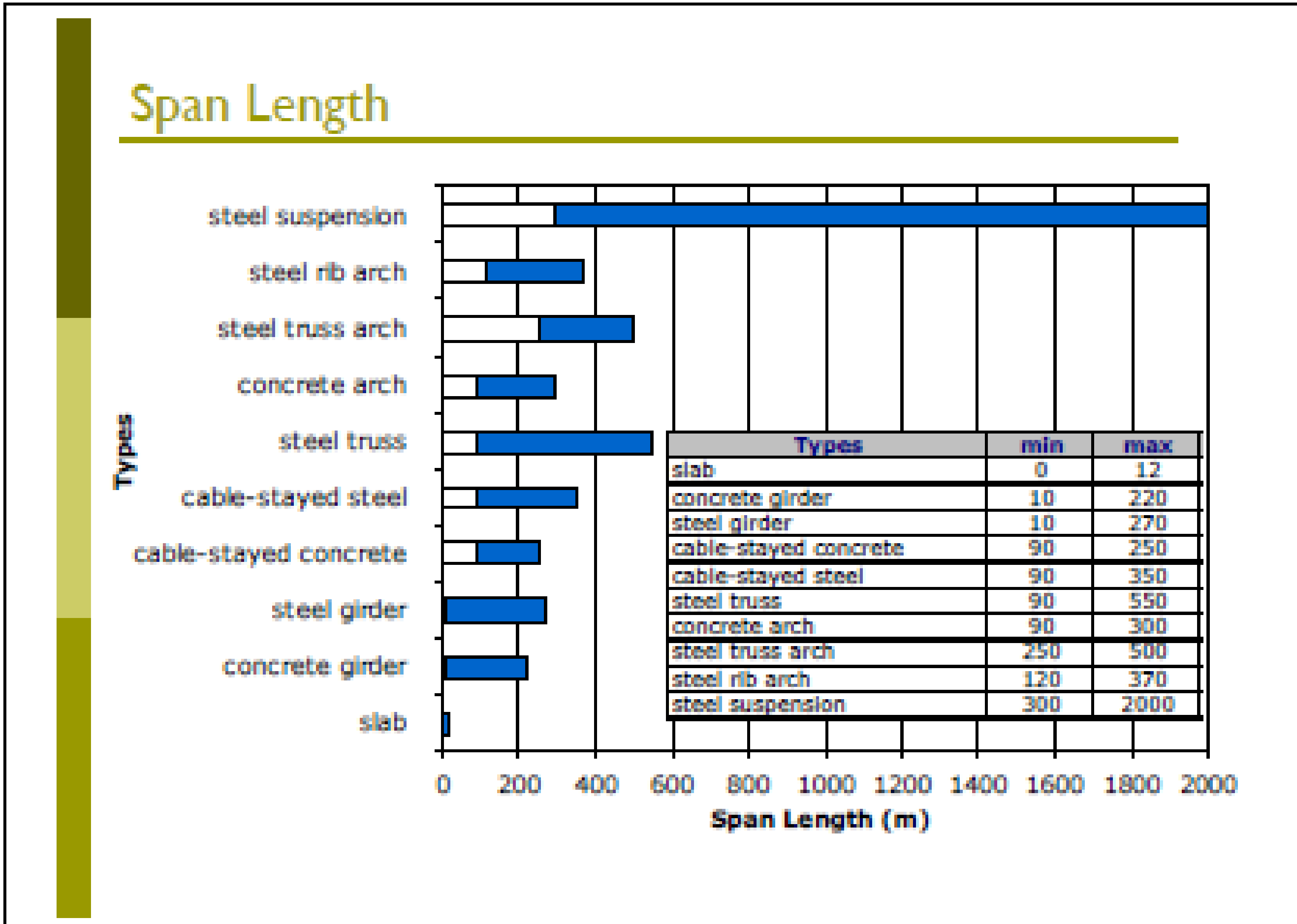


- Roadway deck can be:
  - (Prestressed) Concrete Box Deck
  - Steel Box Deck
  - Steel Truss Deck

Contd.

- As compared with the stiffened suspension bridge, the cables are straight rather than curved. As a result, the stiffness is greater
- The cables are anchored to the deck and cause compressive forces in the deck.
- All individual cables are shorter than full length of the superstructure. They are normally constructed of individual wire ropes, supplied complete with end fittings, pre-stretched and not spun.
- Aerodynamic stability has not been found to be a problem in structures to date.
- It is economical over 200-500m.

Suitability on the basis of span



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

C. Construction and other function

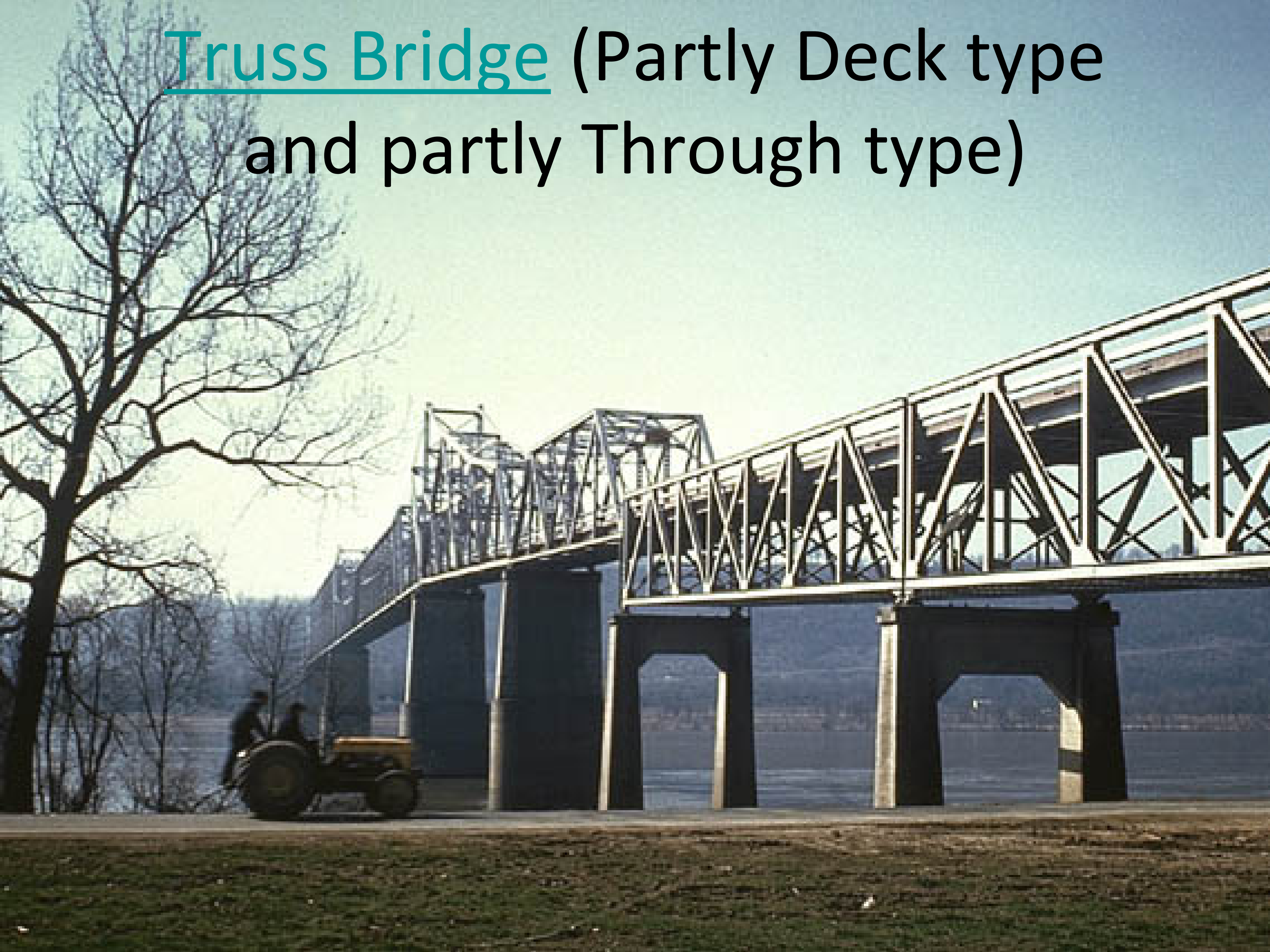
C-1): According to inter-span relations

- Simple: Independent spans; large B.M and S.F
- Continuous: Design moments are reduced; foundation supported on good rock or differential settlement of supports is eliminated
- Cantilever/Balanced bridges: Slight differential settlements under the pier or abutment are not detrimental

C-2): According to position of bridge floor.

– Deck
– Through
– Half/Semi Through and
– Suspended Bridge.

Truss Bridge (Partly Deck type and partly Through type)



C-3): Method of connections.

- Pin jointed
- Riveted or
- Welded

C-4): According to road level

- High level or
- Submersible.

C-5): According to the method of clearance for navigation

- High level
- Movable-bascule
- Movable swing or transporter bridge.

C-6): According to duration of use and service

- Permanent/temporary
- Military (Bailey)

C-7): According to function

- Aqueduct
- Viaduct
- Pedestrian
- Highway
- Railway or pipe bridges

C-8): According to span length

• Culvert	<= 6m
• Minor/Short span bridge	6m-60m
• Major/Medium span bridge	>60m-150m
• Long span bridge	>150m

C-9): According to degree of redundancy

- Determinate or
- Indeterminate

SOME FAMOUS BRIDGES

Bridge Design

- Hydraulic Data (Hydraulic Design)
  - H.F.L, Scour Depth, Clear waterway etc.
- For details Refer IRC:5 2015) and Essentials of Bridge Engineering By Victor Johnson
- Selection of Bridge Type
- Selection of Bridge Site
- Structural Design

Selection of a Bridge Type

Consider the followings:

- Span length
- Bridge length
- Beam spacing
- Material available
- Site conditions (foundations, height, space constraints) Requirement for shipping channel leads to long span bridge
- Speed of construction
- Constructability
- Technology/Equipment available
- Aesthetics
- Cost
- Access for maintenance

Contd.

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

Contd.

Beam Spacing

Beam spacing determine the number of girders

- Large Spacing $\rightarrow$ 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

Contd.

Materials

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

Contd.

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

Contd.

Site Requirement

- Is the bridge straight or Curved? If curved
  - Precast I-Girder cannot be Curved
  - Segmental pre-stressed can have slight curve
  - Cast-in-place
  - Box girder is preferable for curved sites (Pre-cast/Cast-in-place)
- Transportation/Shipping of prefabricated pieces to site

Contd.

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 require the least maintenance

Contd.

Aesthetics

- An ugly bridge, although safe, serviceable, and inexpensive, is not a good bridge choice
- Long span bridge over a river can be a landmark; thus, aesthetics should be an important factor
- Bridge should blend with the environment
- Avoid unnecessary decorations
- Bridge should have an appearance of adequate strength

Aesthetics contd.

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, Landscaping

Selection of Bridge Site

- Investigation And Planning

Before starting the design process of a bridge the following factors need to be considered

- Need for the bridge and the type of traffic to which it will be subjected to (both present and future)
- Various available alternatives vis-à-vis restrictions and constraints regarding selection of site as well as type of bridge.

Contd.

- Soil/sub soil conditions of the different alternative sites along with the stream conditions at the site.
- Aesthetics and cost likely to be involved.

SELECTION OF SITE. (Contd….)

- In addition to the technically required feasibility of site
- Aspects regarding social and political affairs of society need to be given due consideration.
- In urban areas the designer is not provided with many alternatives and most of the times the site is fixed.
- Designed and planned keeping in view the only option available.

Contd.

- In areas where a number of alternatives are available the site with the following ideal characteristics can be selected.
  - a straight reach of the river
  - a narrow channel with firm banks
  - suitable high level banks for h.f.l on each side
  - rock or other hard in-erodable strata close to the river bed level.
  - economical approaches
  - proximity to the direct alignment of road
  - absence of sharp curves
  - absence of expensive river training works
  - where excessive under water construction can be avoided