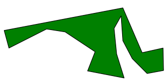
# ENCE 717
# BRIDGE ENGINEERING

C. C. Fu, Ph.D., P.E.
The BEST Center
University of Maryland
September 2008



## Role of Bridge Engineer

- The bridge engineer is often involved with several or all aspects of bridge planning, design, and management
- The bridge engineer works closely with other civil engineers who are in charge of the roadway design and alignment.
- After the alignment is determined, the bridge engineer often controls the bridge type, aesthetics, and technical details
- The bridge engineer is often charged with reviewing shop drawing and often construction details
- The owner, who is often a department of transportation or other public agency, is charged with the management of the bridge, either doing the work in-house or hiring consultants

## Role of Bridge Engineer (cont.)

- Bridge management includes routine inspections, repair, rehabilitation and retrofits or even replacement (4R) as necessary
- In summary, the bridge engineer has significant control over the design, construction, and maintenance processes. In return, bridge engineer has significant responsibility for public safety and resources
- In short, the bridge is (or interface closely with) the planner, architect, designer, constructor, and facility manager.

## Bridge Structure Selection

- Environmental Assessment Consideration (Appendix A: FHWA Order)
  - Historic: consulting with the State Historic Preservation Officer
  - Construction Impact
  - Flood Plain (stream or river subject to overflow)
  - Wetlands
  - “Landmark”

## Bridge Structure Selection (cont.)

- Design Philosophy
  - Safety
  - Serviceability (including durability of materials)
  - Inspectability
  - Maintainability
  - Rideability
  - Deformations (Deflections)
  - Constructability
  - Economy (Appendix B: Economic Evaluation; Appendix C: Caltran Estimate)
  - Bridge Aesthetics

## Bridge Structure Selection (cont.)

- Life Costs vs. First Cost

  "Ideal" Life-Cycle Costs

  $LCC = DC + BC + OC + LP + RC$

where

DC = Design Costs

BC = Estimated Bid Costs

OC = Estimated Maintenance/Operating Costs

LP = Cost accrued by the traveling public due to delays and detours required for maintenance and/or rehabilitation

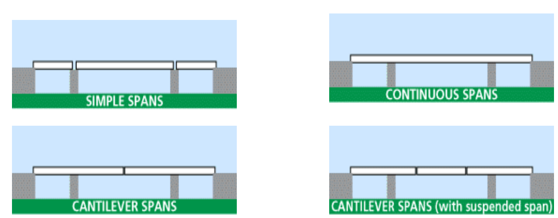
RC = Rehabilitation/Replacement Construction Costs

## Bridge Structure Selection (cont.)

- Parameters in selecting the Type, Size and Location (TS&L)
  - Span Length (pier location, site constraints, best combination of super- and sub-structure costs)
  - Accessibility to the site (weight limit, on-site fabrication)
  - Estimated Costs
  - Beam Spacing
  - Material Availability (local supplier?)
  - Time available for design and construction (urban area time constraints)
  - Geometry – curved or straight?
- Deck Superstructures (Appendix D: Common Deck Superstructures)

## Basic Types of Spans

The three basic types of spans are shown below. Any of these spans may be constructed using beams, girders or trusses. Arch bridges are either simple or continuous (hinged). A cantilever bridge may also include a suspended span.



## Type of Bridges

(Appendix E: Span Ranges for Various Bridge Types;
Appendix F: Penn DOT's Selection of Bridge Types;
Appendix G: Caltran's Types of Structures)

Types of Bridges:

A. Main Structure Coincides with the Deck Line
B. Main Structure Below the Deck Line
C. Main Structure Above the Deck Line

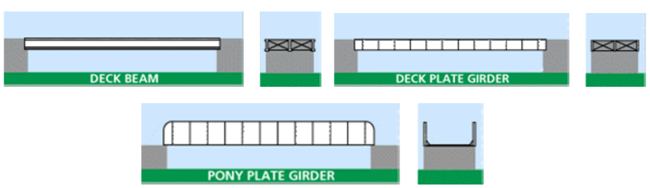
## Type of Bridges

A. Main Structure Coincides with the Deck Line

1. Slab (solid and voided)
2. T-beam (cast-in-place)
3. I-beam (precast or prestressed)
4. Wide-flange beam (composite and noncomposite)
5. Concrete box (cast-in-place and segmental, prestressed)
6. Steel Box (orthotropic deck)
7. Steel plate girder (straight and haunched)

## Beam/Girder Bridge

Simple deck beam bridges are usually metal or reinforced concrete. Other beam and girder types are constructed of metal. The end section of the two deck configuration shows the cross-bracing commonly used between beams. The pony end section shows knee braces which prevent deflection where the girders and deck meet.




## Girder Bridge Example

## Type of Bridges

B. Main Structure Below the Deck Line

1. Masonry arch
2. Concrete arch
3. Steel truss-arch
4. Steel deck truss
5. Rigid frame
6. Inclined leg frame
7. Arch – O'Connor

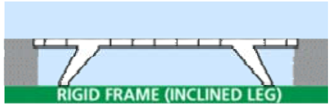
## Type of Bridges

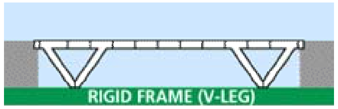
C. Main Structure Above the Deck Line

1. Suspension
2. Cable-stayed
3. Through-truss
4. Suspension – O'Connor
5. Cable-stayed
6. Truss

## Rigid Frame Bridge

Many modern bridges use new designs developed using computer stress analysis. The rigid frame type has superstructure and substructure which are integrated. Commonly, the legs or the intersection of the leg and deck are a single piece which is riveted to other sections.

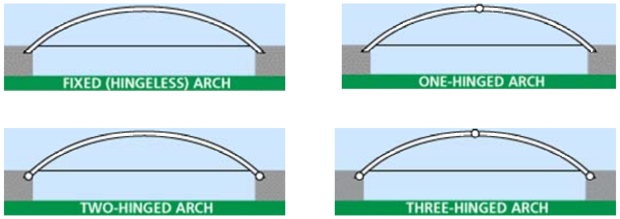



## Rigid Frame Bridge (cont.)

## Arch Bridge

There are several ways to classify arch bridges. The placement of the deck in relation to the superstructure provides the descriptive terms used in all bridges: deck, pony, and through.




## Tied Arch Bridge

The double-decked Fremont Bridge, Portland, Orgeon

The tied arch span: 902 feet

Built: 1973

## Arch Bridge (cont.)

Some metal bridges which appear to be open spandrel deck arch are, in fact, cantilever; these rely on diagonal bracing. A true arch bridge relies on vertical members to transmit the load which is carried by the arch.

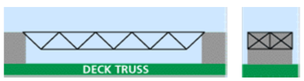

## Deck Arch Truss

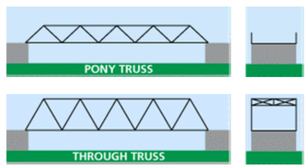
New River Gorge bridge, Fayetteville, WV

Main span length: 1700 ft., Built: 1978

## Truss Bridge

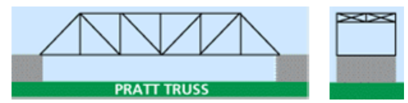
Examples of the three common travel surface configurations are shown in the Truss type drawings below. In a Deck configuration, traffic travels on top of the main structure; in a Pony configuration, traffic travels between parallel superstructures which are not cross-braced at the top; in a Through configuration, traffic travels through the superstructure (usually a truss) which is cross-braced above and below the traffic.



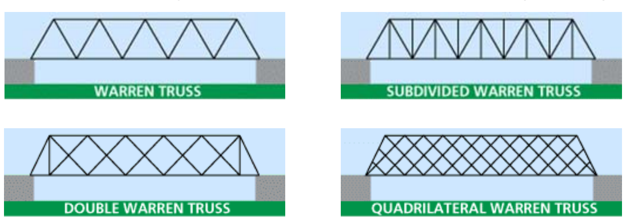

## Pratt Truss

The Pratt truss is a very common type, but has many variations. Originally designed by Thomas and Caleb Pratt in 1844, the Pratt truss successfully made the transition from wood designs to metal. The basic identifying features are the diagonal web members which form a V-shape. The center section commonly has crossing diagonal members. Additional counter braces may be used and can make identification more difficult, however the Pratt and its variations are the most common type of all trusses.



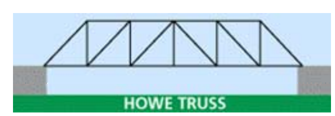

## Warren Truss

A Warren truss, patented by James Warren and Willoughby Monzoni of Great Britain in 1848, can be identified by the presence of many equilateral or isoceles triangles formed by the web members which connect the top and bottom chords. These triangles may also be further subdivided. Warren truss may also be found in covered bridge designs.



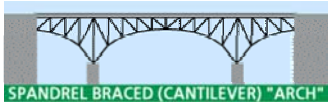

## Howe Truss

The other truss types shown are less common on modern bridges. A Howe truss at first appears similar to a Pratt truss, but the Howe diagonal web members are inclined toward the center of the span to form A-shapes. The vertical members are in tension while the diagonal members are in compression, exactly opposite the structure of a Pratt truss. Patented in 1840 by William Howe, this design was common on early railroads. The Howe truss was patented as an improvement to the Long truss which is discussed with covered bridge types.



## Cantilever Truss

A cantilever is a structural member which projects beyond its support and is supported at only one end. Cantilever bridges are constructed using trusses, beams, or girders. Employing the cantilever principles allows structures to achieve spans longer than simple spans of the same superstructure type. They may also include a suspended span which hangs between the ends of opposing cantilever arms.




## Cantilever Truss (cont.)

Some bridges which appear to be arch type are, in fact, cantilever truss. These may be identified by the diagonal braces which are used in the open spandrel. A true arch bridge relies on vertical members to transfer the load to the arch. Pratt and Warren bracing are among the most commonly used truss types.



## Cantilever Through Truss Bridge

Forth Bridge, Queensferry, Scotland

Main sections: 5360 ft., Maximum span: 1710(2), 4 spans total, Built: 1890

## Truss

- A bridge truss has two major structural advantages: (1) the primary member forces are axial loads; (2) the open web system permits the use of a greater overall depth than for an equivalent solid web girder. 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.
- These advantages are achieved at the expense of increased fabrication and maintenance costs.

## Suspension Bridge

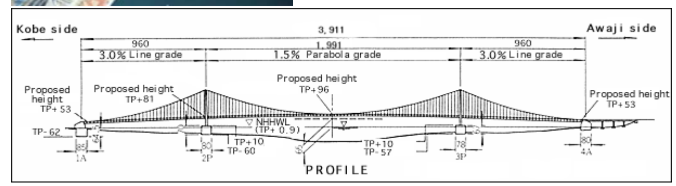
The longest bridges in the world are suspension bridges or their cousins, the cable-stayed bridge. The deck is hung from suspenders of wire rope, eyebars or other materials. Materials for the other parts also vary: piers may be steel or masonry; the deck may be made of girders or trussed.


## Suspension Bridge (cont.)

Akashi Kaikyo Bridge(AKB) between Kobe and Awaji Island, Japan

Total Length:3,911m

Section Length: 960 m + 1,991 m + 960 m




## Suspension – O'Connor

- The major element of the stiffened suspension bridge is a flexible cable, shaped and supported in such a way that it can transfer the major loads to the towers and anchorages by direct tension.
- This cable is commonly constructed from high strength wires, either case the allowable stresses are high, typically of the order of 600 MPa for parallel stands.
- The deck is hung from the cable by hangers constructed of high strength wire ropes in tension.

## Suspension – by O'Connor (cont.)

- This stiffening system serves to (a) control aerodynamic movements and (b) limit local angle changes in the deck. It may be unnecessary in cases where the dead load is great.
- The complete structure can be erected without intermediate staging from the ground.
- The main structure is elegant and neatly expresses it function.
- The height of the main towers can be a disadvantage in some areas; for example, within the approach circuits for an airport.

## Suspension – by O'Connor (cont.)

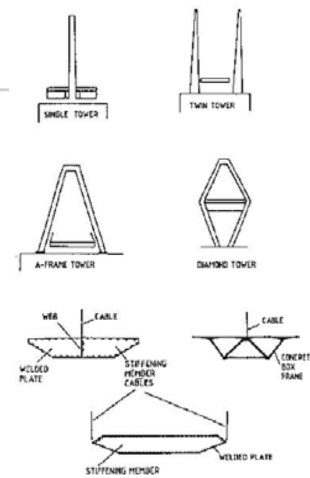
- It is the only alternative for spans over 600 m, and it is generally regarded as competitive for spans down to 300 m. However, even shorter spans have been built, including some very attractive pedestrian bridges.

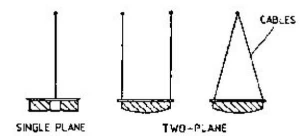
Westbound (1973)
Eastbound (1952)

suspension (truss deck) (1600 ft.)
,truss (480 ft.)
,truss (600 ft.)
,truss (780 ft.)

## Cable-stayed Bridge

The cable-stayed bridge is becoming very popular. A great advantage of the cable-stayed bridge is that it is essentially made of cantilevers, and can be constructed by building out from the towers.






## Cable-stayed Bridge (cont.)

Normandy Bridge on the river Seine, near Le Havre (France).

Main span: 856-m, Total length: 2141-m, Built: 1995

## Cable-stayed

- The use of high strength cables in tension leads to economy in material, weight, and cost.
- As compared with the stiffened suspension bridge, the cables are straight rather than curved. As a result, the stiffness is greater. It will be recalled that the nonlinearity of the stiffened suspension bridge results from changes in the cable curvature and the corresponding change in bending moment taken by the dead-load cable tension. The phenomenon cannot occur in an arrangement with straight cables.

## Cable-stayed

- The cables are anchored to the deck and cause compressive forces in the deck. For economical design, the deck system must participate in carrying these forces. In a concrete structure, this axial force compresses the deck.
- All individual cables are shorter than the full length of the superstructure. They are normally constructed of individual wire ropes, supplied complete with end fittings, prestretched and not spun. The cable erection problem differs greatly from that in the conventional suspension bridge.

## Cable-stayed

- There is great freedom of choice in selecting the structural arrangement.
- Compared with the stiffened suspension bridge, the cable-braced girder bridge tends to be less efficient in supporting dead load, but more efficient under live load. As a result, it is not likely to be economical on the longest spans. It is commonly claimed to be economical over the range 100-350 m, but some designers would extend the upper bound as high as 800 m.

## Cable-stayed

- The presence of the cables facilitates the erection of a cable-stayed girder bridge. Temporary backstays of this type have been common in the cantilever erection of girder bridges. Adjustment of the cables provides an effective control during erection.
- Aerodynamic instability has not been found to be a problem in structures erected to date.

Parallel Pattern

Radial Pattern

## What type of bridge is this?

New Woodraw Wilson Memorial Bridge