Design of Bridges using Limit State by IRC-112 Code

Training Programme for
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What is a BRIDGE?

• Bridge is a structure which covers a gap

• Generally bridges carry a road or railway across a natural or artificial obstacle such as, a river, canal or another railway or another road

• Bridge is a structure corresponding to the heaviest responsibility in carrying a free flow of transport and is the most significant component of a transportation system in case of communication over spacings/gaps for whatever reason such as aquatic obstacles, valleys and gorges etc.
Bridge is the **KEY ELEMENT** in a Transportation System
If the Bridge Fails, the System Fails

The importance of a Bridge can be visualized by considering the comparison between the two main components of a highway system i.e. a road and bridge itself.

**EXAMPLE:** Suppose in a road there occurs deterioration and ultimately a crack, thus making a sort of inconvenience but it wont result in stopping of the flow of traffic as traffic can pass or otherwise a bypass can be provided. The traffic no doubt will pass with a slower speed but in case of a bridge its flow is completely stopped incase of the failure of the bridge, that is the reason its often called “If the bridge fails the structure fails” as the function of the structure could no longer be served at all.
## Classification of Bridges

<table>
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<th>Concrete</th>
<th>Wood</th>
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Discussion on Classification According To STRUCTURAL FORM

Distinctive Features of **Girder Bridge**

Distinctive Features of **Arch Bridge**

Distinctive Features of **Truss Bridge**

Distinctive Features of **Suspension Bridge**

Distinctive Features of **Cable-Stayed Bridges**
Distinctive Features of Girder Bridges

• Widely constructed
• Usually used for Short and Medium spans
• Carry load in Shear and Flexural bending
• Efficient distribution of material is not possible
• Stability concerns limits the stresses and associated economy
• Economical and long lasting solution for vast majority of bridges
• Decks and girder usually act together to support the entire load in highway bridges
Distinctive Features of **Arch Bridge**

- Arch action reduces bending moments (that is Tensile Stresses)
- Economical as compared to equivalent straight simply supported Girder or Truss bridge
- Suitable site is a Valley with arch foundations on a DRY ROCK SLOPES
- Conventional curved arch rib has high Fabrication and Erection costs
- Erection easiest for Cantilever Arch and most difficult for Tied Arch
- Arch is predominantly a Compression member. Buckling must be worked to the detail so as to avoid reductions in allowable stresses.
**Distinctive Features of Arch Bridge**

- Classic arch form tends to favor Concrete as a construction material.
- Conventional arch has two moment resistant components: The deck and the Arch Rib.
- Near the crown of the arch and the region where Spandrel Columns are short, undesirable B.M. can occur. By using Pin ended columns it can be avoided.
- Space beneath the arch is less and hence danger for collision with the Rib, specially on a highway.
- Curved shaped is always very pleasing and arch is the most successful and beautiful structure.
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

• These advantages are achieved at the expense of increased fabrication and maintenance costs

• Other bridge types have rendered the truss bridge types less likely to be used due to its high maintenance and fabrication costs.

• The truss is instead being used widely as the stiffening structure for the suspension bridges due to its acceptable aerodynamic behavior since the wind gusts can pass through the truss as is not with the case in girder, arch bridges.
Distinctive Features of **Truss Bridge**

• It’s a light weight structure it can be assembled member by member using lifting equipment of small capacity.

• Rarely aesthetically pleasing complexity of member intersections if viewed from oblique direction

• In large span structures poor aesthetic appearance of the truss bridge is compensated with the large scale of the structure. For moderate spans its best to provide a simple and regular structure.
Distinctive Features of Suspension Bridge

• Major element is a flexible cable, shaped and supported in such a way that it transfers the loads to the towers and anchorage.

• This cable is commonly constructed from High Strength wires, either spun in situ or formed from component, spirally formed wire ropes. In either case allowable stresses are high of the order of 600 MPA.

• The deck is hung from the cable by Hangers constructed of high strength ropes in tension.

• As in the long spans the Self-weight of the structures becomes significant, so the use of high strength steel in tension, primarily in cables and secondarily in hangers leads to an economical structure.

• The economy of the cable must be balanced against the cost of the associated anchorage and towers. The anchorage cost may be high where foundation material is poor.
Distinctive Features of **Suspension Bridge**

- The main cable is stiffened either by a pair of stiffening trusses or by a system of girders at deck level.

- 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 its function.

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

- The height of the main towers can be a disadvantage in some areas; for example, within the approach road for an AIRPORT.
Distinctive Features of Cable-stayed Bridge

• 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.

• The cables are anchored to the deck and cause compressive forces in the deck. For economical design, the deck must participate in carrying these forces.

• All individual cables are shorter than full length of the superstructure. They are normally constructed of individual wire ropes, supplied complete with end fittings, prestretched and not spun.

• There is a great freedom of choice in selecting the structural arrangement.

• Less efficient under Dead Load but more efficient in support Live Load. It is economical over 100-350m, some designer would extend the upper bound as high as 800m.
Distinctive Features of Cable-stayed Bridge

• Aerodynamic stability has not been found to be a problem in structures erected to date

• When the cables are arranged in the single plane, at the longitudinal center line of the deck, the appearance of the structure is simplified and avoids cable intersections when the bridge is viewed obliquely
Discussion on Classification According To SPAN

Small Span Bridges (up to 15m)

Medium Span Bridges (up to 50m)

Large Span Bridges (50-150m)

Extra Large (Long) Span Bridges (over 150m)
Small Span Bridges (up to 15m)

- Culvert Bridge
- Slab Bridges
- T-Beam Bridge
- Wood Beam Bridge
- Pre-cast Concrete Box Beam Bridge
- Pre-cast Concrete I-Beam Bridge
- Rolled Steel Beam Bridge
Medium Span Bridges (up to 50m)

- Pre-cast Concrete Box Beam & Pre-cast Concrete I-Beam
- Composite Rolled Steel Beam Bridge
- Composite Steel Plate Girder Bridge
- Cast-in-place RCC Box Girder Bridge
- Cast-in-place Post-Tensioned Concrete Box Girder
- Composite Steel Box Girder
Large Span Bridges (50 to 150m)

- Composite Steel Plate Girder Bridge
- Cast-in-place Post-Tensioned concrete Box Girder
- Post-Tensioned Concrete Segmental Construction
- Concrete Arch and Steel Arch
Extra Large (Long) Span Bridges
(Over 150m)

- Cable Stayed Bridge
- Suspension Bridge
Discussion on Classification According To Structural Arrangement

The classification of the bridge types can also be according to the location of the main structure elements relative to the surface on which the user travels, as follows:

- **Main Structure Below the Deck Line**
- **Main Structure Above the Deck Line**
- **Main Structure coincides with the Deck Line**
FACTORS CONSIDERED IN DECIDING BRIDGE TYPE

In general all the factors are related to economy, safety and aesthetics.

- Geometric Conditions of the Site
- Subsurface Conditions of the Site
- Functional Requirements
- Aesthetics
- Economics and Ease of Maintenance
- Construction and Erection Consideration
- Legal Considerations
Geometric Conditions of the Site

• The type of bridge selected will always depend on the horizontal and vertical alignment of the highway route and on the clearances above and below the roadway.

• **For Example:** if the roadway is on a curve, continuous box girders and slabs are a good choice because they have a pleasing appearance, can readily be built on a curve, and have a relatively high torsion resistance.

• Relatively high bridges with larger spans over navigable waterways will require a different bridge type than one with medium spans crossing a flood plain.

• The site geometry will also dictate how traffic can be handled during construction, which is an important safety issue and must be considered early in the planning stage.
Subsurface conditions of the soil

• The foundation soils at a site will determine whether abutments and piers can be founded on spread footings, driven piles, or drilled shafts.

• If the subsurface investigation indicates that creep settlement is going to be a problem, the bridge type selected must be one that can accommodate differential settlement over time.

• Drainage conditions on the surface and below ground must be understood because they influence the magnitude of earth pressures, movement of embankments, and stability of cuts or fills.

• For Example: An inclined leg frame bridge requires strong foundation material that can resist both horizontal and vertical thrust. If it is not present, then another bridge type is more appropriate.
• The potential for seismic activity at a site should also be a part of the subsurface investigation. If seismicity is high, the substructure details will change, affecting the superstructure loads as well.

• All of these conditions influence the choice of substructure components which in turn influence the choice of superstructure.
Functional Requirements

• Bridge must function to carry present and future volumes of traffic.

• Decisions must be made on the number of lanes of traffic, inclusion of sidewalks and/or bike paths, whether width of the bridge deck should include medians, drainage of the surface waters, snow removal, and future wearing surface.

• For Example: In the case of stream and flood plain crossings, the bridge must continue to function during periods of high water and not impose a severe constriction or obstruction to the flow of water or debris.

• Satisfaction of these functional requirements will recommend some bridge types over others.

• For Example: if future widening and replacement of bridge decks is a concern, multiple girder bridge types are preferred over concrete segmental box girders.
Aesthetics

• It should be the goal of every bridge designer to obtain a positive aesthetic response to the bridge type selected.

• There are no equations, no computer programs or design specifications that can make our bridge beautiful.

• It is more an awareness of beauty on our part so that we can sense when we are in the presence of something good.

• Aesthetics must be a part of the bridge design program from the beginning. It can’t be added on at the end to make the bridge look nice. At that time it is too late. From the beginning, the engineer must consider aesthetics in the selection of spans, depths of girders, piers, abutments, and the relationship.
Economic and ease of maintenance

• The initial cost and maintenance cost over the life of the bridge govern when comparing the economics of different bridge types.

• A general rule is that the bridge with the minimum number of spans, fewest deck joints, and widest spacing of girders will be the most economical.

• For Example: (1) By reducing the number of spans in a bridge layout by one span, the construction cost of one pier is eliminated. (2) Deck joints are a high maintenance cost item, so minimizing their number will reduce the life cycle cost of the bridge. (3) When using the empirical design of bridge decks in the AASHTO (1994) LRFD Specifications, the same reinforcement is used for deck spans up to 4.1m. Therefore, there is little cost increase in the deck for wider spacing for girders and fewer girders means less cost although at the “expense” of deeper sections.
Economic and ease of maintenance

• Generally, concrete structures require less maintenance than steel structure. The cost and hazard of maintenance painting of steel structures should be considered in type selection studies.

• One effective way to reduce the overall project cost is to allow contractors to propose an alternative design or designs.
Construction and Erection Considerations

• The length of the time required to construct a bridge is important and will vary with the bridge type.

• Generally, larger the prefabricated or pre-cast members shorter the construction time. However, the larger the members, the more difficult they are to transport and lift into place.

• The availability of skilled labor and specified materials will also influence the choice of a particular bridge type.

• For Example: if there are no pre-cast plants for pre-stressed girders within easy transport but there is a steel fabrication plant nearby that could make the steel structure more economical.

• The only way to determine which bridge type is more economical is to bid alternative designs.
Discussion on Bridge Components

- Components of a Girder bridge (Beam Bridge)
Components of a T-Beam Bridge
General Bridge Components

✓ **Bridge Bearings:** These are supports on a bridge pier, which carry the weight of the bridge and control the movements at the bridge supports, including the temperature expansion and contraction. They may be metal rockers, rollers or slides or merely rubber or laminated rubber (Rubber with steel plates glued into it).

✓ **Bridge Dampers & Isolators:** Bridge dampers are devices that absorb energy generated by earthquake waves and lateral load.

✓ **Bridge Pier:** A wide column or short wall of masonry or plain or reinforced concrete for carrying loads as a support for a bridge, but in any case it is founded on firm ground below the river mud.
General Bridge Components

✓ **Bridge Cap:** The highest part of a bridge pier on which the bridge bearings or rollers are seated. It may be of stone, brick or plain or reinforced concrete.

✓ **Bridge Deck:** The load bearing floor of a bridge which carries and spreads the loads to the main beams. It is either of reinforced concrete., pre-stressed concrete, welded steel etc.

✓ **Abutment:** A support of an arch or bridge etc which may carry a horizontal force as well as weight.

✓ **Joints:** weakest area, distress at joint may create problem

✓ **Expansion Joints:** These are provided to accommodate the translations due to possible shrinkage and expansions due to temperature changes.
Components of a Girder bridge (Beam Bridge)
GIRDER BRIDGE
Photo 3 (a)  Laminated rubber bearing with lead plug press-fitted into core (LRB)
Bridge Cap and Damper
ARCH BRIDGE
Suspension Bridge