STEEL BRIDGES

Bridges are the structures that allow movement of highway and railway traffic over natural or artificial gaps in the topology of the area such as canals, rivers, gap between hills and difference of level in crossing roads etc.

Selection of type of bridge mainly depends on:

- **Local conditions,**
- **Availability and cost of materials,**
- **Volume of traffic,**
- **Site requirements,**

STEEL BRIDGES

Selection of type of bridge mainly depends on: (cont…)

- Geographical conditions,
- Aesthetics
- Expected economic return

The design of bridges is further influenced by:

- The required clearances,
- Erection possibilities,
- Foundation choices and
- Hydraulic characteristics of the stream, if one is involved

For example, a longer span may become economical in case the piers are very expensive to construct.

STEEL BRIDGES

There are many structural differences between a building and a bridge, some of these are:

1. Bridges are designed for heavy and concentrated moving loads whereas buildings are usually designed for static distributed loads.
2. The impact of moving loads is quite considerable as compared with residential and official buildings.
3. Fatigue may become a problem and hence may reduce the strength due to large number of loading cycles.
4. Greater part of the structure is exposed to atmosphere.
5. The controlling design specifications for bridges are provided by organizations different from those dealing with the building design.

   For example, AASHTO Specification may be employed for bridges in place of AISC Specification for steel buildings.

STEEL BRIDGES

Steel bridges are classified depending on their use into the following categories:

1. Foot or pedestrian bridge used to carry pedestrian traffic, bicycles or small hand driven carts.
2. Highway bridges.
3. Railway bridges.
4. Combined highway and railway bridges.

STEEL BRIDGES

Deck of Bridge

- A deck is the actual carriageway of the bridge.
- It consists of concrete or orthotropic slab and wearing surface.
- Stringers and floor beams are also present for larger decks in addition to the slab (Figure 1).

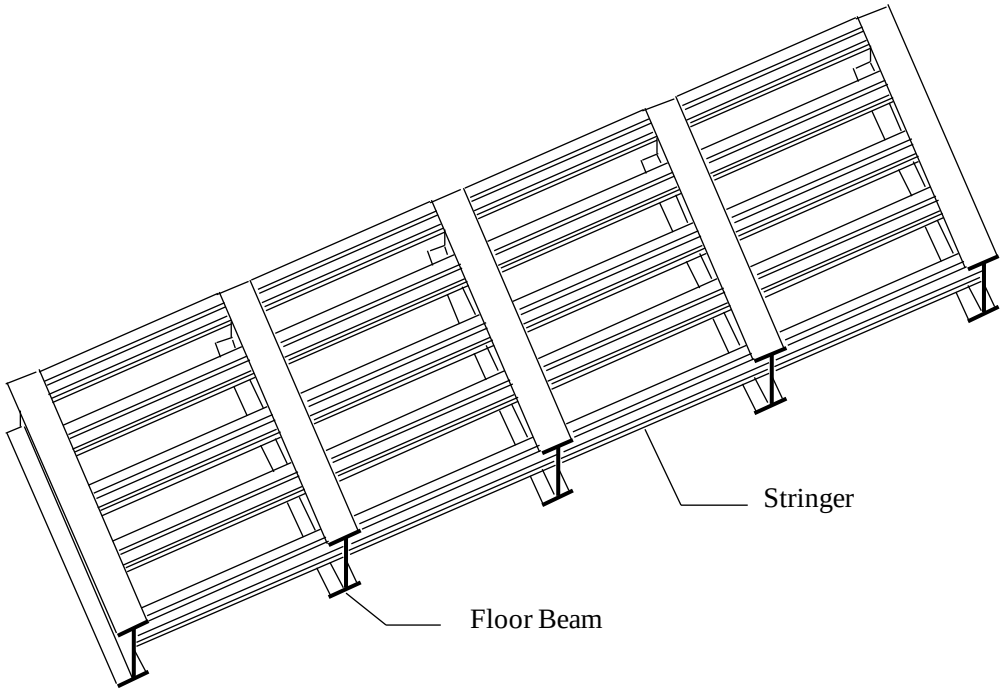


Figure 1. Typical Steel Deck Supporting Elements.

STEEL BRIDGES

Deck or Through Bridge

- Depending upon the position of the longitudinal supporting elements with respect to the deck, the bridges may be deck type or through type.
- A ***Deck Bridge*** is a bridge built at or near the top level of the main supporting members of the superstructure, which hang below the deck and are not visible from the bridge.
- In case of ***Through Bridge***, the carriageway is supported at the bottom of the main supporting members that are visible while traveling on the bridge.

STEEL BRIDGES

Types of Steel Bridges

Truss Through Bridges are the bridges where the deck is supported on the lower chord of the truss.

The upper chord of the two longitudinal side trusses is braced.

The traffic moves through the two trusses and the top transverse bracing (shown in Figure 2).

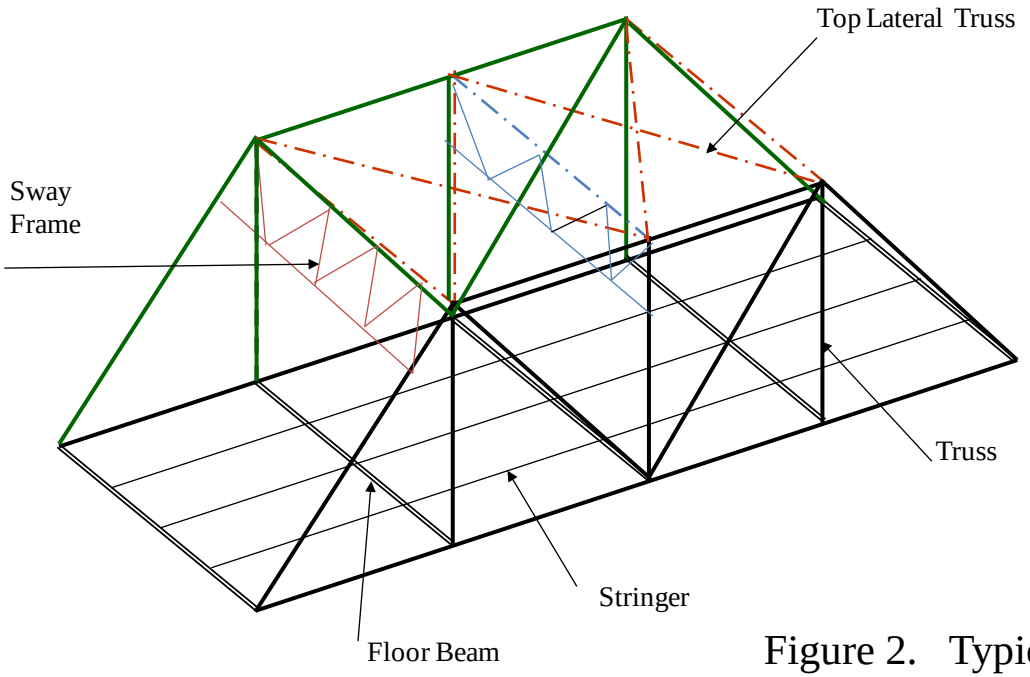


Figure 2. Typical Truss Through Bridge.

STEEL BRIDGES

Types of Steel Bridges (cont…)

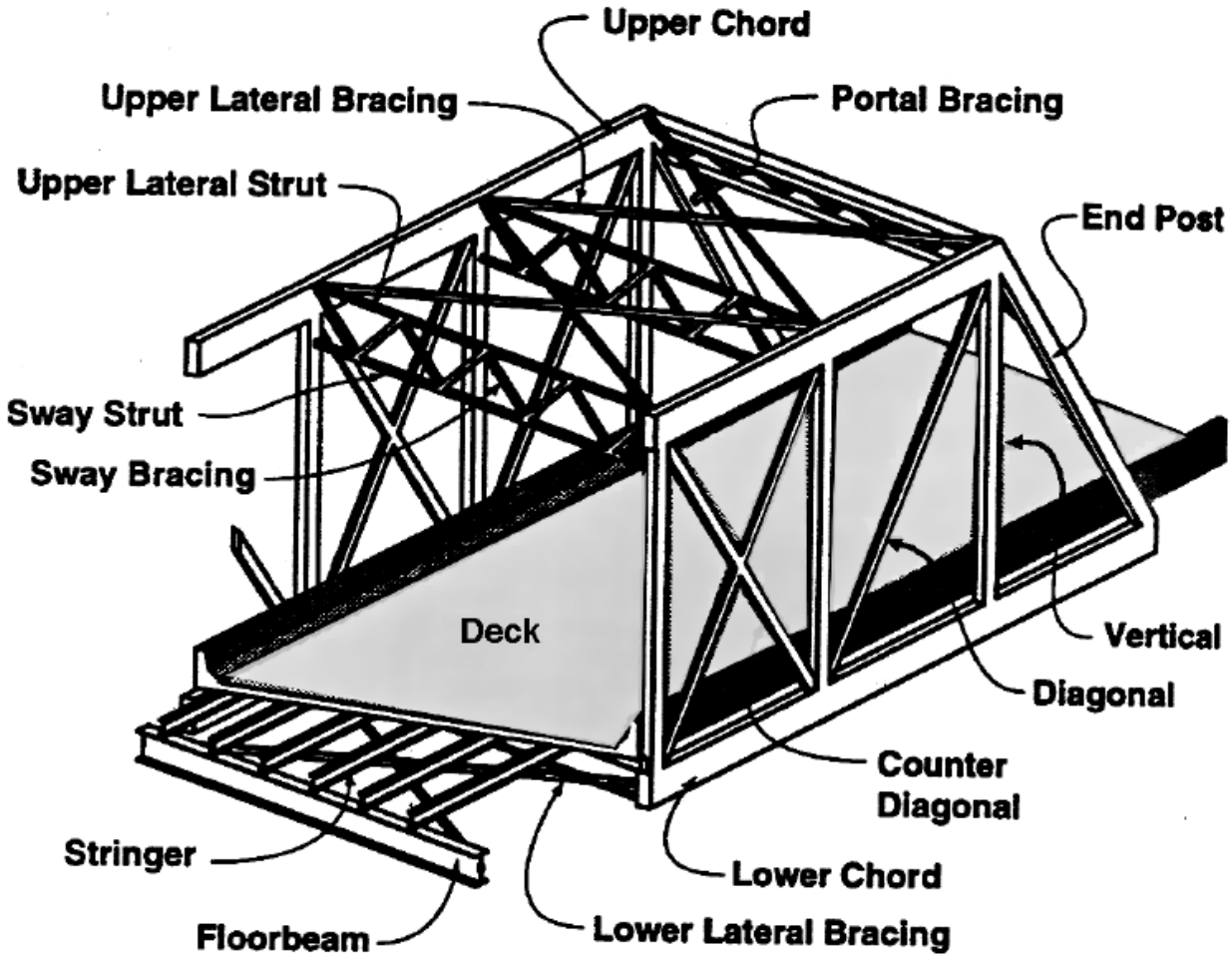


FIGURE 16.4 Typical truss members.

STEEL BRIDGES

Types of Steel Bridges (cont…)

A ***Fixed Bridge*** permanently remains in one position.

One or more parts of a ***Movable Bridge*** are made movable to allow the vessels to pass through the stream underneath in case sufficient clearance is not available.

The bridges are made movable in the horizontal and the vertical planes.

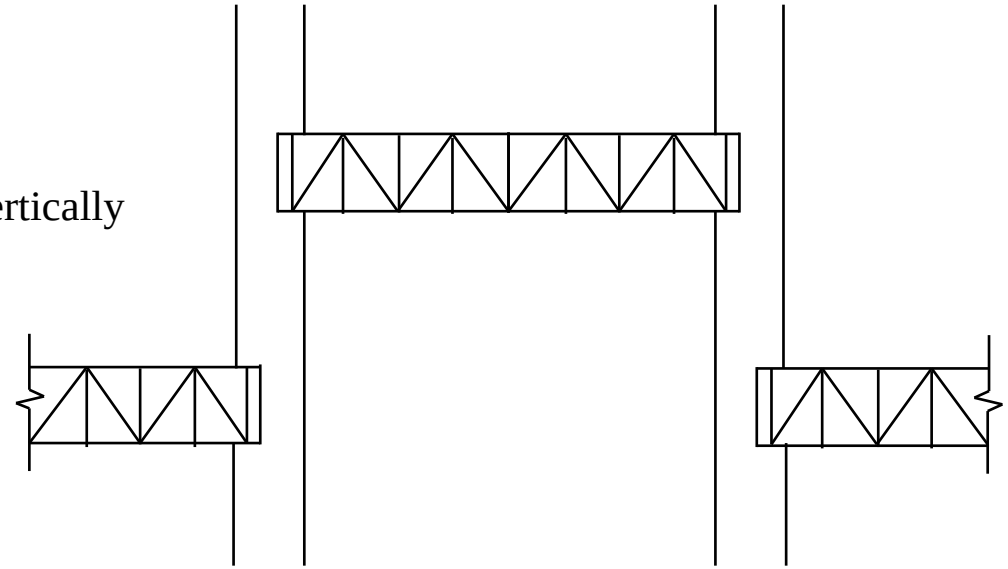


Figure 3. Line Diagram of a Vertically Movable Bridge.

STEEL BRIDGES

Types of Steel Bridges (cont…)

- The main supporting elements of a steel bridge may be *rolled beams, plate girders, trusses and beams with suspension cables*.
  - Rolled beams in non-composite bridges may be used for spans up to *28 m*.
  - Composite rolled beams may be used for spans *from 15 to 38 m*.
  - Plate girders may be used for spans *from 25 to 45 m.*
  - Box girders are economical for spans *from 45 to 75 m*.
  - Simply supported trusses are used for spans *from 45 to 180 m*.
  - Continuous trusses are preferred for spans ranging *from 75 to 240 m*.

STEEL BRIDGES

Types of Steel Bridges (cont…)

- ***Slab Bridge*** is the one consisting of a simple one-way reinforced concrete slab without any beams or trusses.

  These are used to cover short openings in the road topology.

- ***Beam and Slab Bridges*** consist of reinforced concrete slab supported over longitudinal steel beams (Figure 4).

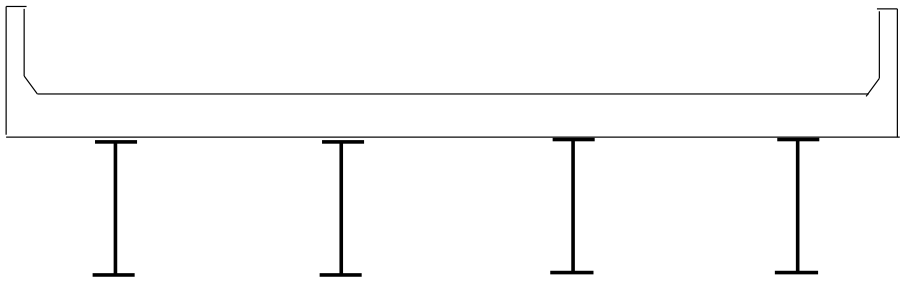


Figure 4. Cast-in-Place or Precast Concrete Slab Supported by Steel Beams.

STEEL BRIDGES

Types of Steel Bridges (cont…)

If the steel beams in the above type are continuously connected to the slab by providing shear studs or the top flange of the beam is cast within the concrete, **Composite Beam Bridge** is obtained (Figure 5).

This type may be economical up to a span of *38 m*.

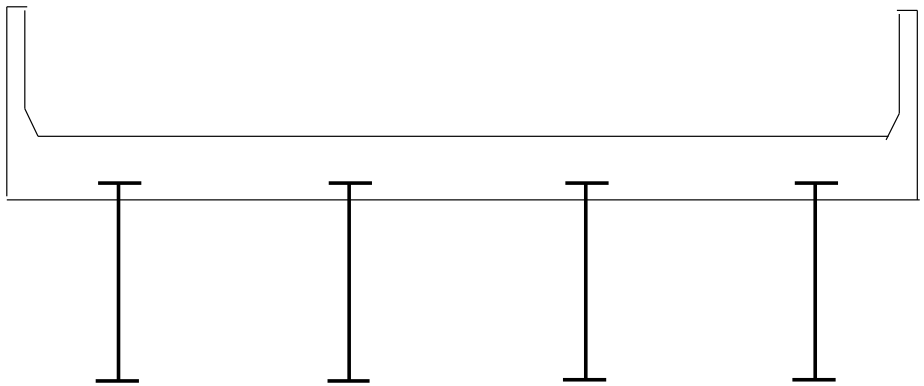


Figure 5. Composite Steel Beam Bridges.

STEEL BRIDGES

Types of Steel Bridges (cont…)

Plate Girder Bridges are used for spans of *25 to 45 m*.

The deck in these bridges is supported on two longitudinal plate girders present on the sides of the roadway.

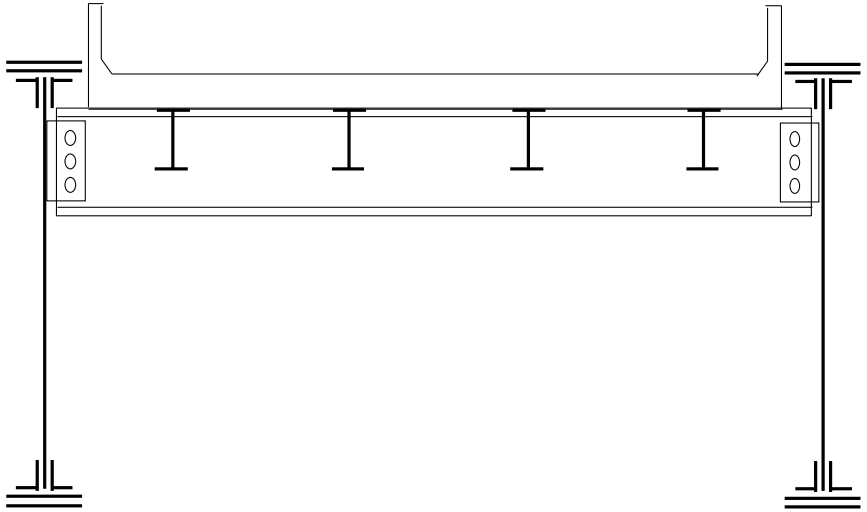
If the plate girders are provided below the deck, the bridge is called *plate girder deck bridge* (Figure 6).

In case of *plate girder through bridge*, the traffic moves on the deck supported at the lower flange or at a certain depth of the main member (Figure 7).

STEEL BRIDGES

Types of Steel Bridges (cont…)

Figure 6. A Typical Plate Girder Deck Bridge.



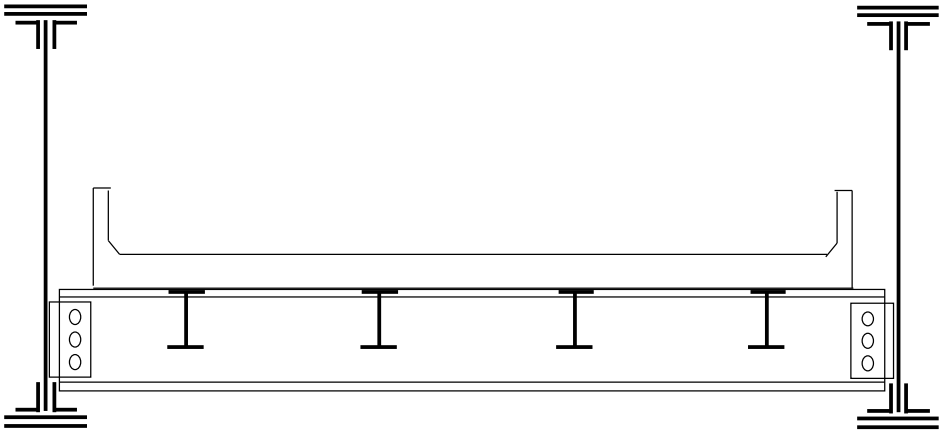


Figure 7. A Plate Girder Through Bridge.

STEEL BRIDGES

Types of Steel Bridges (cont…)

In case of ***Orthotropic Deck Bridges***, an orthotropic deck consisting of longitudinal folded steel plate resting on cross girders, provided at a spacing of *3 to 5 m*.

The cavities of the plate are filled with tar and gravel and topped by wearing surface (Figure 8).

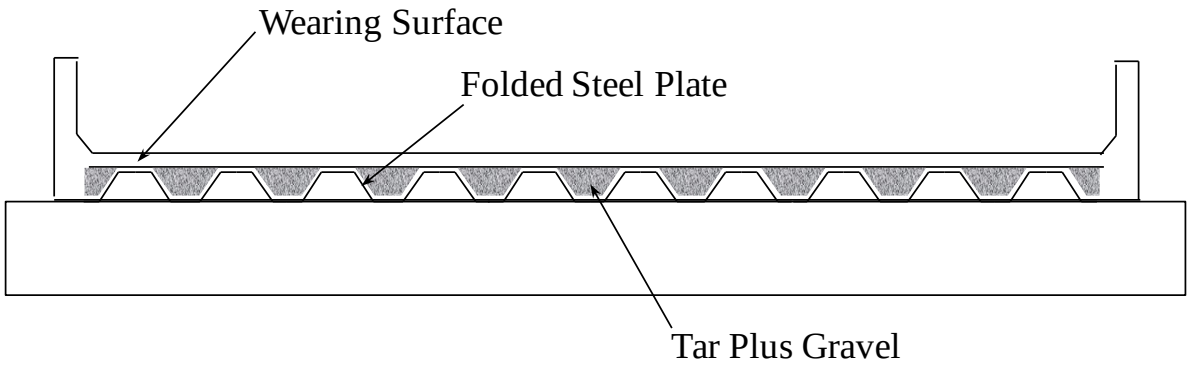


Figure 8. An Orthotropic Deck with Steel Folded Plate.

STEEL BRIDGES

Types of Steel Bridges (cont…)

Box Girder Bridge is used for curved and longer span bridges (Figure 9).
These bridges decrease the total depth requirement and can resist torsion to a large extent.

Hybrid Girder Bridges are those plate girder or box girder bridges where high strength steel is used for flanges and ordinary steel is employed for the web of the supporting elements.

For spans in excess of 160 m, ***Suspension or Cable Stayed Bridges*** may become economical.
Line diagrams of two types of these bridges are shown in Figure 10.

STEEL BRIDGES

Types of Steel Bridges (cont…)

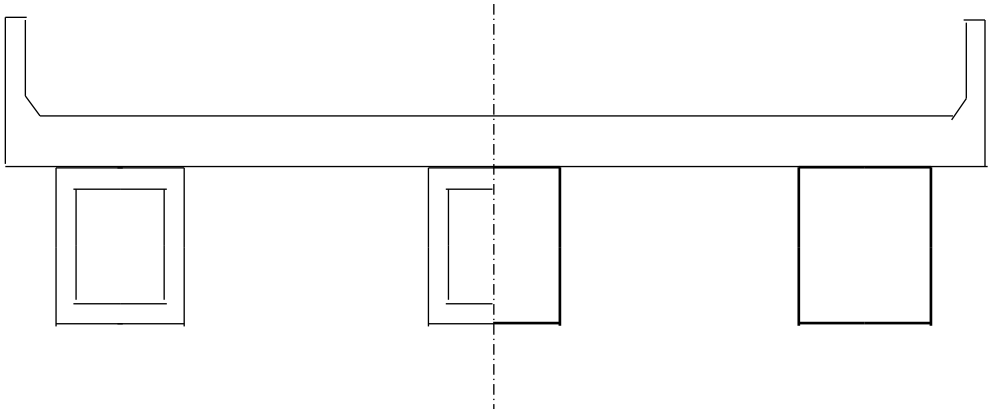


Figure 9. Cast-in-Place Concrete Slab over Closed Steel or Precast Concrete Boxes.

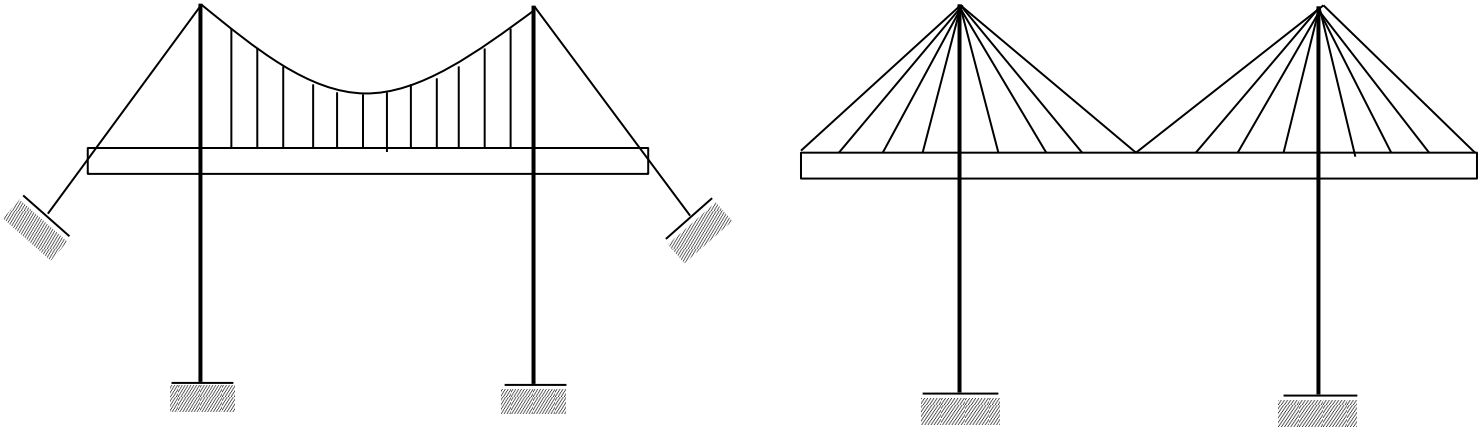


Figure 10. Suspension and Cable Stayed Bridges.

STEEL BRIDGES

Types of Steel Bridges (cont…)

Pre-stressed Steel Bridges are those plate girder bridges in which the high bending moment sections are pre-stressed by high strength steel tendons in a direction opposite to the applied loading.

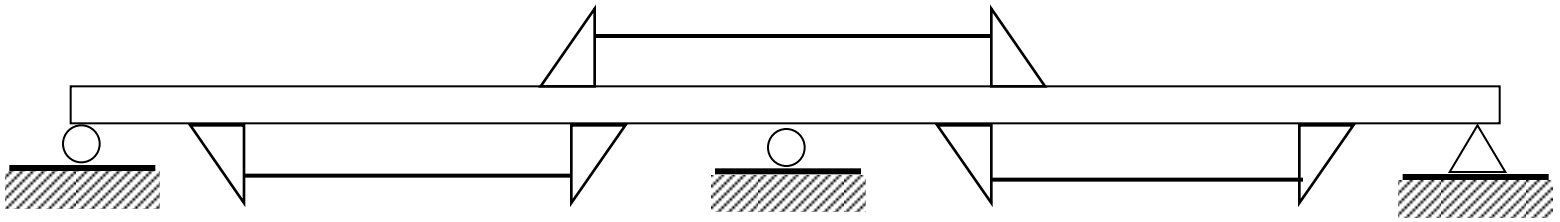


Figure 11. Example of a Pre-stressed Continuous Bridge Girder.

STEEL BRIDGES

Advantages of steel beam bridges

- Steel is a high quality, homogeneous and isotropic material that is perfectly elastic up to its yield point.
- It has equal and high strengths in tension and compression.
- The material remains un-cracked and exhibits appreciable ductility.
- Lesser construction time, compared with reinforced and pre-stressed concrete bridges, reduces the overall cost.
- The basic skeleton of steel bridges may very easily be erected over various gaps in natural surface.

STEEL BRIDGES

Advantages of steel beam bridges (cont…)

- The design, erection and fabrication procedures for steel bridges are very well established.

- Due to lesser self-weight of these bridges, the foundation cost is also reduced.

- For their lesser depths, the steel bridges are preferred where underneath clearance is important.

- Repair, rehabilitation and up gradation of steel bridges are usually easier than concrete bridges.

STEEL BRIDGES

General Terms

- ***Stringers:*** These are longitudinal bridge deck beams spanning between the transverse floor beams and placed parallel to the roadway.
- ***Floor Beams:*** Floor beams are the main girders of the bridge deck spanning between trusses or plate girders and running perpendicular to the roadway.
- **Core width** is defined as the width of the monolithic deck without the overhangs.
- **Footprint** is the specified wheel contact area over the roadway.

STEEL BRIDGES

General Terms (cont…)

- **Force Effect** is defined as a deformation, stress or stress resultant caused by the applied loads, imposed deformations.
- **Lever Rule** means the statical summation of moments about any point to calculate the reaction at some other point.
- **Skew Angle** is defined as the angle between the centerline of a bridge support and a line normal to the roadway centerline.
- Two closely spaced and interconnected axles of equal weight are together called a **Tandem**.

STEEL BRIDGES

General Terms (cont…)

Concrete Slab Haunch: A layer of concrete is usually projected below the slab surface to surround top flange of the steel beam, called concrete haunch.

This haunch provides lateral support to the top flange of the steel beam and thus prevents lateral buckling of the beam.

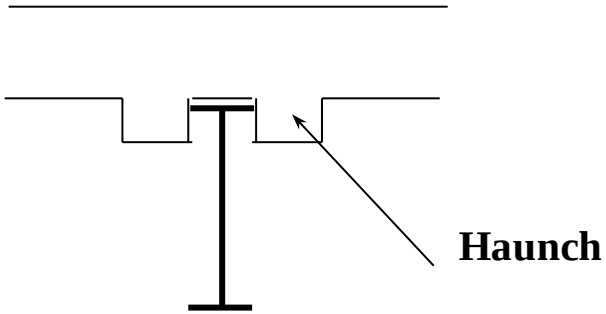


Figure 12. A Concrete Haunch.

STEEL BRIDGES

General Terms (cont…)

Diaphragm: This is a single steel member or a frame used to connect the longitudinal steel beams of a bridge, provided at the required interval. Part of a typical cross frame is shown in Figure 13.

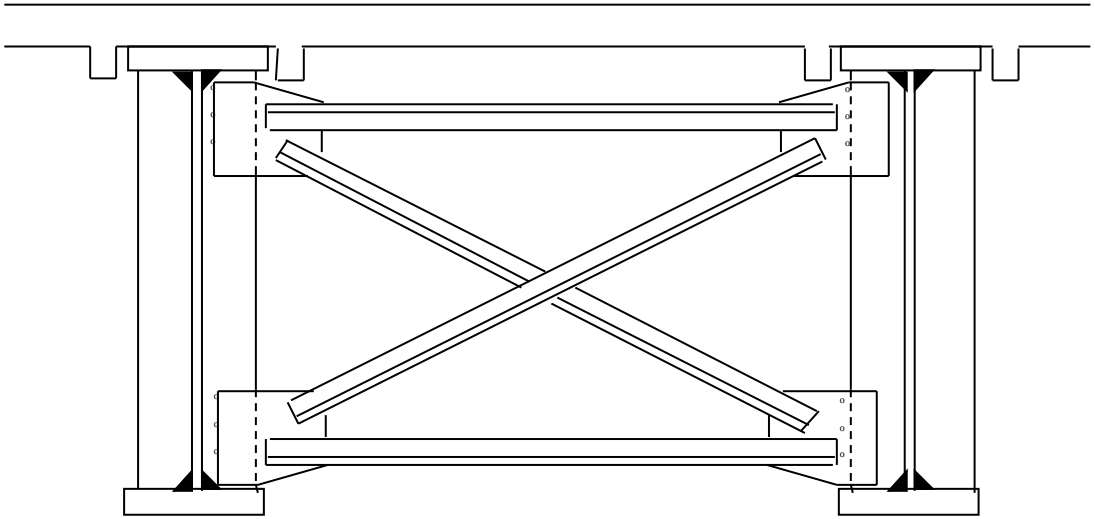


Figure 13. Cross Frame.

STEEL BRIDGES

Lecture # 2

STEEL BRIDGES

Design Lane

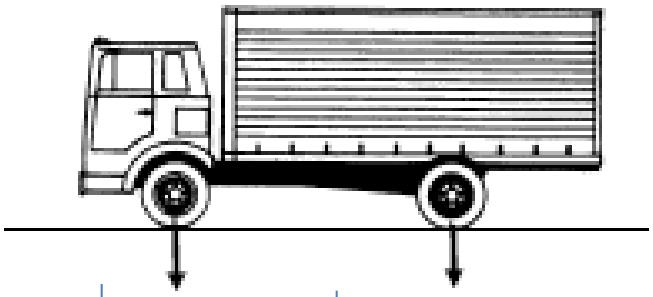
- The design lane has a width equal to the lesser of 3600 mm or width of the traffic lane.
- Roadway widths from 6000 to 7200 mm shall have two design lanes, each equal to one-half the roadway width.
- The number of design lanes is taken as the integer part of the result when the clear roadway width in mm between curbs is divided by 3600.
- If the design lanes are more than one, reduction factor of Table 9.1 is applied on the live load force effect called ***Multiple Presence Factor*** denoted by m.

Number of Loaded Lanes	Multiple Presence Factor
1	1.20
2	1.00
3	0.85
>3	0.65

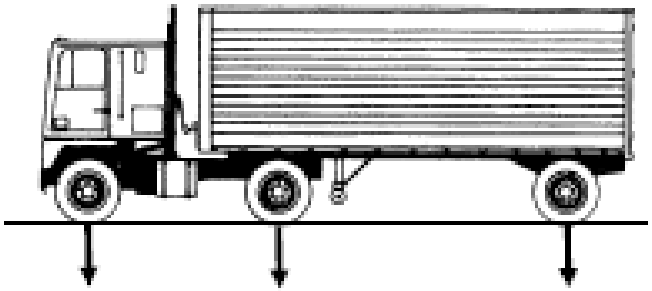
STEEL BRIDGES

Design Vehicular Live Load

- H20 means a highway truck with two axles and weighing 20 tons.
- HS20 means a highway truck similar to H20 truck but having a semi-trailer with one additional axle.
- H15 and HS15 are defined in a similar way.



H20	8 kips	32 kips
H15	6 kips	24 kips



HS20	8 kips	32 kips	32 kips
HS15	6 kips	24 kips	24 kips

STEEL BRIDGES

Design Vehicular Live Load

- The new specification uses HL93 (highway loading of 1993).
- In case of HL93 loading, the vehicular live load on the bridge roadway consists of a combination of design truck (or design tandem) and the design lane load.
- The design lane load shall occupy a width of 3000 mm transversely within a design lane
- All design lanes must be loaded simultaneously by the truck or tandem and the lane loads.
- The force effects from truck or tandem load shall be subjected to dynamic load allowance of 33%, but force effects from the design lane load shall not be subjected to a dynamic load allowance.

STEEL BRIDGES

Design Vehicular Live Load

HL-93 Loading (Design Truck)

View of HL-93 Design Truck Showing Axle Loads

STEEL BRIDGES

Design Vehicular Live Load

HL-93 Loading

- The design truck or tandem shall be placed transversely at 300 mm from the face of curb or railing for the design of bridge overhang and 600 mm from edge of the design lane for the design of all other components.
- The *design tandem* shall consist of a pair of 110 kN axles at a longitudinal spacing of 1200 mm with the transverse center-to-center spacing of the wheels being 1800 mm.
- The *design lane load* shall be 9.3 kN/m along the length, having a width of 3000 mm.

STEEL BRIDGES

Pedistrian Loads

- A pedestrian load of 3600 N/m^2 is used on all sidewalks simultaneously with the vehicular design live load.
- Separate bridges for pedestrian and bicycle traffic should be designed for a live load of 4100 N/m^2.
- The dynamic load allowance is not considered for these loads.

STEEL BRIDGES

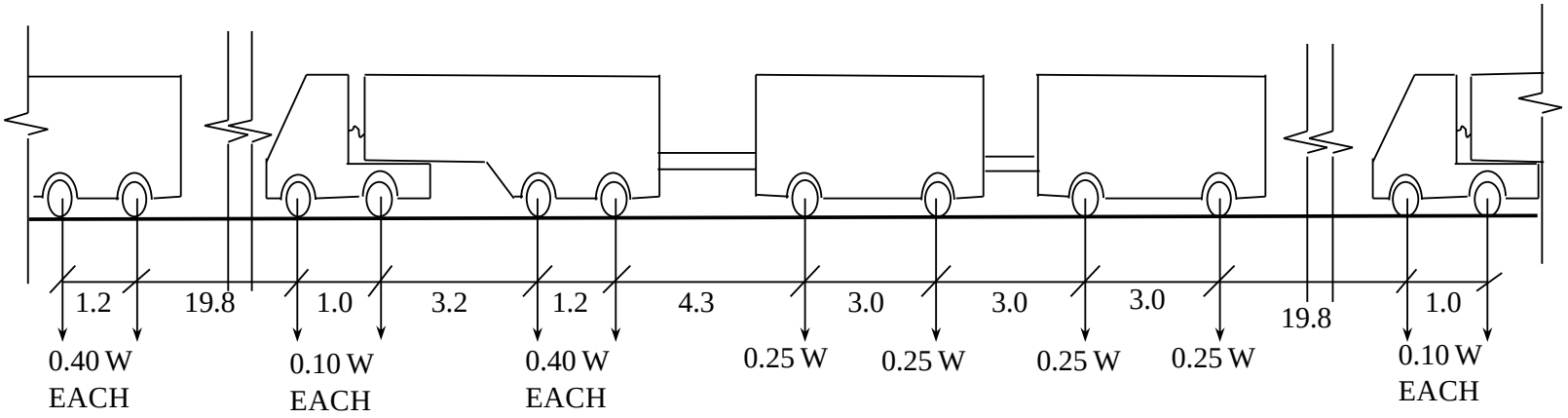
Pakistan Code Of Practice Loading For Highway Bridges (1967)

The highway loading according to the Pakistan Code of Practice for Highway Bridges consists of Class A, Class B and Class AA loadings.

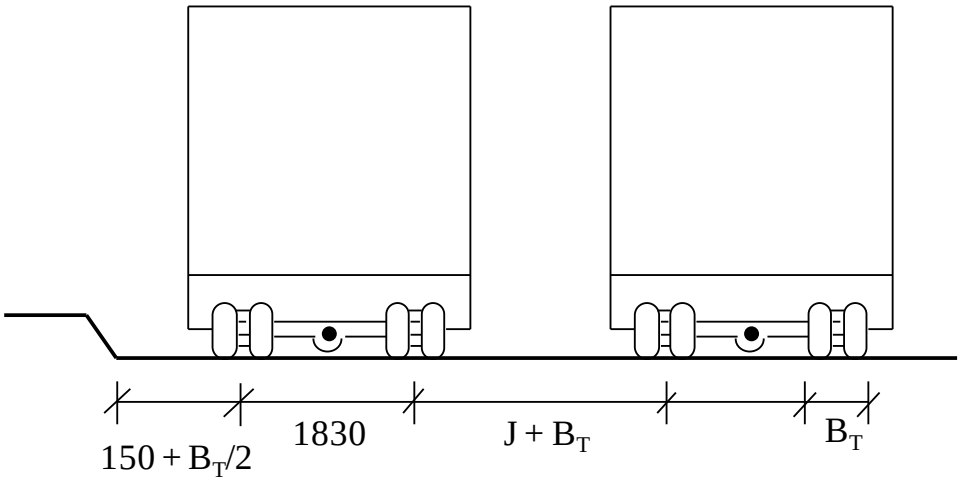
Standard Truck/Tank	Weight of Truck/Tank *W* (kN)
Class A	275
Class B	165
Military Tank	700

STEEL BRIDGES

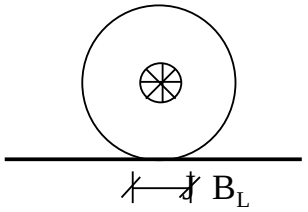
Class A & B Trucks



AXLE LOADS AND DISTANCES FOR CLASS A & B TRUCKS



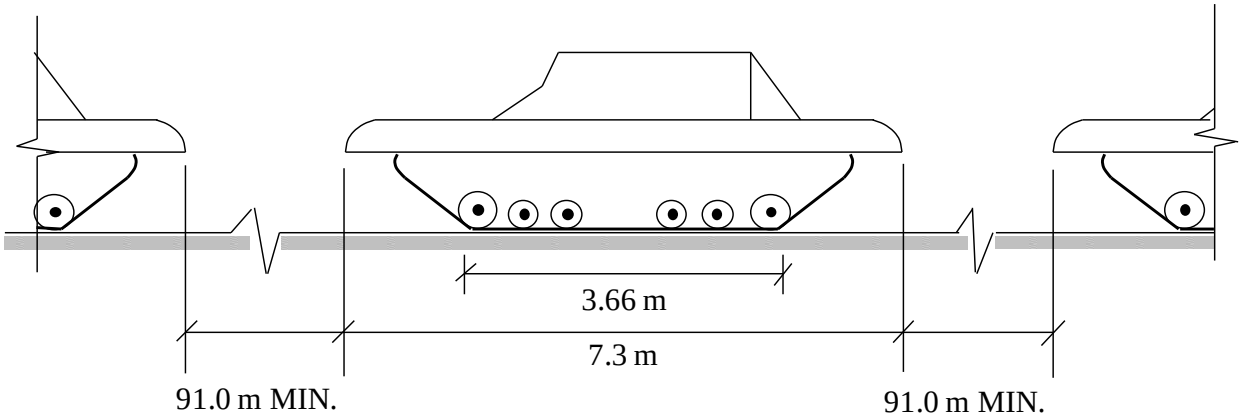
TRANSVERSE POSITION OF TRUCKS



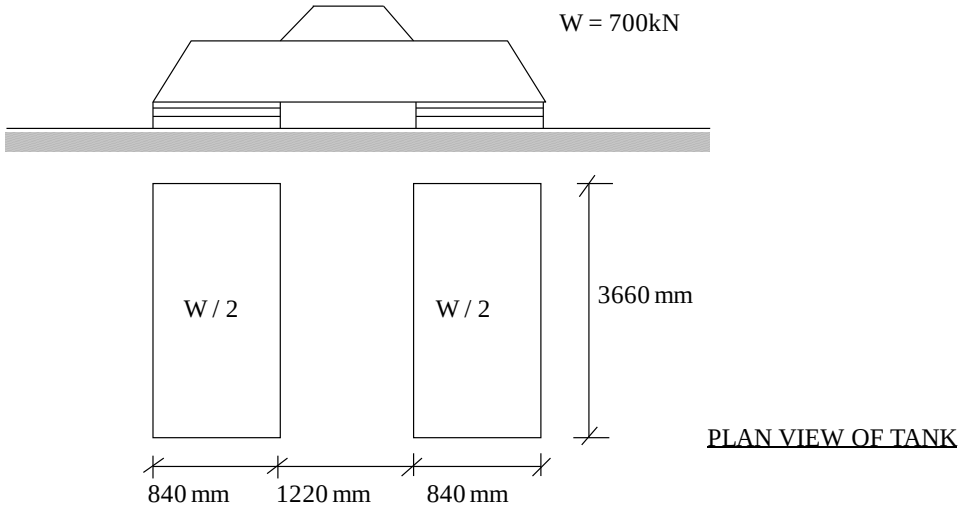
WHEEL IN LONGITUDINAL VIEW

STEEL BRIDGES

Class AA Tank Loading



LONGITUDINAL TANK VIEW



PLAN VIEW OF TANK

STEEL BRIDGES

Class A & B Trucks

Table . Ground Contact Dimensions.

Axle Load	Longitudinal Tire Contact Length B_L	Transverse Tires Contact Width B_T
(kN)	(mm)	(mm)
110.4	255	510
66.4, 69.0	205	380
27.6	150	205
41.5	150	305
16.6	125	180

STEEL BRIDGES

Class A & B Trucks

Table . Design Transverse Spacing Between Trucks (J).

Clear Road Width R_w (m)	**Distance - J For Most Critical Design Condition (mm)**
5.0 or less	0
5.0 to 5.5	800 (R_w - 5)
5.5 to 7.3	400 + 450 (R_w - 5.5)
Above 7.3	1210

STEEL BRIDGES

Mercedes Benz Truck

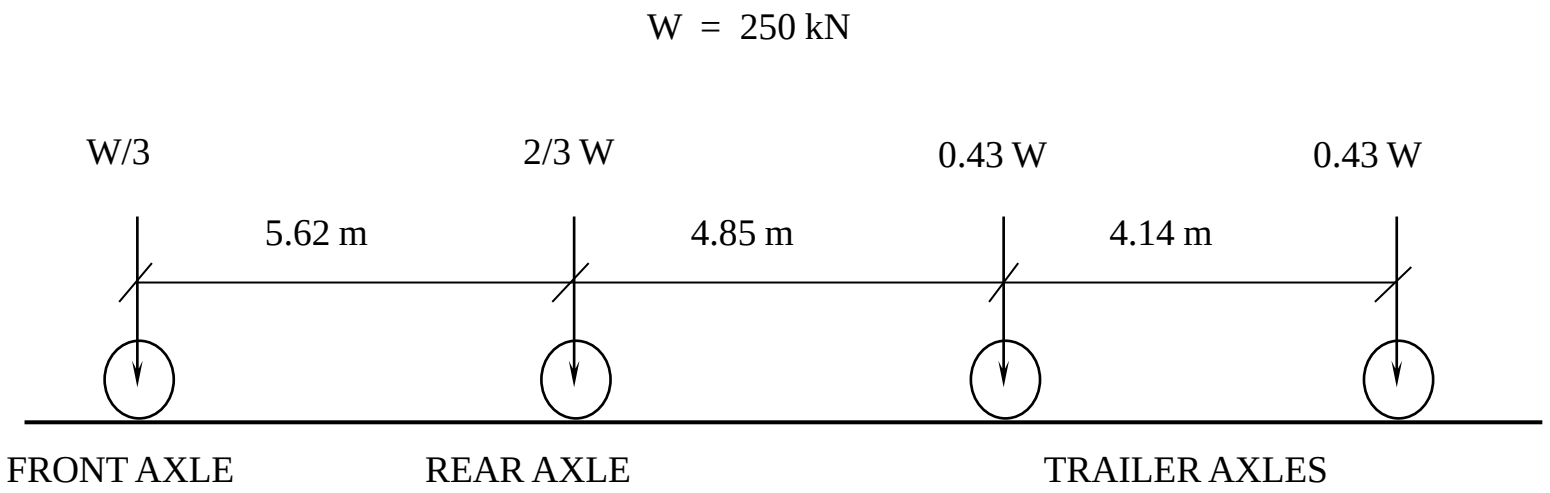


Fig. Axle Loads For Mercedes Benz Truck.

STEEL BRIDGES

Distribution of live load

- The truck loads on the bridge deck are moving at different locations along the width and length of the slab.
- When these loads occupy certain critical positions, maximum forces occur in the members.
- For approximate design of the deck, usually one-dimensional analysis is carried out considering only the girder.
- In such cases, it becomes very important to find the effect of loads along the lateral direction of the member.

STEEL BRIDGES

Distribution of live load (cont....)

- Estimating contribution of the transversely placed loads (with respect to direction of traffic movement) over the centerline of a particular member, spanning along the length of the bridge, is called ***lateral distribution of loads*.**
- Thus, by the lateral distribution, equivalent loads are obtained at the members.
- These equivalent loads are then placed along the length of the member according to the criteria of maximum forces in case of moving loads.
- Maximum force effects are then obtained from this ***longitudinal distribution of the loads***.

STEEL BRIDGES

Distribution of live load (cont….)

- However, for beams or slab strips placed transverse to the traffic direction, longitudinal distribution of loads is to be performed first to get the equivalent loads.
- These equivalent loads are then placed transversely at suitable locations to get extreme forces.
- This method of performing manual 1-D analysis is called ***Approximate Method of Analysis***.

STEEL BRIDGES

Conditions For Approximate Method

- Spacing of beams, *S*, should be between1.1 and 4.9 m.
- Thickness of deck slab, t_s, should be between 110 and 300 mm.
- Length of beam should be between 6.0 and 73.0 m.
- Number of longitudinal beams in the cross-section, Nb, should be greater than or equal to 4.
- The deck cross-section should be one of the standard types given in the AASHTO Specification.
- The width of deck should be constant.

STEEL BRIDGES

Conditions For Approximate Method (cont.....)

- Beams should be parallel and should have approximately the same stiffness.
- The roadway part of the overhang, d_e, does not exceed 910 mm.
- The given expressions are only applicable to concrete deck on steel or concrete beams.

STEEL BRIDGES

Notation Used

S = spacing of beams or webs (mm)

L = span of beam (mm)

N_b = number of beams, stringers or girders

t_s = depth of concrete slab (mm)

n = modular ratio between beam and deck materials

I = moment of inertia of beam (mm^4)

e_g = distance between the centers of the basic beam and deck (mm), considered zero for non-composite beams

STEEL BRIDGES

Notation Used (cont.....)

A = area of stringer, beam or girder

K_g = $n\left(I + Ae_g^2\right)$, longitudinal stiffness parameter (moment of inertia of one beam modified to equivalent concrete section and transferred to a point at the center of the slab)

$K_g/L\,t_s^3$ = a parameter proportional to the ratio of beam stiffness to total slab stiffness in transverse direction at the level of the slab centerline

STEEL BRIDGES

Notation Used (cont.....)

g = distribution factor, and

D_e = distance between the center of exterior beam and the interior edge of curb or traffic barrier mm). It shall be taken positive if the exterior web is inside the curb and negative when it is outside the curb.

STEEL BRIDGES

Lateral Distribution Factors For Interior Beams

One design lane loaded

For Moment: $$g = 0.06 + \left(\frac{S}{4300}\right)^{0.4}\left(\frac{S}{L}\right)^{0.3}\left(\frac{K_g}{L t_s^3}\right)^{0.1}$$

For Shear: $$g = 0.36 + \left(\frac{S}{7600}\right)$$

when $4 \times 10^9 \le K_g \le 3 \times 10^{12}$

STEEL BRIDGES

Lateral Distribution Factors For Interior Beams

Two or more design lanes loaded

***For Moment*:** $$g = 0.075 + \left(\frac{S}{2900}\right)^{0.6}\left(\frac{S}{L}\right)^{0.2}\left(\frac{K_g}{L t_s^3}\right)^{0.1}$$

For Shear: $$g = 0.2 + \left(\frac{S}{3600}\right) - \left(\frac{S}{10700}\right)^{2.0}$$

$$\text{when } \; 4 \text{ x } 10^9 \le K_g \le 3 \text{ x } 10^{12}$$

STEEL BRIDGES

Lateral Distribution Factors For Exterior Beams

- The distance, d_e, shall be taken as positive if the exterior web is within the roadway and negative if it is outside the roadway.
- The expressions given below are applicable for concrete deck on steel or concrete beams.

Limitations: $-300 \leq d_e \leq 910$

STEEL BRIDGES

Lateral Distribution Factors For Exterior Beams

One design lane loaded

For Moment: Use lever rule

For Shear: Use lever rule

Two or more design lanes loaded

For Moment: $g = e\, g_{interior}$

where $e = 0.77 + \frac{d_e}{2800} \geq 1.0$

For Shear: $g = e\, g_{interior}$

where $e = 0.6 + \frac{d_e}{3000}$

STEEL BRIDGES

Distribution Factors For Transverse Floor Beams

- If the ***transverse floor beams*** are directly supporting the deck slab, the distribution factors are given in AASHTO Specification.
- However, if the ***floor beams*** are taking load only from longitudinally placed stringers then lever rule may be used to get the distribution factors.