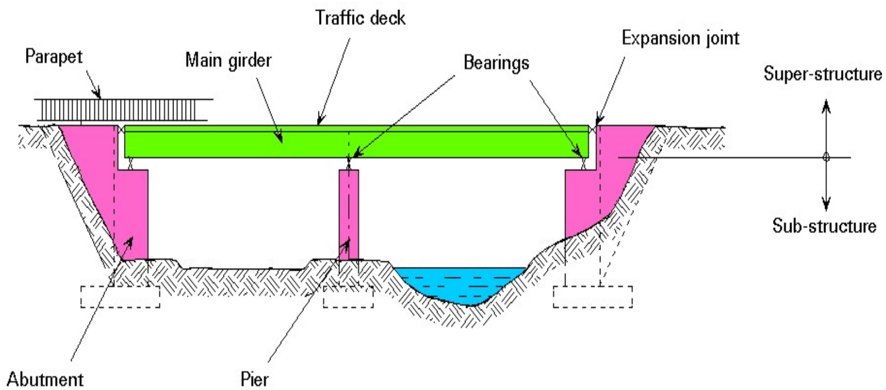
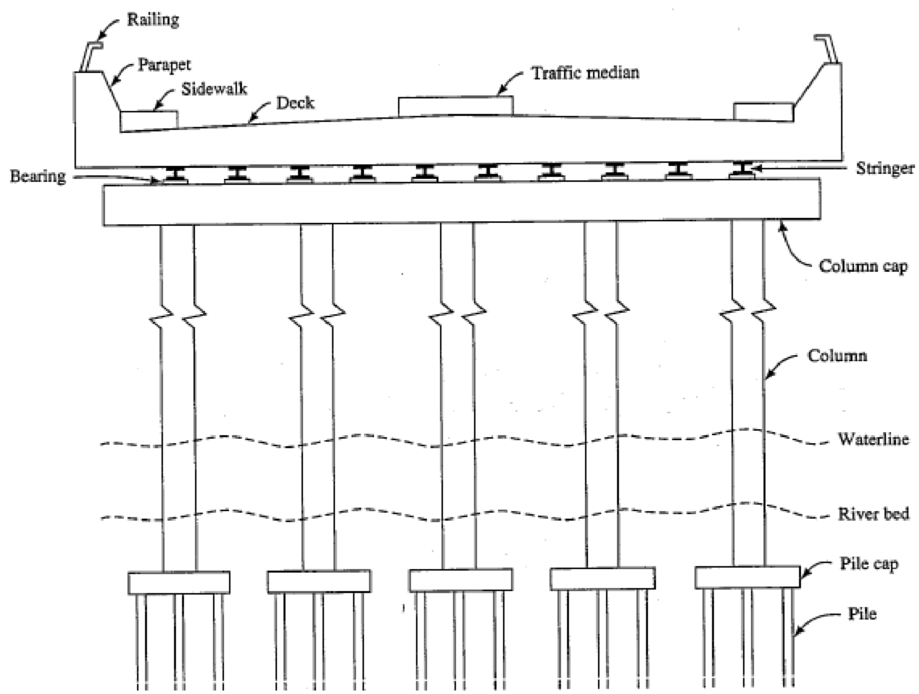
BRIDGE TERMINOLOGY

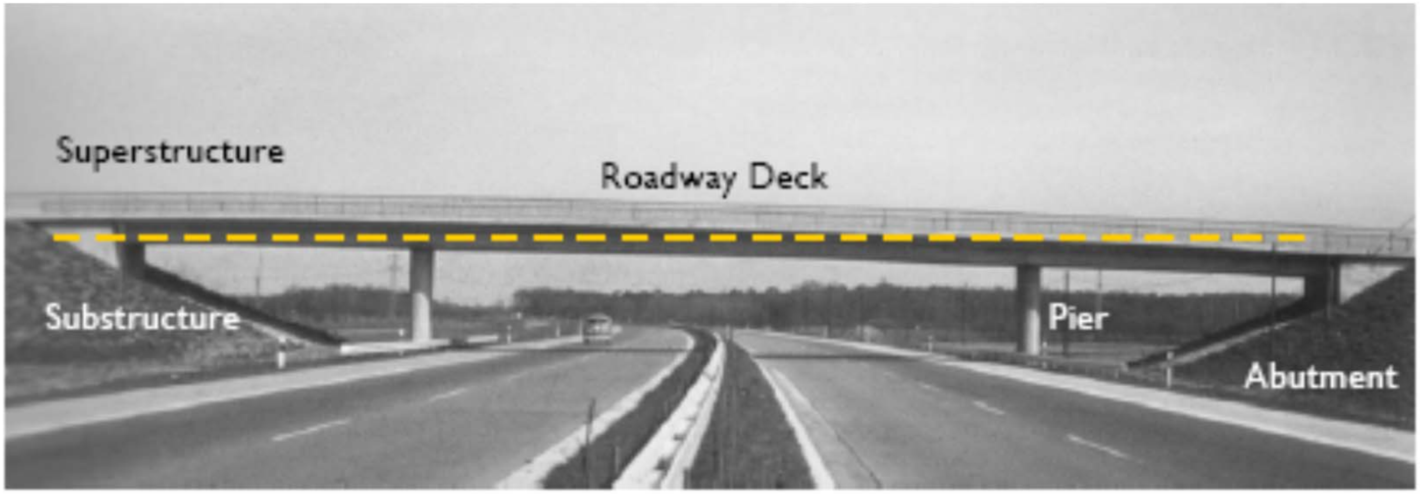


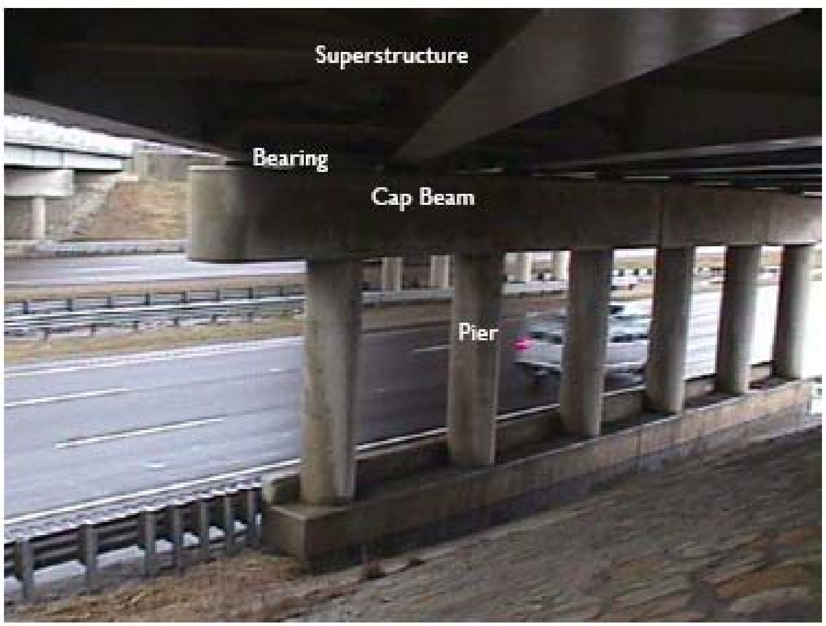
Typical Slab on Girder Bridge



Substructure - includes the piers, the abutments and the foundations.

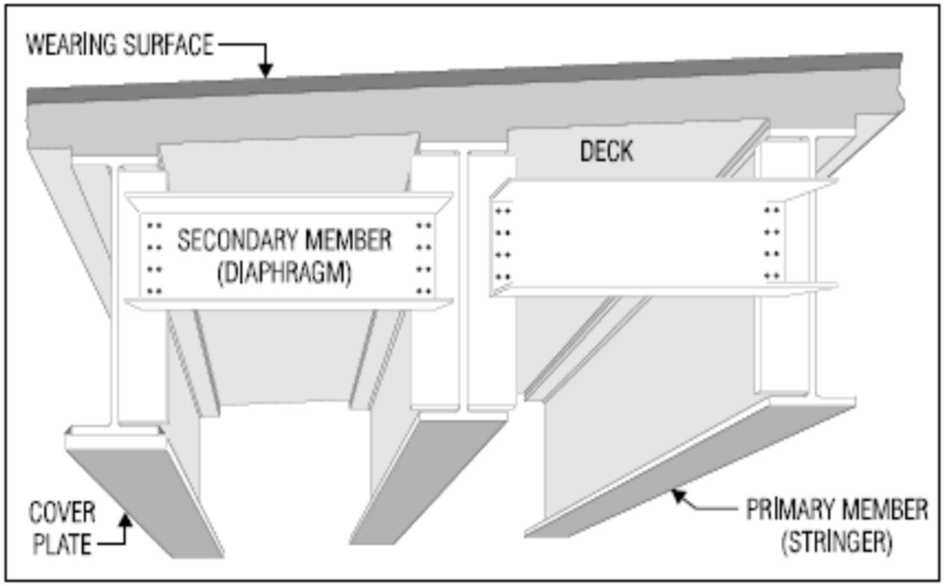
Superstructure - comprises all the components of a bridge above the supports.


Superstructure
Roadway Deck
Substructure
Pier
Abutment


Superstructure
Bearing
Cap Beam
Pier


Superstructure
Cap Beam
Piers

BRIDGE TERMINOLOGY



- **Primary Members.** distribute loads longitudinally and are usually designed principally to resist flexure and shear.

- **Secondary Members:** are bracing between primary members designed to resist cross-sectional deformation of the superstructure frame and help distribute part of the vertical load between stringers. They are also used for the stability of the structure during construction.

BRIDGE TERMINOLOGY

- **Wearing Surface.** The wearing surface (course) is that portion of the deck cross section which resists traffic wear. In some instances this is a separate layer made of bituminous material, while in some other cases it is a integral part of concrete deck.

- **Deck.** The *deck* is the physical extension of the roadway across the obstruction to be bridged. The main function of the deck is to distribute loads *transversely* along the bridge cross section.

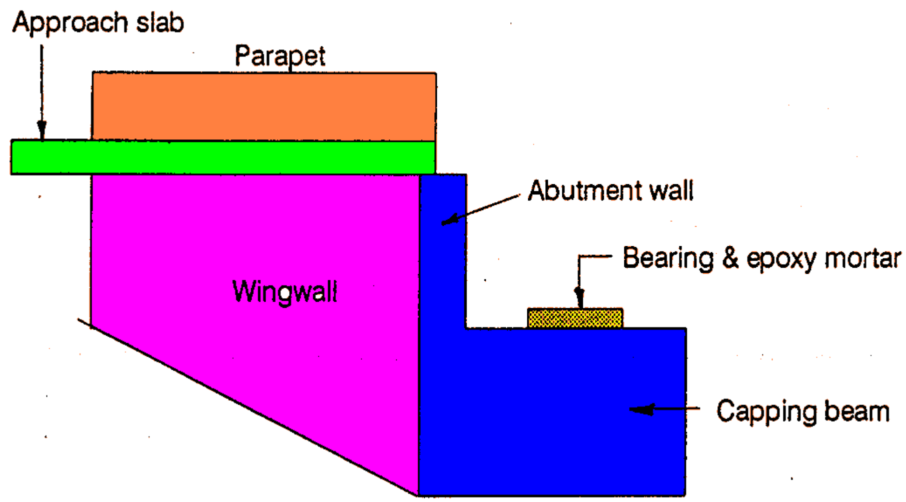
- **Stringers:** Beam type primary members are also called ***stringers* or *girders*.** These stringers could be steel wide flange stringers, steel plate girders (i.e., steel plates welded together to form an I section), prestressed concrete, glued laminated timber, or some other type of beam.

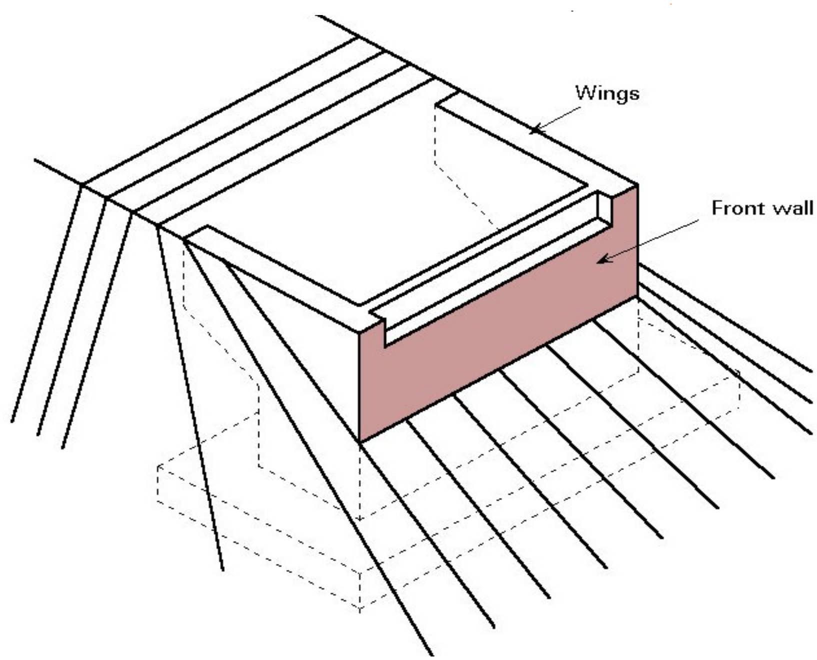
BRIDGE TERMINOLOGY

- **Abutments are earth-retaining structures which support the superstructure at the beginning and end of a bridge.**

- **The abutments establish the connection between the bridge superstructure and the embankments.**
- **They are designed to support the loads due to the superstructure which are transmitted through the bearings and to the pressures of the soil contained by the abutment.**

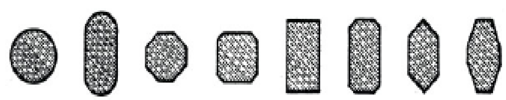
- **A wing wall is a side wall to the abutment back wall or stem designed to assist in confining earth behind the abutment.**



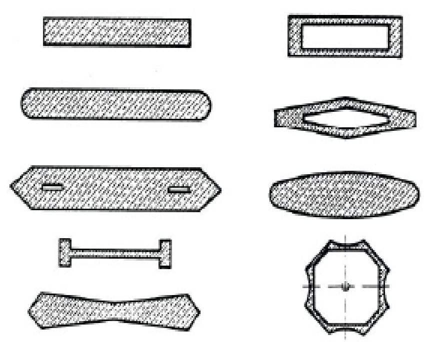


BRIDGE TERMINOLOGY

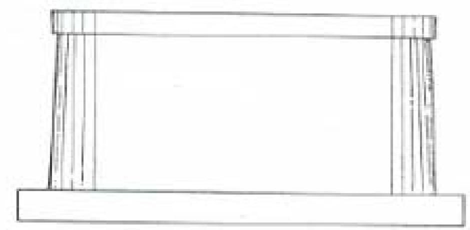
- Piers are structures which support the superstructure at intermediate points between the end supports (abutments). Like abutments, piers come in a variety of forms. From an aesthetic standpoint, piers are one of the most visible components of a bridge and can make the difference between a visually pleasing structure and an unattractive one.



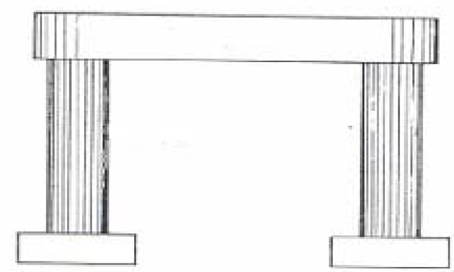
Typical cross-section of piers for overcrossing and viducts on land



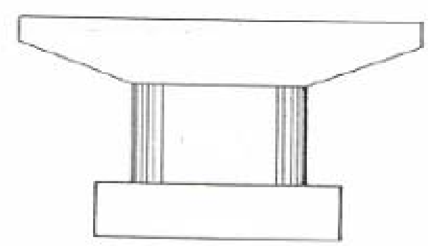
Typical cross-section of piers for river and waterway crossing



Solid Pier



Column Bent or Open Pier



Cantilever Pier or Hammered Pier

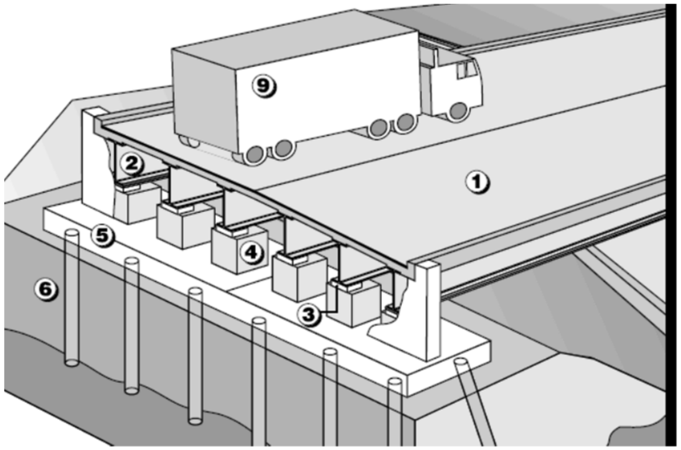
BRIDGE TERMINOLOGY

- **Bearing** is a structural device positioned between bridge superstructure and substructure which transmit the vertical and horizontal loads of the superstructure to the substructure, and accommodate movements between the superstructure and the substructure
- **Role of Bearing**
  - **To transmit load from superstructure to substructure**
  - **Accommodate relative movement between superstructure and substructure**
- **Types**
  - **Fixed Bearing**

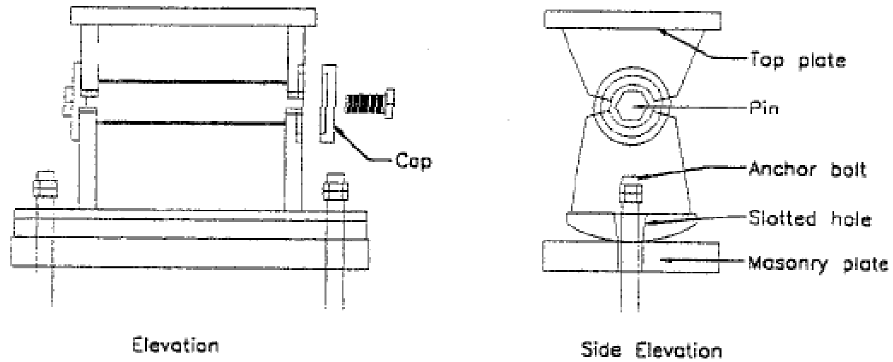
    Rotational movement only
  - **Expansion Bearing**

    Rotational movement

    Translational movement



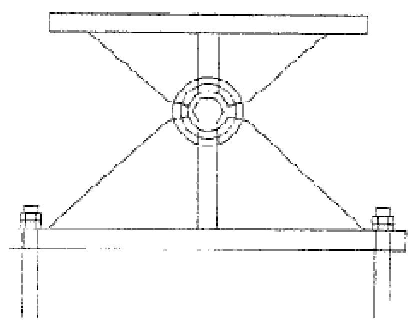
ROCKER/ PIN/ ROLLER BEARING



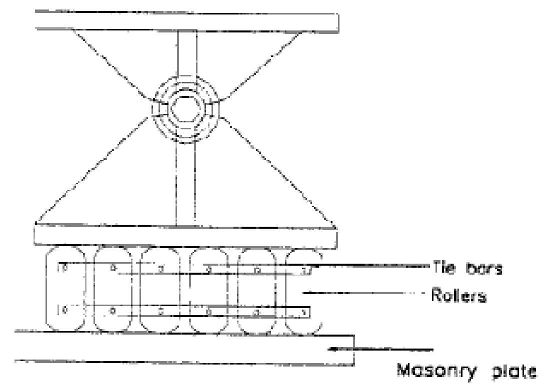
Rocker Bearing

Mostly used for steel beams

- Can carry large loads
- Requires high clearance
- Corrosion can be a Problem
- Need regular inspections
- High maintenance cost

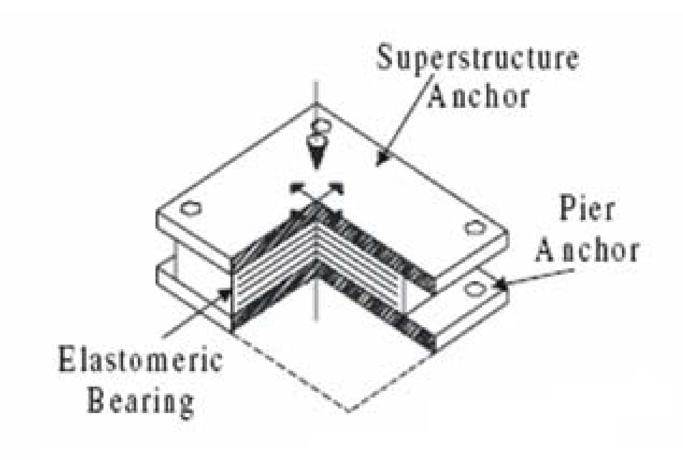


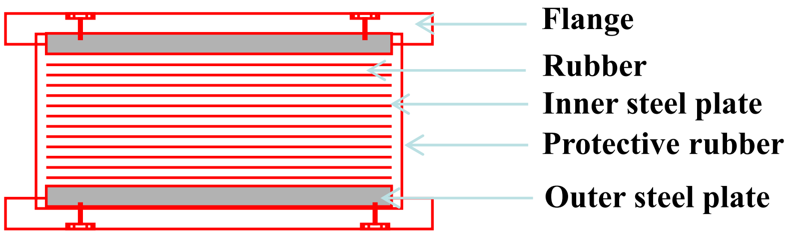
Pin Beaing



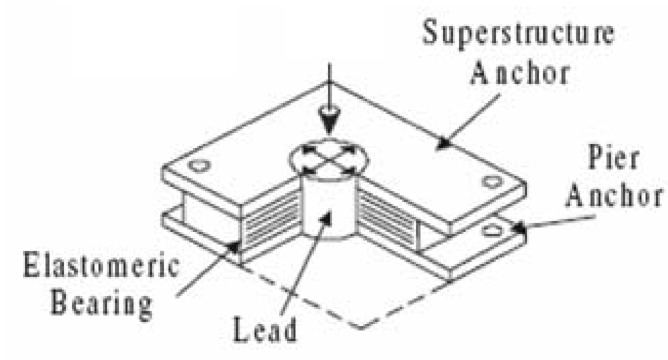
Roller Bearing

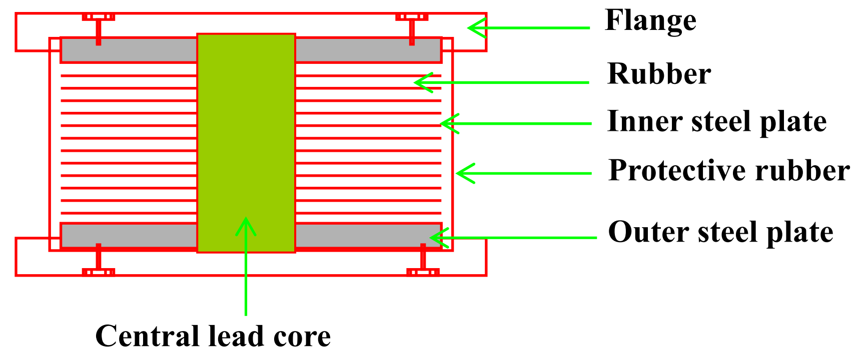
ELASTOMERIC BEARING





ELASTOMERIC BEARING





LEAD RUBBER BEARING

- Made up of natural or synthetic rubber.
- Very flexible in shear but very stiff against volumetric change.
- Steel or fiberglass is typically used to reinforced the pad in alternate layers to prevent it from “bulging” under high load allowing it to resist higher loads.
- Can accommodate both rotational and translational movements through the deformation of pad.

LIVE LOAD

Live load is the force due to vehicles moving on the bridge

There are several types of vehicles
Car, Van, Buses, Trucks ,Semi-Trailer ,Special vehicles ,Military vehicles

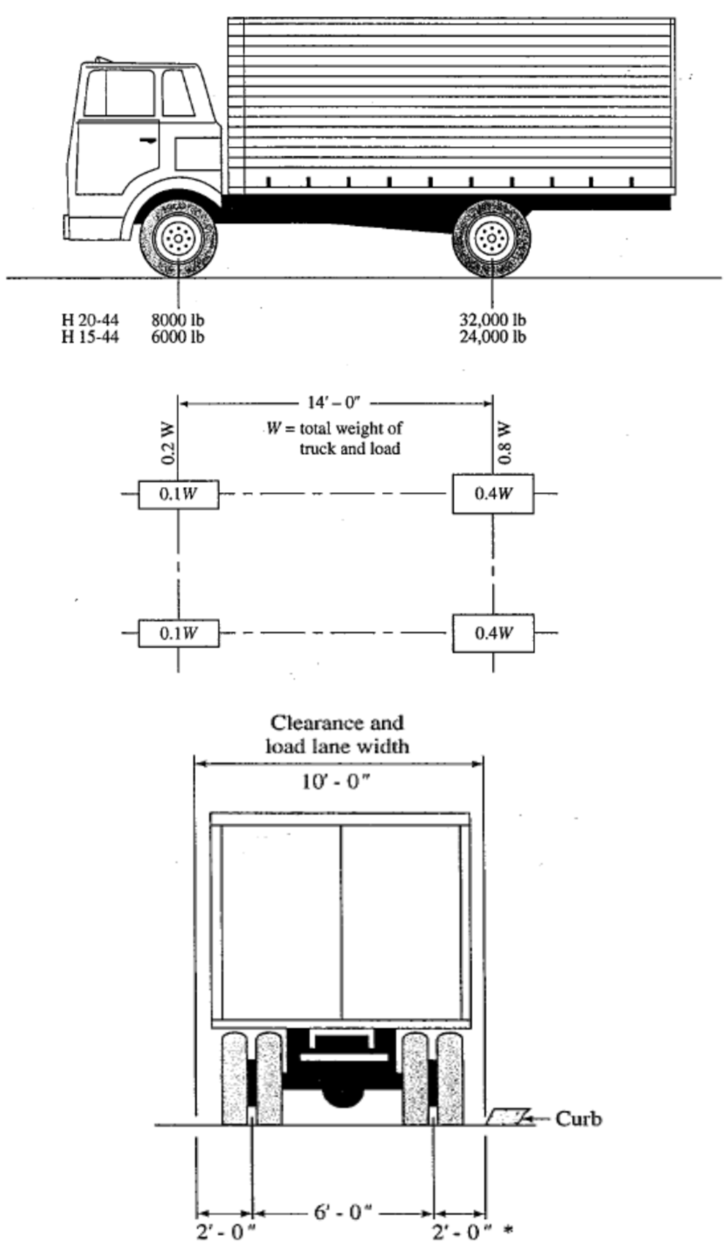
For design purpose, we are interested the kind of vehicle that produce the worst effect

For designing purpose, the design vehicular loads are divided into three categories (AASHTO 3.7).

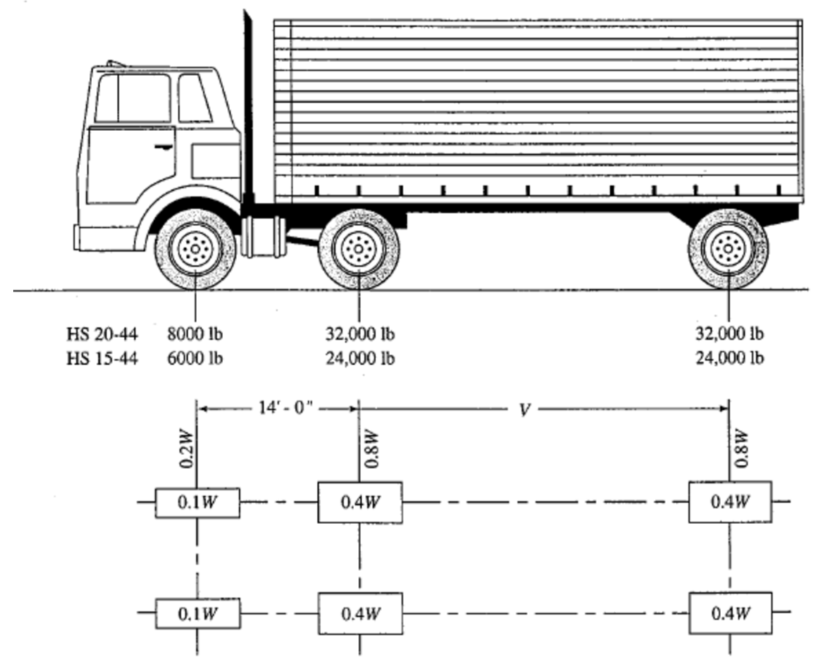
- Design Truck
- Design Lane loading
- Alternate military (or design tandem) loading

It should be recognized, however, that these vehicles are merely *model,* or *hypothetical,* vehicles and do not resemble any particular real vehicle in existence. The presumption is that any legal actual vehicle crossing the bridge should *not* cause stresses greater than those caused by the hypothetical vehicle.

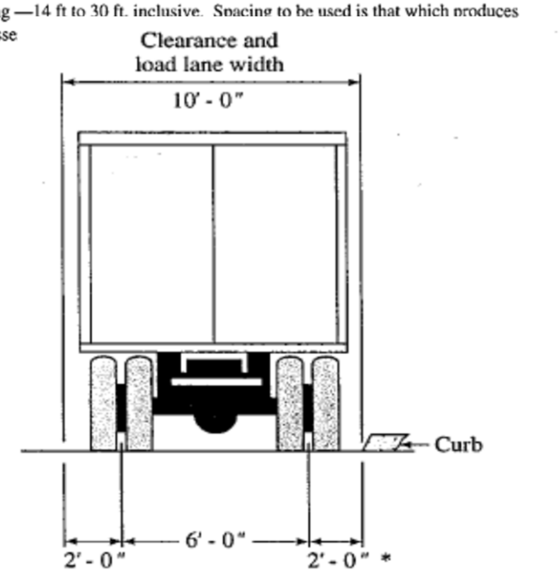
DESIGN TRUCK LOADING



Standard H truck loading [AASHTO, 1992].



W = Combined weight on the first two axles, which is the same as for the corresponding H truck.
V = Variable spacing —14 ft to 30 ft. inclusive. Spacing to be used is that which produces maximum stresse



Standard HS truck loading [AASHTO, 1992].

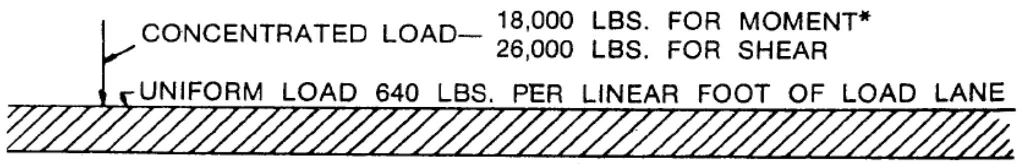
DESIGN TRUCK LOADING

Design truck loading. Also referred to as standard truck loading, this originated in the 1920s, and although it has been revised periodically, its basic format has remained unchanged. Two systems of loadings are provided: The H loading and the heavier HS loading (the letter "S" refers to *semitrailer*). In each case, there are two standard classes of loadings (AASHTO 3.7.2)

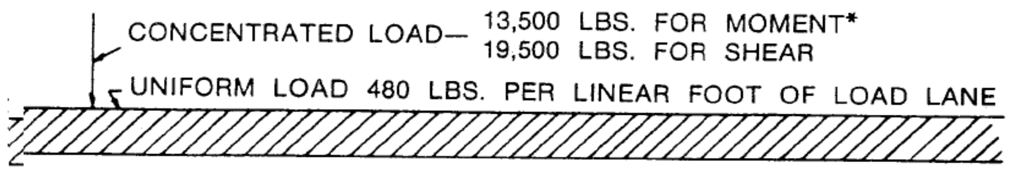
- H15-44 and H20-44
- HS15-44 and HS20-44

In these designations, the number 44 refers to the fact that these loadings were standardized and first published in the 1944 AASHO specifications. The H loadings consist of a two-axle truck, and the numbers 15 and 20 in the loading classification refer to the gross truck weight in tons (1 ton = 2000 lb). The HS loadings consist of a tractor truck with semitrailer (designated by the letter "S" in "HS"). The numbers following the letters "HS" indicate the total load in tons carried by the *axles* of the tractor; the load on the semitrailer is additional.

DESIGN LANE LOADING



H20-44 LOADING
HS20-44 LOADING

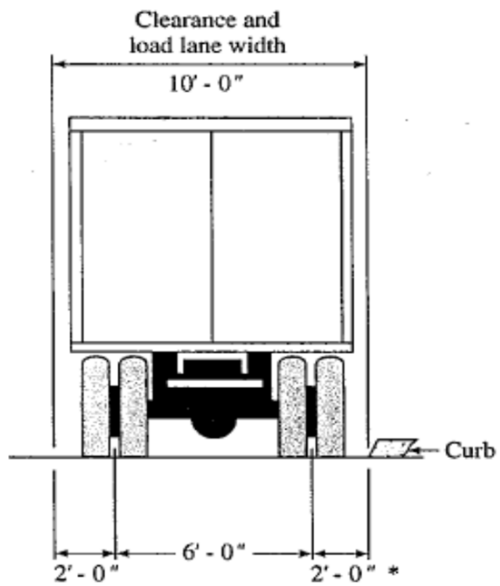


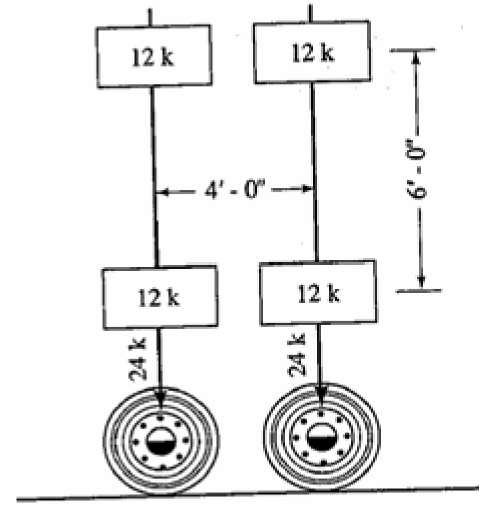
H15-44 LOADING
HS15-44 LOADING

Design lane loading. Lane loading was developed to better model loading on long spans, where a string of light vehicles might be critical.

Lane loading also has two classes of loadings, and in each class two different loadings are provided. These loadings are designated in the same manner as the truck loadings (namely, H15-44, HS15-44, H20-44, HS20-44). Basically, the lane load consists of a *uniform load* accompanied by a *concentrated load.*

DESIGN TANDEM LOADING





Alternate military (or design tandem) loading. This loading originated in 1956 as a Federal Highway Administration requirement for bridges on the Interstate Highway System, to provide load-carrying capacity for certain heavy military vehicles. It is applicable to certain bridges in the state highway systems. The alternate bridge loading consists of two axles spaced 4 ft apart with each axle carrying 24 kips. This load produces slightly higher live-load moments in spans under 40 ft.

AASHTO 3.7.4 [AASHTO, 1992] specifies that this alternate loading, or the HS20-44 loading, whichever produces the greater stress, be considered as the minimum design loading for highway bridges.

IMPACT

From an engineering standpoint, *impact load* can be defined as a *suddenly applied load*. From a vibration standpoint, impact load is defined as a load whose period of application is shorter than the fundamental period for the structure on which the load is applied. In the context of bridges, the phenomenon of impact is related to the bridge-vehicle interaction. From a designer's viewpoint, it deals with the notion of dynamic load amplification.

Dynamic response = impact factor × maximum static response

Total response = $(1 + I)$ × maximum static response

To simplify this complex problem of evaluating the dynamic effects of moving loads, current bridge design practice is to use an empirical impact factor that varies only with span . AASHTO 3.8.2 specifies that the dynamic effects of moving loads be expressed as a *fraction of the live loads* according to the following empirical formula:

$$I = \frac{50}{L + 125}$$

where I = Impact factor (maximum 30 percent or 0.3)

L = Length, in feet, of the portion of the span that is loaded to produce the maximum stress in the member

MULTIPLE PRESENCE OF LIVE LOAD

- Bridges has more than one lane
- It's almost impossible to have maximum load effect on ALL lanes at the same time
- The more lanes you have, the lesser chance that all will be loaded to maximum at the same time
- We take care of this by using Multiple Presence Factor

Reduction in live-load intensity AASHTO 3.12.1

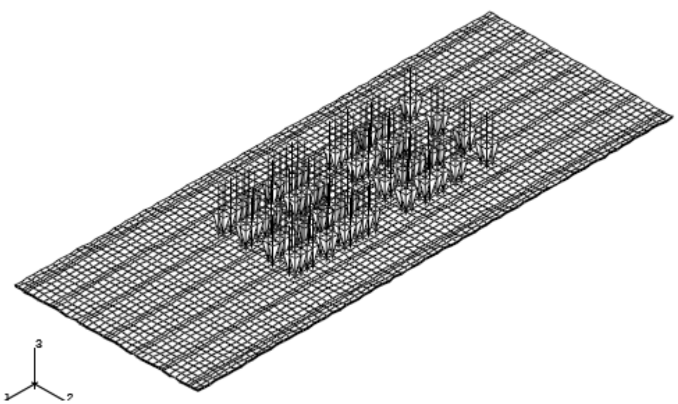
	Percent reduction
One or two lanes	100
Three lanes	90
Four lanes or more	75

METHODS OF ANALYSIS OF SLABS AND BEAMS

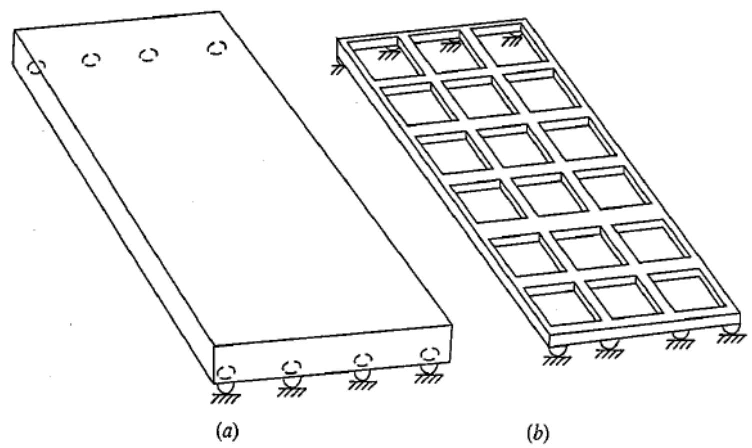
Methods of analysis of bridge decks can be classified as

- Classical methods
- Computer methods
- Simplified methods

Various methods of analyzing bridge decks, such as the grillage method, the folded plate method, and the equivalent orthotropic plate method, referred to previously, belong to the category of so-called classical methods. Burdened with cumbersome mathematics, these methods do not offer very efficient solutions, particularly for longhand calculations, and therefore they are not very appealing to design engineers



Finite Element Analysis



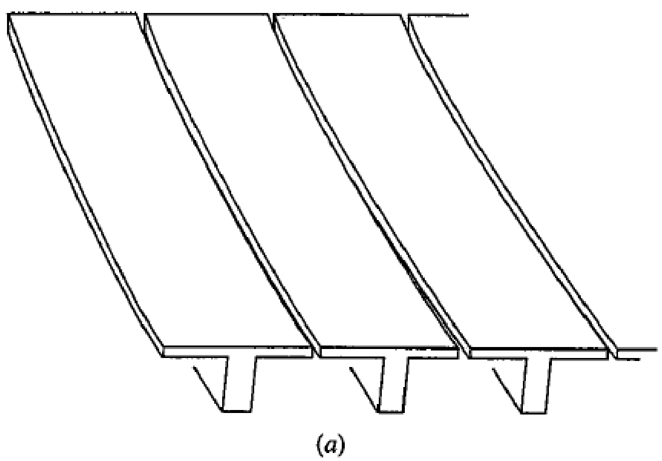
Grillage analysis of slab deck:
(a) Prototype deck (b) equivalent grillage

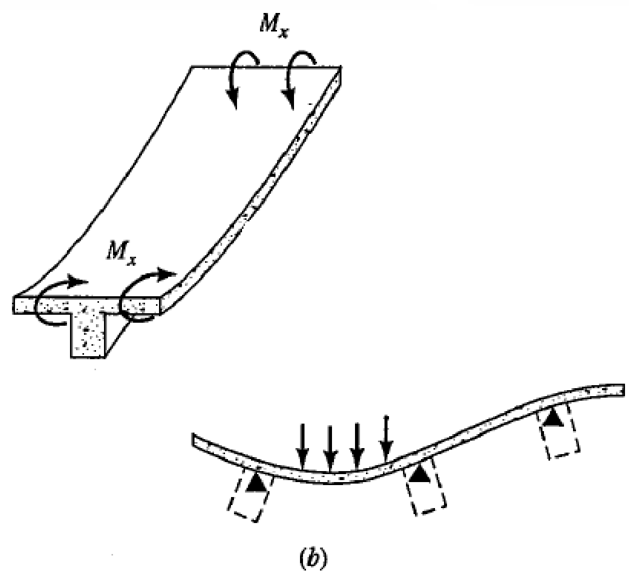
METHODS OF ANALYSIS OF SLABS AND BEAMS

Beam-and-slab decks of various configurations can be idealized as comprising a series of longitudinally spanning parallel T-beams

Under load, the response of a slab is characterized by longitudinal bending as flanges of T-beams, accompanied by transverse bending as a continuous beam.

Mathematically, these decks can be analyzed by the grillage method and finite element method.





Response of a beam-and-slab deck. (*a*) Longitudinal bending as flanges of T-beams. (*b*) Transverse bending as a continuous beam

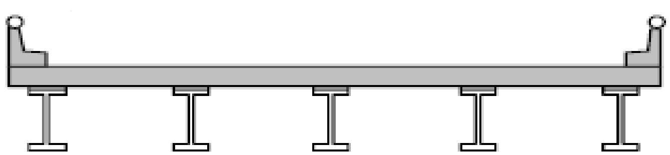
LIVE LOAD DISTRIBURION

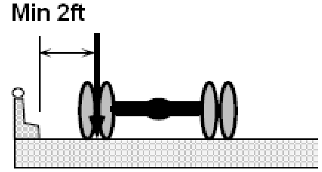
The effect of live load on the bridge structures depends on many parameters including:

- span length,
- weight of vehicle,
- axle loads (load per wheel),
- axle configuration,
- position of the vehicle on the bridge (transverse and longitudinal),
- number of vehicles on the bridge (multiple presence),
- girder spacing,
- stiffness of structural members (slab and girders).

Live Load Placement

- Transversely (for designs of slabs and overhangs)





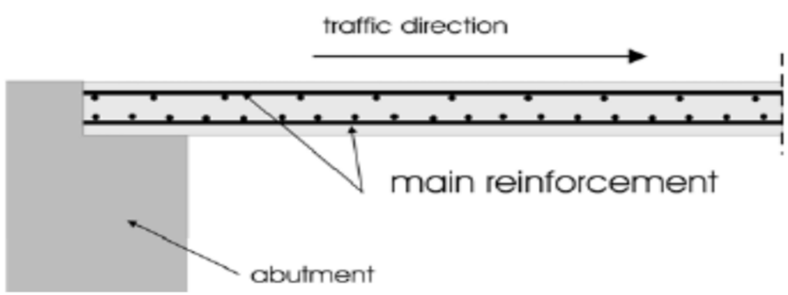
- Longitudinally (for design of main girder)

AASHTO METHOD OF LIVE LOAD DISTRIBUTION IN SLABS

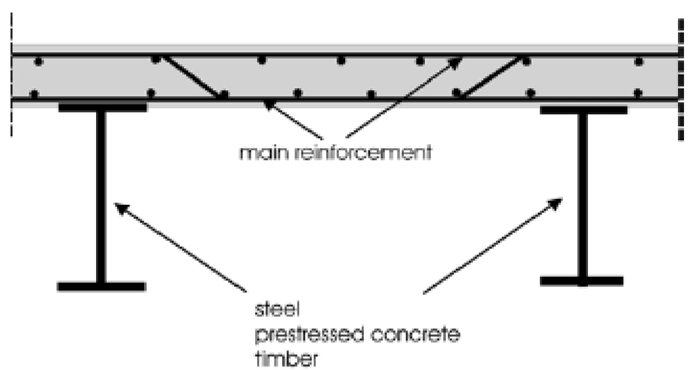
Support conditions for slab

Two cases are considered, based on the direction of the span of the slab:

1. The deck consists only of a reinforced concrete slab supported on abutments and/or piers. The main reinforcement in this case runs *parallel to traffic*.



2. The deck slab is supported over a number of parallel steel, concrete, or timber beams. The main reinforcement in this case is oriented *perpendicular to traffic*.



AASHTO METHOD OF LIVE LOAD DISTRIBUTION IN SLABS

Case 1: Slab supported on an abutment and/or piers

Two methods are prescribed in AASHTO 3.24.3.2 for determining slab moments.

Method 1. Moment is calculated as if it were caused by a concentrated load acting on a simple span.

The truck wheel load is distributed over a width of E $(4 + 0.06S)$ ft, to a maximum of 7.0 ft.

$$E = 4 + 0.06S \text{ (ft)}$$

Maximum moment is obtained by placing the concentrated load so obtained at the midspan, which gives

$$M = \frac{P'S}{4} \qquad \text{where } S = \text{span (ft)}$$

$$P' = P/E \text{ for truck loading}$$
$$= P/2E \text{ for lane loading}$$

$$P = P_{15} = 12{,}000 \text{ lb for H15 truck loading}$$
$$= P_{20} = 16{,}000 \text{ lb for H20 truck loading}$$
$$= 13{,}500 \text{ lb for H15 lane loading}$$
$$= 18{,}000 \text{ lb for H20 lane loading}$$

Note that in the case of lane loading, the uniform lane loading should also be distributed over the width of $2E$ and moment $(wS^2/8)$, calculated accordingly.

AASHTO METHOD OF LIVE LOAD DISTRIBUTION IN SLABS

Method 2. Alternatively, for HS20 loading, the maximum live-load moment (*LLM*) per foot width of slab can be closely approximated by the following empirical formulas:

$LLM = 900S$ ft-lb For spans up to 50 ft,

$LLM = 1000(1.3S - 20.0)$ ft-lb For spans > 50 to 100 ft,

For HS15 loading, *LLM* can be taken as three-fourths of the preceding values.

The edges of the deck slab are stiffened. This can be accomplished by providing:

1- an additionally reinforced slab section,
2- a beam integral with and deeper than the slab,
3- or an integrally reinforced section composed of slab and curb.

This portion of the slab, known as the *longitudinal edge beam*, is designed for a live-load moment equal

$LLM = 0.1PS$ where $P = P_{15}$ or P_{20}

According to AASHTO, the *value of moment for the edge beam is not to be increased for impact considerations.*

AASHTO METHOD OF LIVE LOAD DISTRIBUTION IN SLABS

Case 2: Slab supported on beams and stringers

$$LLM = \frac{P(S+2)}{32} \text{ ft-lb}$$

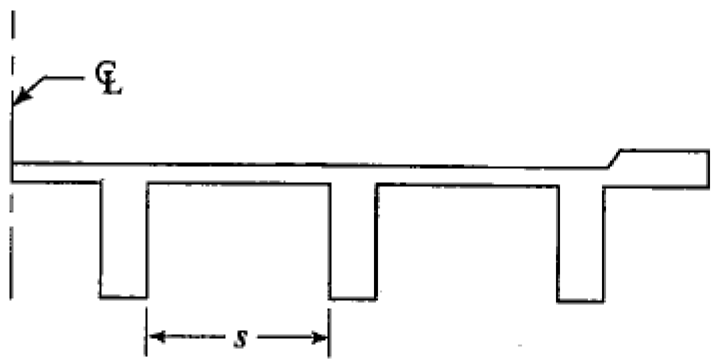
where $P_i = P_{20} = 16{,}000$ lb (load on one rear wheel of an HS20 truck)
$= P_{15} = 12{,}000$ lb (load on one rear wheel of an HS15 truck)

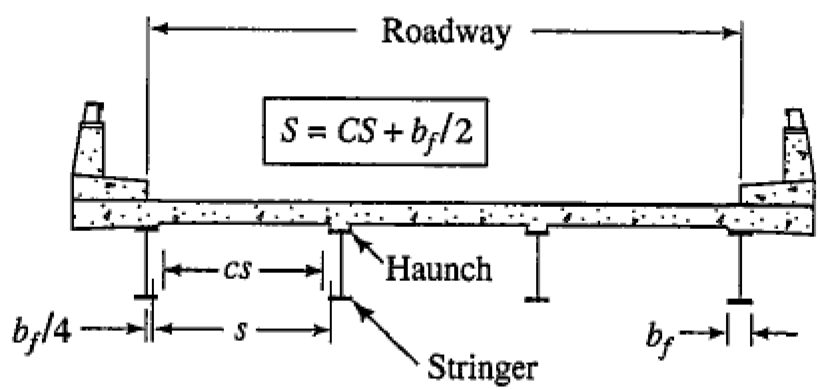
For T-beam section

$S=$ clear span

For slab is supported on steel stringers

$S=$ the clear span plus half the width of the stringer flange





AASHTO METHOD OF LIVE LOAD DISTRIBUTION IN BEAMS

AASHTO 3.23 provides a simplified, but empirical, method to determine the lateral distribution of moving loads to both exterior and interior stringers.This method is referred to as *distribution of loads* . According to this method of analysis, Shear and moment in a stringer due to moving loads are first determined from influence lines. These values are then multiplied by the appropriate *live-load distribution factors*, DF (AASHTO Table 3.23.1) and by the impact factors $(1 + I)$, to obtain design shear and moments in stringers.

For a slab-on-stringer bridge *with four or more stringers*, the following distribution factors are used:

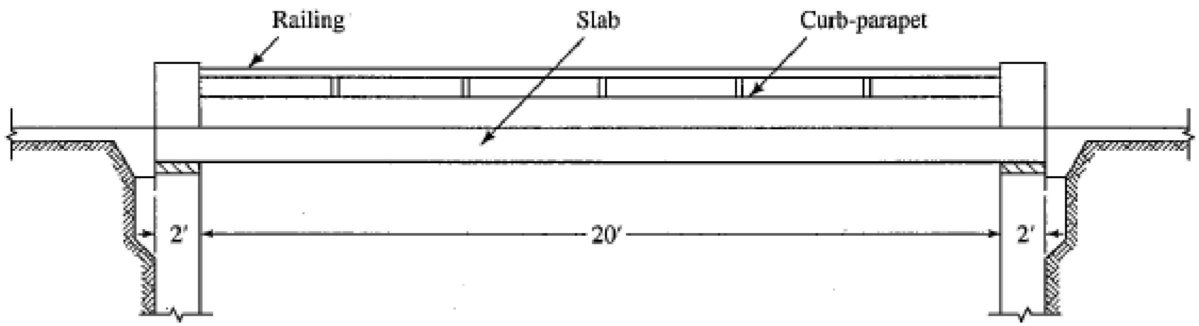
$$DF = \frac{S}{5.5} \quad (S \leq 6 \text{ ft}) \qquad \text{or} \qquad DF = \frac{S}{4.0 + 0.25S} \quad (6 < S \leq 14 \text{ ft})$$

where S = Distance Between Exterior and Adjacent Interior Stringer

design live-load moment

$$M_{L+I} = (\text{moment from influence lines for wheel loads})\left(\tfrac{1}{2}\right)(DF)(1 + I)$$

EXAMPLE Design a two-lane reinforced concrete slab bridge for a clear span of 20 ft to carry HS20 loading. A provision of 30 lb/ft ^{2} of dead load should be made in the design for the future wearing surface. The following data are given: $f_c' = 3000$ psi, Grade 40 reinforcement, clear width = 40 ft.



Calculations. The design of a slab bridge essentially consists of two parts: design of the slab and design of the longitudinal edge beams.

Design by the service load method: Design of slab. Assume 6 in. to the center of the bearings from the face of the abutments:

$$L = S = 20 + 2 \times \left(\frac{6}{12}\right) = 21 \text{ ft}$$

The minimum slab thickness is given by AASHTO 8.9.3 for deflection control:

$$t_{min} = 1.2\left(\frac{S + 10}{30}\right)$$

$$= 1.2\left(\frac{21 + 10}{30}\right)$$

$$= 1.24 \text{ ft}$$

Therefore, try a 15-in.-thick slab.

Self-weight of slab	$= 1 \times 1.25 \times 150$	$= 187.5$ lb/ft^2
Wearing surface		$= 30.0$ lb/ft^2
Total load		$= 217.5$ lb/ft^2

Dead-load moment $M_D = wL^2/8 = 0.2175 \times (21)^2/8 = 11{,}990$ lb-ft

To calculate live-load moment, the weight of one rear wheel of the HS20 truck (16 kips) is distributed over a width, E, per AASHTO 3.24.3.2:

$$E = 4 + 0.06S = 4 + 0.06 \times 21 = 5.26 < 7.0 \text{ ft}$$

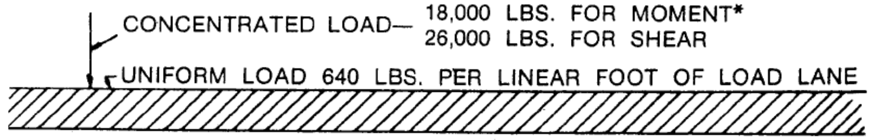
$$\text{The weight on a unit width of slab} = \frac{\text{weight of one rear wheel}}{E}$$

$$= \frac{16{,}000}{5.26}$$

$$= 3042 \text{ lb}$$

This 3042-lb load is treated as a concentrated load on a span of 21 ft, and the corresponding live-load moment is

$$M_{L,\text{truck}} = \frac{PS}{4} = 3042 \times \frac{21}{4} = 15{,}970 \text{ lb-ft}$$



HS20-44 LOADING

Compare this with moment due to HS20 lane loading. The lane load (both the uniform and the concentrated) is distributed over a width of $2E$; thus,

$$w = \frac{640}{2 \times 5.26} = 60.8 \text{ psf}$$

The live-load moment due to this load is

$$M_w = \frac{wL^2}{8} = \frac{60.8 \times (21)^2}{8} = 3352 \text{ lb-ft}$$

The concentrated load is

$$P = \frac{18}{2 \times 5.26} = 1.711 \text{ kips}$$

The moment due to this load is given by

$$M_{\text{conc load}} = \frac{PL}{4} = \frac{1.711 \times 21}{4} = 8.98 \text{ kip-ft}$$

The moment due to this load is given by

$$M_{\text{conc load}} = \frac{PL}{4} = \frac{1.711 \times 21}{4} = 8.98 \text{ kip-ft}$$

The total live-load moment due to lane loading is

$$M_L = 3.352 + 8.98 = 12.332 \text{ kip-ft} < 15.97 \text{ kip-ft (truck loading)}$$

Therefore, the truck loading governs. Use $M_L = 15.97$ kip-ft (the larger value)

$$\text{Impact: } I = \frac{50}{L + 125} = \frac{50}{21 + 125} = 0.342 > 0.3$$

Hence, use $I = 0.3$ (maximum value). Thus,

$$M_I = 0.3 \times 15.97 = 4.79 \text{ kip-ft}$$

$$M_{\text{total}} = 11.99 + 15.97 + 4.79 = 32.75 \text{ kip-ft}$$

$n = E_s/E_c$ = modular ratio

$$k = \frac{n}{n + f_s/f_c} \text{ (the neutral axis factor)}$$

$$j = 1 - \frac{k}{3} \text{ (lever-arm factor)}$$

$f_c = 1200\,psi$

$f_s = 20000\,psi$

$n = 9$ For $f'_c = 3000$ psi

$k = 0.351$ and $j = 0.883$ Thus

The depth of the slab

$$d = \sqrt{\frac{2M}{f_c k j b}} = \sqrt{\frac{2 \times 32.75 \times 12}{1.2 \times 0.351 \times 0.883 \times 12}} = 13.2 \text{ in.}$$

Assuming #8 for main reinforcing bar, and 1 in. as clear cover, the total required slab thickness is $h = 13.2 + 0.5 + 1 = 14.7$ in. Use $h = 15$ in., required for deflection control.

Area of reinforcing steel required:

Then, the effective depth is $d = 15 - 0.5 - 1.0 = 13.5$ in.

$$A_s = \frac{M}{f_s j d} = \frac{32.75 \times 12}{20 \times 0.883 \times 13.5} = 1.65 \text{ in.}^2$$

Therefore, provide #9 @ 7 in. o.c., $A_s = 1.71$ in.^{2}

Distribution reinforcement (AASHTO 3.24.10.2)

Percentage of reinforcement $= 100/\sqrt{S} = 100/\sqrt{21} = 21.82\% < 50\%$ max.

Therefore, $A_s = 0.2182 \times 1.65 = 0.36$ in.^{2} Provide #6 @ 15 in. o.c., $A_s = 0.36$ in.^{2}, directly above and perpendicular to the main reinforcement.

Temperature reinforcement (AASHTO 8.20.1)

$$A_s = \frac{1}{8} \text{ in.}^2 \text{ per ft}$$

in each direction. Provide #4 @ 18 in. o.c. in each direction below the top face of the slab.

Shear and bond (AASHTO 3.24.4). Slab designed for bending by the previous method is considered satisfactory in shear and bond; hence, no further checking is necessary.

Check for minimum reinforcement (AASHTO 8.17.1.1)

$$f_r = 7.5\sqrt{f_c'} = 7.5\sqrt{3000} = 410.8 \text{ psi}$$

$$I_{cr} = \frac{bh^3}{12} = \frac{12 \times 15^3}{12} = 3375 \text{ in.}^4$$

$$M_{cr} = \frac{f_r I_{cr}}{h/2} = \frac{410.8 \times 3375}{7.5 \times 12{,}000} = 15.41 \text{ kip-ft}$$

$$1.2M_{cr} = 1.2 \times 15.41 = 18.5 \text{ kip-ft}$$

$$M_{design} = 32.75 \text{ kip-ft} > 1.2M_{cr} = 18.5 \text{ kip-ft; OK.}$$

Design of longitudinal edge beam

AASHTO 3.24.8 stipulates that edge beams be provided for all slabs having primary reinforcement parallel to traffic. Three alternatives are suggested for providing edge beams:

1. A slab section additionally reinforced
2. A beam integral with and deeper than the slab
3. An integrally reinforced section of slab and curb

choose the first alternative—an additionally reinforced section of the slab as the longitudinal edge beam.

Choose $b = 24$ in.,

so that the cross section of the longitudinal edge beam is 24 in. × 15 in.

Provide a curb 10 in. high (standard depth)

which gives the total height of the beam as 25 in. (for computing the self-weight).

Self-weight (including the curb)	$= 24 \times 25 \times \frac{150}{144}$	= 625 lb/ft
Weight of railing (assumed)		= 15 lb/ft
Total dead load		= 640 lb/ft

$$M_D = 0.64 \times (21)^2/8 = 35.28 \text{ kip-ft}$$

The live-load moment in a longitudinal edge beam is given by AASHTO 3.24.8.2:

$$M_L = 0.10 P_{20} S = 0.10 \times 16{,}000 \times 21 = 33.6 \text{ kip-ft}$$

$$M_{\text{total}} = 35.28 + 33.6 = 68.88 \text{ kip-ft}$$

The required beam depth, with $b = 24$ in $k = 0.351$ and $j = 0.883$ for $n = 9$

$$d = \sqrt{\frac{2M}{f_c k j b}} = \sqrt{\frac{2 \times 68.05 \times 12}{1.2 \times 0.351 \times 0.883 \times 24}} = 13.53 \text{ in.}$$

With 1 in. cover and #8 as the main reinforcing bar, $h_{\text{required}} = 13.53 + 1 + 0.5 = 15.03$ in., say 15 in., as provided. The required reinforcement

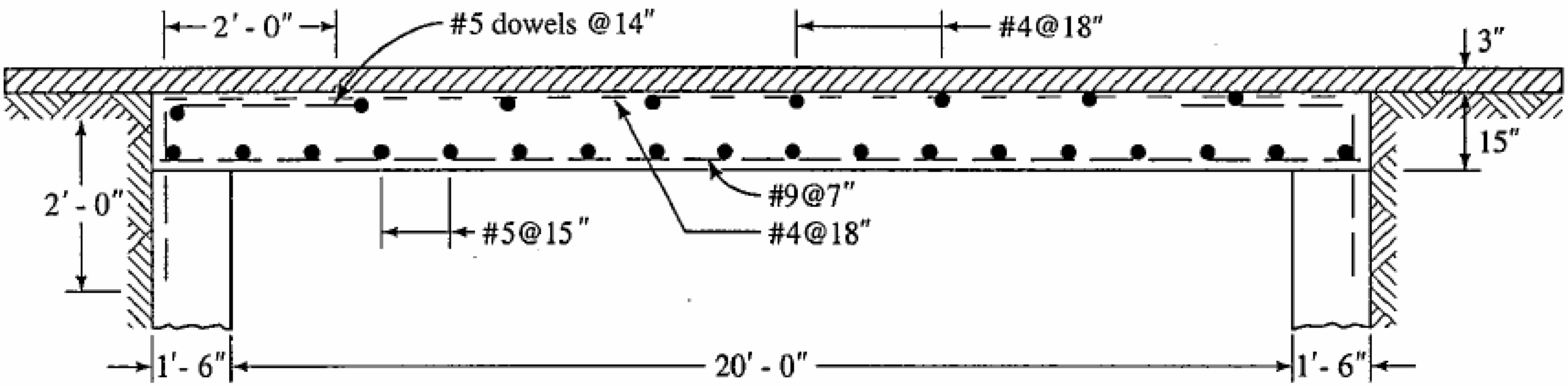
$$A_s = \frac{M}{f_s j d} = \frac{68.88 \times 12}{20.0 \times 0.883 \times 13.5} = 3.47 \text{ in.}^2$$

Therefore, provide four #9 bars, $A_s = 4.0 \text{ in.}^2 > 3.47 \text{ in}^2$

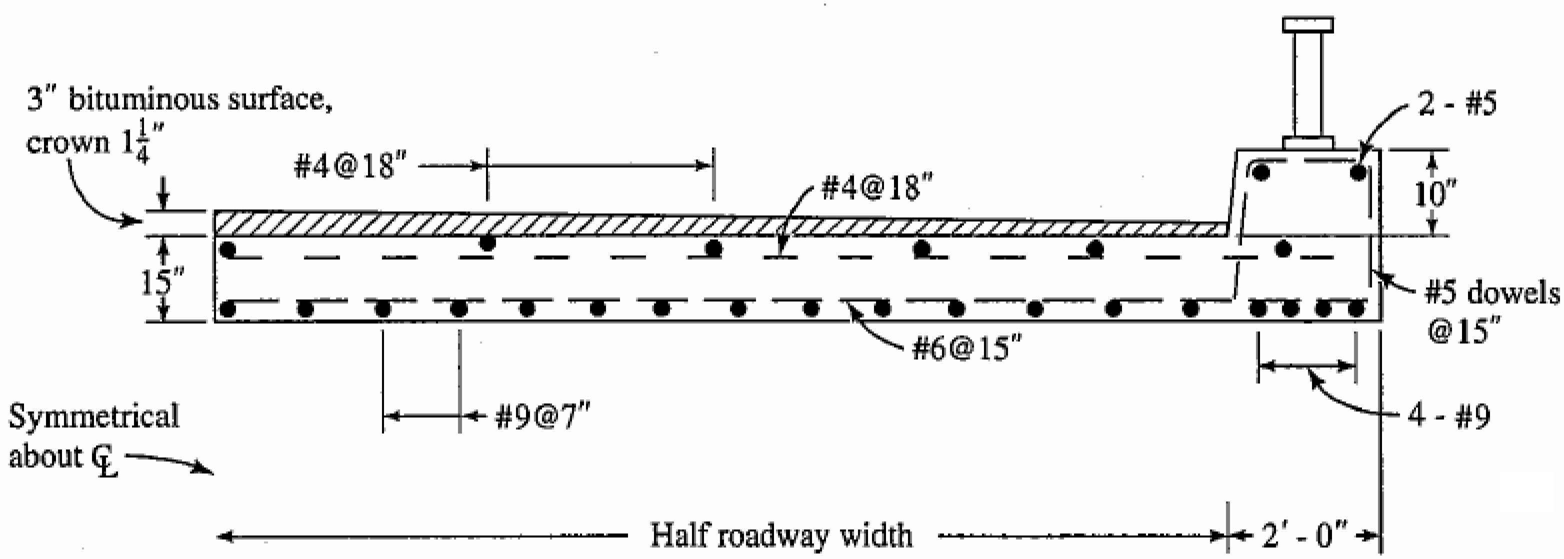
Miscellaneous details.

For effective drainage, the roadway surface is crowned by providing varying thicknesses of the wearing surface across the deck cross section.

According to AASHTO 8.5.1, devices for expansion and contraction due to temperature changes are to be provided at supports only for spans exceeding 40 ft. Thus, bearing pads are not required to be provided for slab bridges. Instead, the slab rests directly on the abutments—on the bridge seat precoated with a bituminous mixture-–and fixed bearings are provided by placing vertical dowels usually @ 12 in. o.c. along the length of the abutments. As shown in Fig. these dowels extend vertically 24 in. into the abutment and bend to extend 24 in. horizontally inside the slab. This detail also acts as a preventive measure against cracking that may occur near the abutment edges.



(*a*) Longitudinal section



(*b*) Transverse section

Reinforcement details (slab and the edge beams)