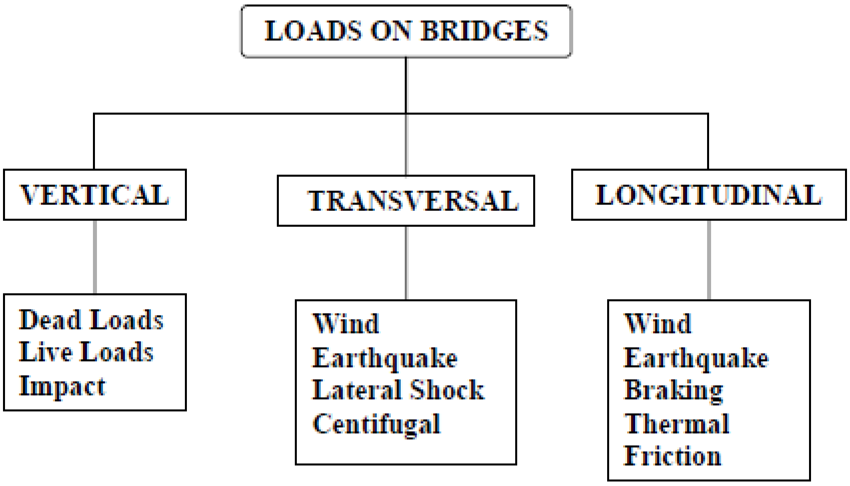
Loads on Bridges

The bridge engineer must take into account a wide variety of loads which vary based on:
1- Duration (permanent or temporary)
2- Direction (vertical, longitudinal, etc.)
3- Deformation (concrete creep, thermal expansion, etc.)
4- Effect (shear, bending, torsion, etc.)
In general, the principal loading which highway bridges are designed by is shown in the following diagram.



Types of Loads on Bridge Components

1-Permanent Loads

Permanent loads are those loads which always remain and act on a bridge throughout its life. The permanent loads are divided into the following three major categories.

1-1-Dead load (D.L)

This would include the deck slab, primary members (beams or girders), secondary members (including all bracing, connection plates, etc.), stiffeners, Diaphragms, floor beam, cross frame, ….)

1-2-Superimposed Dead load

Superimposed dead loads are those loads placed on the superstructure after the deck has cured and begun to work with the primary members in resisting loads. This would include the surfacing (asphalt pavement), sidewalks (foot path), median, guard rails, hand rail, lighting poles, signing, water lines, cables, pipes and others utilities.
It is necessary to make a preliminary estimate for the DL then perform the design based on the estimated value. The weight of the structure can then be calculated and compared with the previously estimated weight. It might be necessary to make more cycle of design based on new D.L .

1-3-Pressures

Pressures due to earth or water are also considered permanent loads. While these loads primarily affect substructure elements, they have the potential of impacting superstructure elements as well at points where these two components interface. Earth pressure on piers and abutments should be computed by recognized soil-mechanics formulas, but the equivalent fluid pressure should be at least ($6kN/m^3$) when it increases stresses and not more than ($4.25kN/m^3$) when it decreases stresses.

Table (1) Unit weight of common materials

Material	γ (kN/m^3)
Steel	78
Reinforced concrete	24
Aluminum	24
Asphalt pavement (surfacing)	22
Plain concrete	22
Compacted soil	18
Aggregate	18
Sand	14-19
Wood	8

2-Temporary Loads

Temporary loads are those loads which are placed on a bridge for only a short period of time. Just as dead loads are the principal permanent loading condition, live loads represent the major temporary.

2-1-Highway Bridge live loading

The term live load means a load that moves along the length of a span. Therefore, a vehicles and person walking along the bridge can be considered live load. To give designers the ability to accurately model the live load on a structure, hypothetical design vehicles based on truck loading (or equivalent lane loading) were developed.

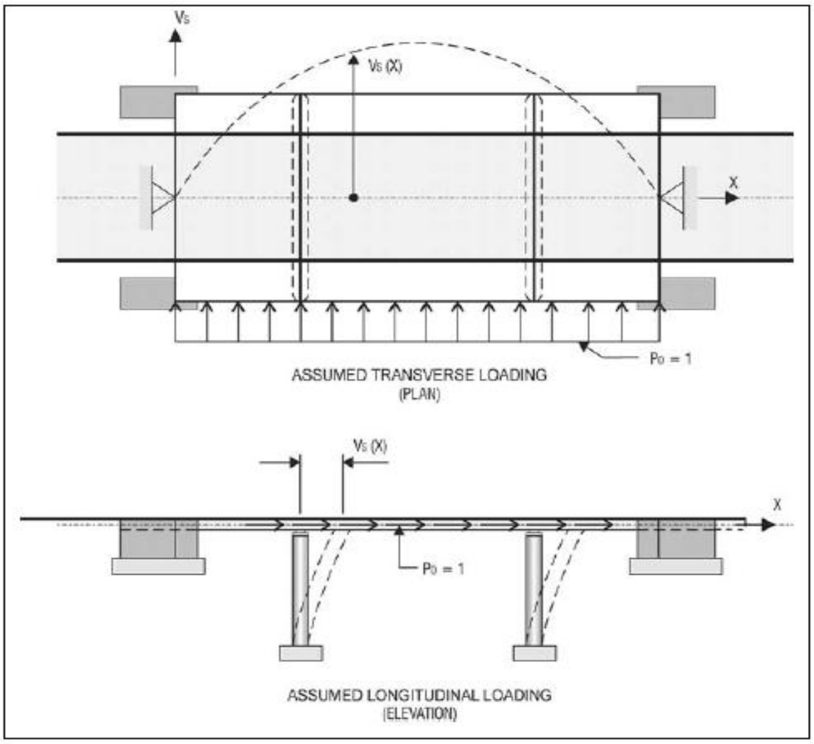
2-2-Earthquake Loading

Earthquake loading is a product of natural forces (Seismic forces) which are dependent on the geographic location of the bridge. All bridges should be designed to insure life safety under the demands imparted by the Maximum Considered Earthquake (MCE). Higher levels of performance may be required by the bridge owner to provide post-earthquake access to emergency facilities or when the time required restoring service after an earthquake would create a major economic impact.

Seismic forces are an important loading consideration that often controls the design of bridges in seismically active regions. The degree of seismic activity is based on the acceleration coefficient at the bridge site. Bridges with an acceleration coefficient greater than (0.19), are considered to be in an area of high seismic activity. This coefficient, along with whether the bridge is classified as essential or not are used to assign the bridge a seismic performance category (SPC).

Based on the SPC and the number of spans, the most frequently used method of analysis to calculate the loading on the bridge due to earthquake forces is Single-mode spectral analysis.

The single-mode spectral analysis method assumes loading in basic transverse and longitudinal directions as illustrated in the following Figure:-



Assumed Loading for Single-Mode Spectral Analysis

For regular, multi-span bridges the single-mode spectral analysis method for calculating equivalent static earthquake loading is as follows:-

The single-mode spectral analysis procedure uses the same method for calculating both longitudinal and transverse earthquake loading. This method utilizes the principle of virtual displacements to develop a mode shape model of the bridge. An arbitrary, uniform static loading (p_o) is applied to the length of the structure to produce an initial displacement (v_s). This displacement, combined dead load weight of the superstructure (and part of the substructure), can be used to determine the resultant earthquake loading. The first step is to calculate the initial displacement of our generalized model. The initial displacement (v_s) is illustrated at the piers and at the end of the last span. This value varies depending on the type of piers in place (e.g., two column or three column piers, solid stem, etc.). The displacement is calculated assuming an arbitrary unit load of ($p_o = 1$).

The next step is to calculate the dead weight value w(x). This represents the dead load of the superstructure and contributing substructure elements (e.g., an integrated pier cap). It is even possible to include live load values for structures in high traffic urban areas where large numbers of vehicles may be present on the structure during an earthquake. Once the values of (v_s) and w(x) are known, the following three factors can be calculated:-

$$(\alpha = \int_0^L Vs(x).dx)\text{..........Eq.(1)}$$

$$(\beta = \int_0^L W(x).Vs(x).dx) \text{ ....Eq.(2)}$$

$$(\gamma = \int_0^L W(x).Vs(x)^2 .dx) \text{ ....Eq.(3)}$$

With these factors known, the fundamental period of the bridge can be computed with the following:-

$$(T = 2\pi\sqrt{\frac{\gamma}{g.K}}) \text{ ....Eq.(4)}$$

Where:-
K=bridge lateral stiffness= $p_o * \alpha$
$p_o = 1$
g = acceleration of gravity (length/time^2)
γ= Dead load of the bridge superstructure and tributary substructure.
At this point, we are ready to compute the resultant horizontal earthquake loading on the structure. This loading can be described as a function of the mass of structure, acceleration coefficient, soil type and fundamental period.

AASHTO provides an elastic seismic response coefficient which quantifies these parameters into a dimensionless value. This single coefficient greatly simplifies the analysis since it does not require the designer to calculate an overall site period. The coefficient is described by:-

$$C_s = \frac{1.2\ A.S}{T^{\frac{2}{3}}} \leq 2.5 \text{ A..........Eq.(5)}$$

Where
A = acceleration coefficient from national ground motion maps.
S = site coefficient specified in the following Table.

Soil Profile Type	Site Coefficient (S)	Description
I	1.0	Rock of any description (shale-like or crystalline) or stiff soils (sands, gravels, stiff clays) less than (60m) in depth overlying rock
II	1.2	Stiff cohesive or deep cohesionless soils more than (60m) in depth overlying rock
III	1.5	Soft to medium-stiff clays and sands characterized by (9m) or more of clay with or without intervening layers of sand.
IV	2.0	Soft clays or silts greater than (12m) of depth.

With the values from Equations (1) through (5) in place, the intensity of the earthquake loading can be computed. This loading is an approximation of the inertial effects resulting from the dynamic deflection of the structure and is defined as:-

$$p_e(x) = \frac{\beta C_s}{\gamma} w(x) v_s(x)$$

This load can now be applied to the structure in a fashion similar to the one in which the initial unit loading of ($p_o = 1$) was at the beginning of the process. Now, though, the value of ($p_e(x)$) is substituted to determine displacement, shears, and moments due to earthquake loading.
It may be noted that, single span bridges do not require seismic analysis.

2-3-Wind Loading

Like earthquake loading, wind loading offers a complicated set of loading conditions which must be idealized in order to provide a workable design. Although the problem of modeling wind forces is a dynamic one, with winds acting over a given time interval, these forces can be approximated as a static load being uniformly distributed over the exposed regions of a bridge.
The exposed region of the bridge is taken as the surface areas of all elements (both superstructure and substructure) as seen in elevation (i.e., perpendicular to the longitudinal axis). The loading on a bridge due to wind forces is specified by AASHTO based on an assumed wind velocity of (160 km/h). For conventional girder/beam type bridges this translates into an intensity of (2.40 kN/m^2) with the minimum total force being (4.38 KN/m). Trusses and arches require wind loads applied with an intensity of (3.60 kN/m^2) with the minimum total force of either (4.38 or 2.19 kN/m), depending on whether the affected member is a windward or leeward chord, respectively. The windward chord is that chord exposed to the prevailing wind and, conversely, the leeward chord is located away from the wind. The design wind pressure on vehicles is based on a wind velocity of (88.5 km/h), acting on a long row of randomly sequenced vehicles, which results a wind pressure of (1.46 kN/m), acting normal to, and (1.8 m) above the bridge deck. This load should be transmitted to the substructure.
For conventional slab-on-stringer bridges, however, with span lengths less than or equal to (38m), AASHTO Standard Specifications allow the simplified wind loading:-

A-Wind Load on Structure:

Transverse Loading = (2.40 kN/m^2)
Longitudinal Loading = (0.58 kN/m^2)

B-Wind Load on Live Load:

Transverse Loading = (1.46 kN/m)
Longitudinal Loading = (0.58 kN/m)

2-4- Channel Forces

Channel forces are those loads imposed on a structure due to water course–related features. These forces include, but are not limited to stream flow, floating ice, and buoyancy. Channel forces, similar to seismic forces, primarily affect substructure elements. The following discussion is offered within the context of design loads in general and their relationship to the substructure:-
Stream Flow: Structures with supports in water courses are at risk for having those supports slide or overturn due to stream flow forces. An excessive stream flow velocity can lead to adverse scour conditions which can undermine footings and threaten the integrity of the structure. In general, the pressure due to stream forces is a result of the change in momentum of water as it impacts a pier and then travels away from it.

AASHTO Standard Specifications defines the average pressure acting on a bridge pier due to flowing water as:-

$$P=K.(V)^2$$

Where

P= average stream pressure (lb/ft^2).

V= average velocity of water (ft/s).

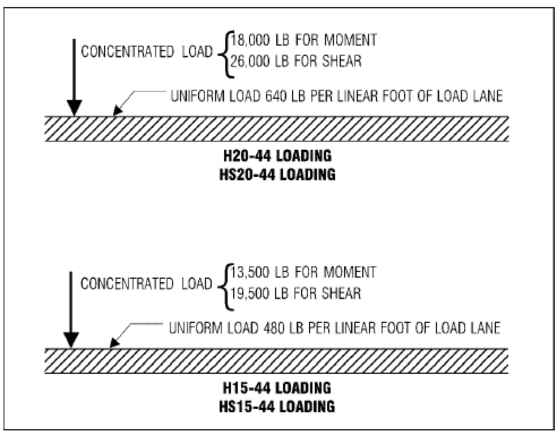
K= constant based on shape of pier (4/3 for square ends, 1/2 for angle ends when angle is 30deg. or less, and 2/3 for circular piers).

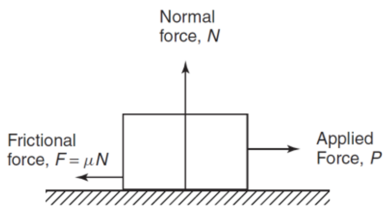
Ice Load: In cold weather climates highway bridges can suffer severe damage from ice floes and ice sheets impacting substructure and from static pressure due to thermal movements of ice sheets. In the case of low clearance bridges, superstructure elements may also be subjected to the ice load. The magnitude of this loading condition is dependent on the characteristics of the ice mass and the exposed surface of the pier it comes in contact with. Generally, the Ice pressure can be assumed as (20 kN/m^2). The design thickness should be determined locally.

Buoyancy: Bridges with components (e.g., piers) which are submerged underwater can sometimes suffer from the effects of buoyancy. This is generally a problem only for very large hollow structures. Buoyance may produce an uplifting force on pier footings and piles.

2-5- Longitudinal Forces

A *longitudinal force* is also called *Braking Force* in AASHTO Specifications. As a truck brakes, the load of the vehicle is transferred from the truck wheels to the bridge deck. AASHTO Standard Specifications specifies that (5%) percent of the appropriate *lane load along with the concentrated force for moment*, as shown in Figure, to be used as the resulting longitudinal force. (Longitudinal forces on highway bridges should be assumed at (5%) of the *lane load plus concentrated load for moment* headed in one direction, *plus forces resulting from friction* in bridge expansion bearings).



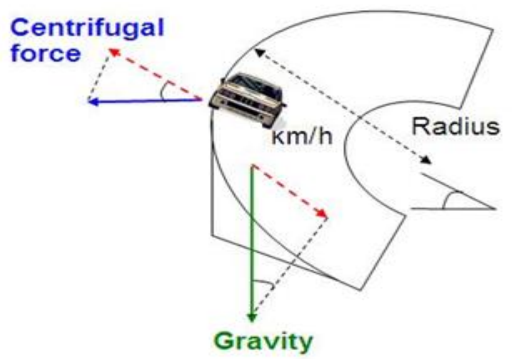


The longitudinal force is applied (1.8 m) above the top of deck surface. All travel lanes are assumed going in the same direction. The effect of longitudinal forces (breaking force) on the superstructure is inconsequential. Substructure elements, however, are affected more significantly. Like longitudinal earthquake forces, the breaking force is resisted by the piers and/or abutments which support fixed bearings.

2-6- Centrifugal Forces

For structures on horizontal curves, the effect of centrifugal force must be calculated. Like longitudinal loading, centrifugal loading simulates a vehicle traveling along the bridge and, in this instance, following a curvilinear path. This force is assumed to act horizontally (1.8m) above deck level and perpendicular to the bridge centerline. The force is defined as:-

$$C = 6.68 * S^2/R$$



Where

S=design speed (mph).

R=radius of curvature (ft).

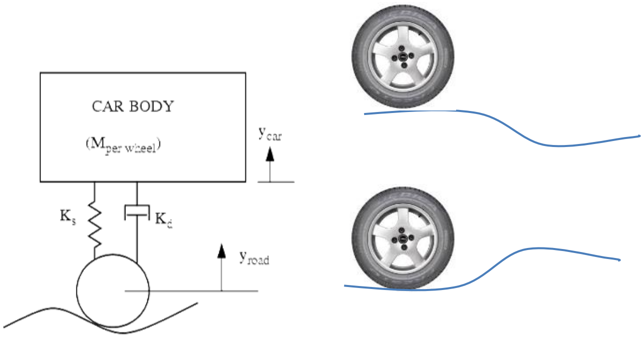
Rather than an actual force, the value *(C)* above is a percentage, similar to the (5%) for longitudinal forces, which is applied to the live load on the structure. This percentage, multiplied by the live load, yields the force to be applied (1.8m) over the deck surface. Unlike longitudinal forces, *centrifugal forces are computed using the truck loading* rather than the lane loading. One standard design truck is placed in each design traffic lane such that maximum forces in the bridge are generated.

Decks that are attached to the superstructure primary members (e.g., a composite concrete deck integrated with steel girders using shear connectors) transmit centrifugal forces to substructure elements through secondary members and bearings at piers and abutments.

2-7-Impact (Dynamic Load Allowance)

In order to account for the dynamic effects of a vehicle riding over a structure, an impact factor is used as a *multiplier* for certain structural elements. From basic dynamics, we know that a load that moves across a member introduces larger stresses than one statically placed on it. While the actual modeling of this effect can be a complex affair, the impact factor used by AASHTO allows for a conservative idealization of the problem. AASHTO Standard Specification defines the impact factor as follows:-

$$I=[15.24/(L+38.1)] \leq 30\%$$



Where

I = impact fraction (not to exceed 30%).

L= length of span loaded to create maximum stress (m).

In addition to the dynamic response of the bridge as a whole to passing vehicles, the impact factor is also designed to take into account the effects of a vehicle vibrating (vehicle motors) and striking imperfections (e.g., pot holes or moves across un-even surface) in the deck.

It may be noted that, to take into account the effect of impact, the live load forces are then multiplied by this factor.

2-8-Construction Loads

It is possible that during the erection of a structure, various members will come under loading conditions which are induced by construction equipment or other types of loads. In situations where this is foreseen during the design process (as in a staged construction or a segmental construction), the designer should take such additional loads into account and present any necessary bracing or support structures on the plans. In other instances, loads are introduced by a method of construction preferred by the contractor. In this case, the contractor should provide for all necessary strengthening of members or support structures. These measures should be submitted by a licensed professional engineer working for the contractor, and reviewed and accepted by the owner.

2-9-Thermal forces

The effects of thermal forces on a structure are significant and should not be underestimated by the designer. In particular, from restraint, may cause overstress, buckling, or cracking. Provision should be made for expansion and contraction due to temperature variations, and on concrete structures, also for shrinkage.

In general, thermal forces are caused by fluctuations in temperature (i.e., from hot to cold or cold to hot) and caused by the structural redundancies or bearing failures. AASHTO Standard Specifications provides recommended temperature ranges for the design of metal and concrete structures. The *coefficient of thermal expansion* for both concrete and steel (per Fahrenheit) is 0.0000065 (approximately 1/150,000). The *shrinkage coefficient* for concrete arches and rigid frames should be assumed as (0.002), equivalent to a temperature drop of (31^{o} F).

2-10-Curbs

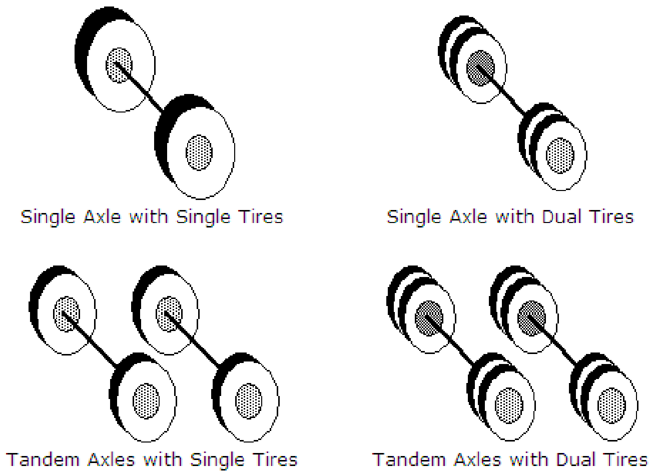
Curbs should resist a force of (7.5kN/m) acting (250mm) above the floor.

3-Deformation and Response Loads

Deformation loads are those loads induced by the internal or external change in material properties or member geometry. Because many bridges have structural redundancies, the effects of deformations such as support settlement, creep and shrinkage in concrete induce stresses on a member outside of conventional dead and live loading. Response loads are those loads created by the response of the structure to a given loading condition. Uplift is an example of a response load.

HIGHWAY BRIDGE LIVE LOADING

The primary function of a bridge is to carry traffic loads: heavy trucks, cars, and trains. ... Therefore, engineers use probable loads as a basis for design.



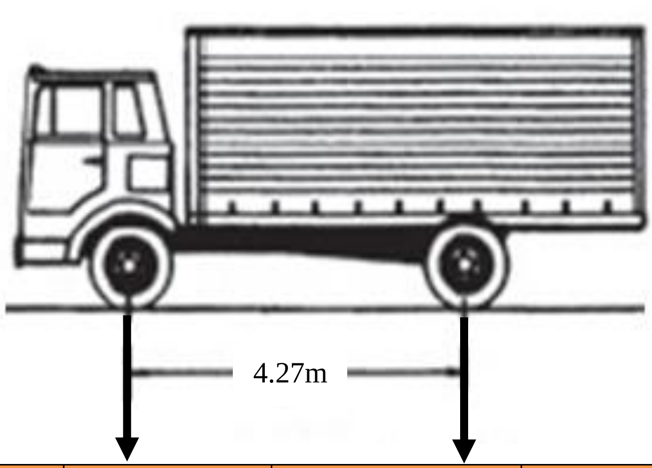
Single Tire

(Wheel Load)

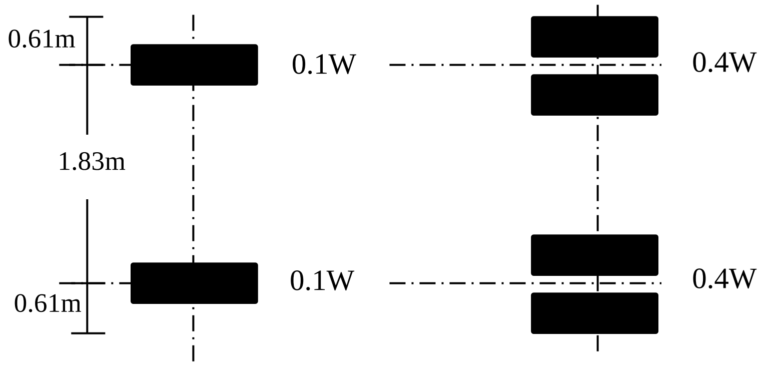
Dual Tire

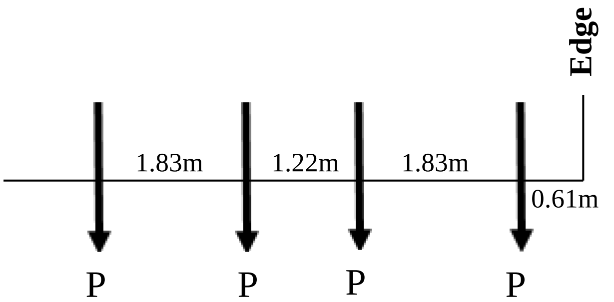
1-AASHTO STANDARD LOADING

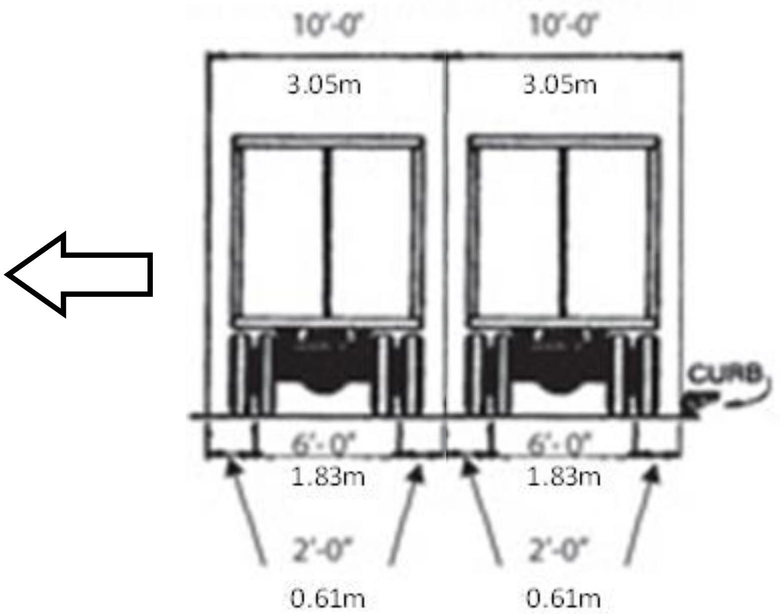
1-1-Standard truck (H-loading)



Designation	Front	Rear	Total Weight
H-20	36kN	144kN	W=180 kN
H-15	27kN	108kN	W=135 kN
H-10	18kN	72kN	W=90 kN

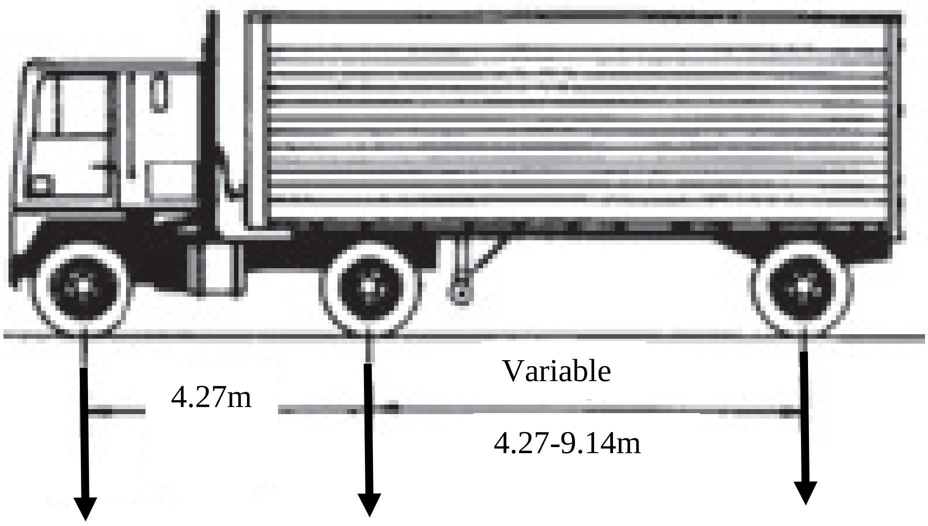




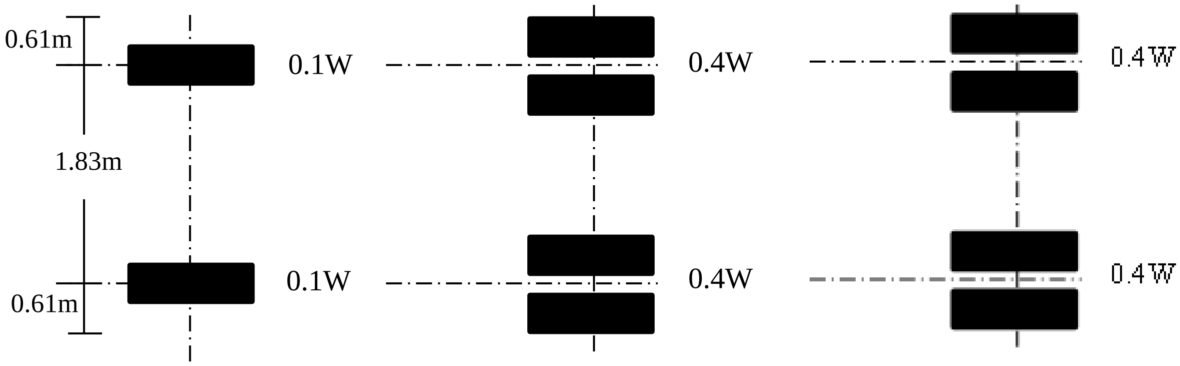


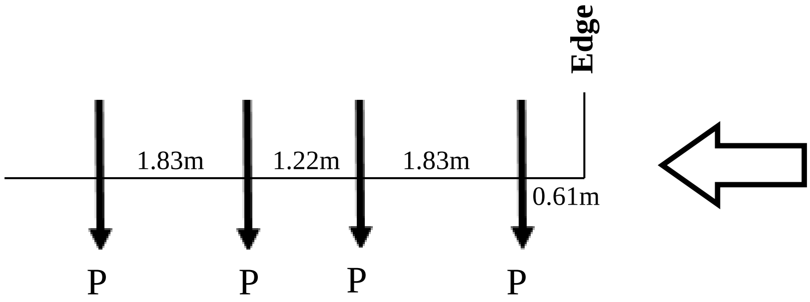
1-2-Standard truck (HS-loading)

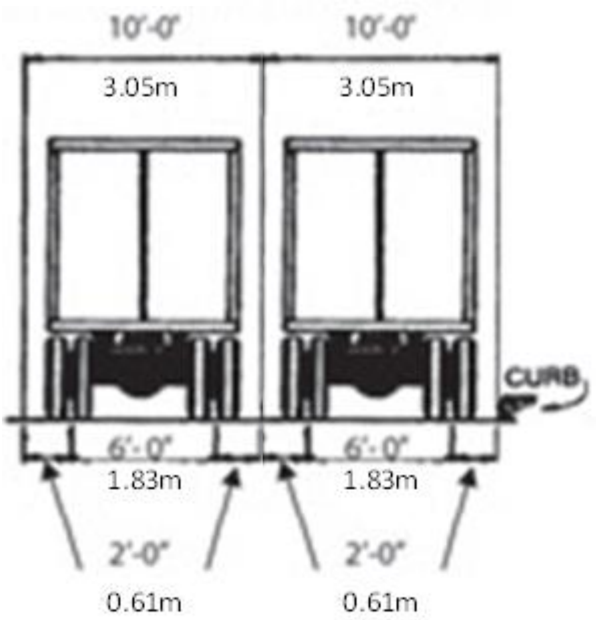
Truck-Traile



Designation	Front	Intermediate	Rear	Total Weight
HS-20	36kN	144kN	144kN	W=324 kN
HS-15	27kN	108kN	108kN	W=243 kN



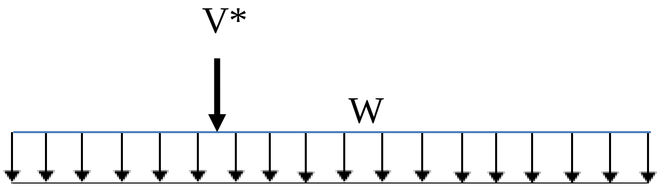




Note:
For HS-20, W=180kN (without Trailer)
For HS-15, W=135kN (without Trailer)

1-3-Equivalent uniform lane load

Lane width=3.05m
W=UDL (uniformly distributed load)
V= KEL (knife edge load)



*Placed anywhere on span to produce max. effect.

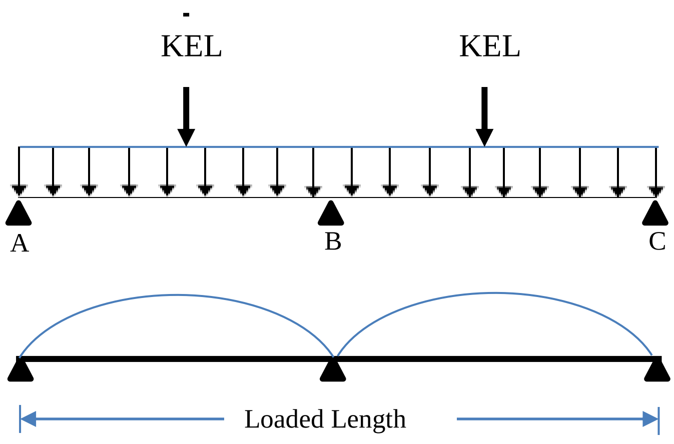
Truck	Equivalent uniform lane load		
	W kN/m-lane	V (kN/lane)	
		Moment	Shear
HS-20	9.3	80	116
HS-15	7.0	60	87
H-20	9.3	80	116
H-15	7.0	60	87
H-10	4.7	40	58

NOTE

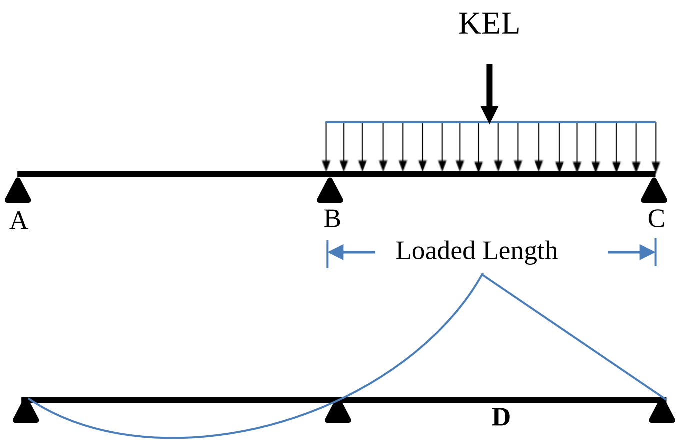
1-H-10 and H-15 are used for design of lightly traveled roads.
2- H-20 and HS-15 are used for design of Expressways.

1-4-Applications of AASHTO live load

1- For HS Trucks: only one truck is to be used per lane per span. For long spans the equivalent uniform loading produces greater stresses than a single truck.
2-The HS-20 and H-20 truck produces greater moment in simple span for spans up to (17m) .For longer spans, the equivalent load produces greater bending moment.
3--In the equivalent uniform load, one (KEL) is used in a simple span and for positive moment in continuous span، and two (KEL) are used for negative moment .

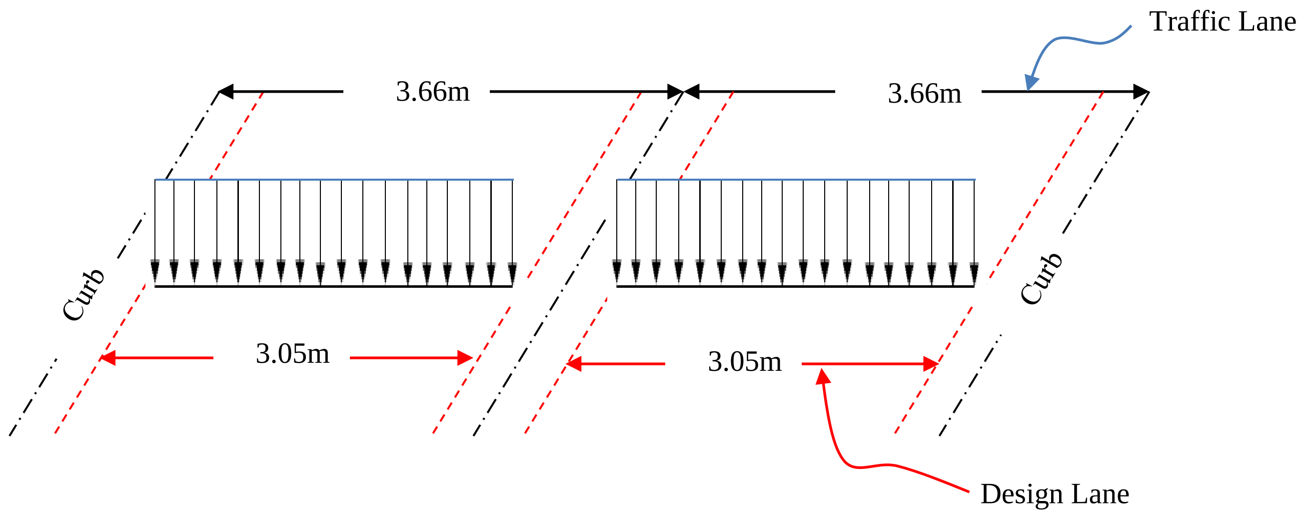


I.L M_B (-ve)



I.L M_D (+ve)

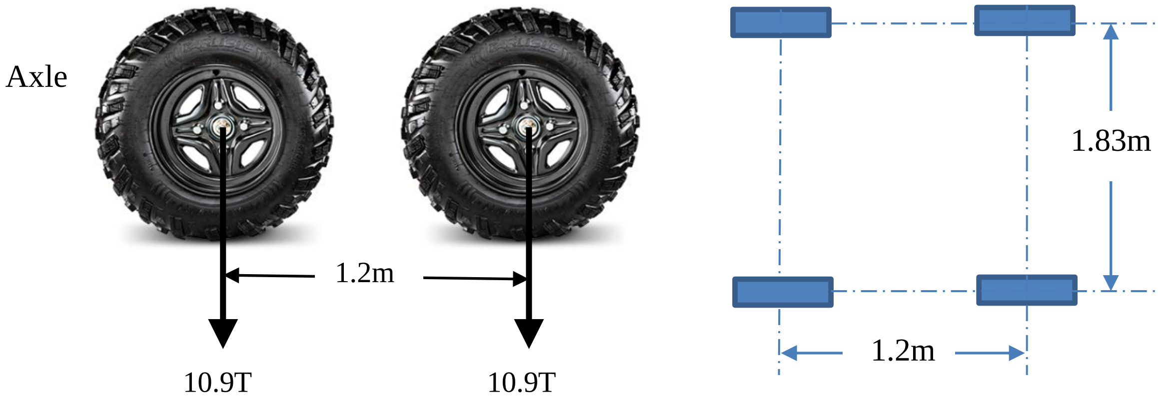
4--The equivalent uniformly distributed load (UDL) can be divided into segment when applied to continuous span.
5--The lane loading and standard trucks shall be assumed to occupy a width of (3.05m). These loads shall be placed in (3.66m) wide design traffic lanes, placed across the bridge deck between the curbs. (Fractional parts of design lanes shall not be use).



Note: Don't use edge distance between curb and UDL.
6--Road way width from (6.1m) to (7.3m) shall have two design lanes.

1-5-AASHTO Military loading

Another form of live loading, known as alternative military loading was developed in (1956) by the Federal Highway Administration (USA). This loading consists of two axles separated by (1.2m) and each weighing (109 KN). This loading is used to represent heavy military vehicles.



1-6-AASHTO'S side walk loading

1-Side walk floors, stringer and their immediate supper shall be designed for a live load of (4.15 kN/m^2).
2-Girders, trusses, arches and other members shall be design for the following sidewalk live load:-

a	Spans (0) to (25ft) in length	(85Ib/ft^2)
b	Spans (26) to (100ft) in length	(60Ib/ft^2)
c	Over (100ft), according to the following equation:- $P=(30+3000/L)((55-W)/50)$	

P=live load / ft^2 (max. 60Ib/ft^2)
L=loaded length of sidewalk in ft.
w=width of sidewalk in ft.
3--pedestrian bridges shall be design for a live load of (4.15kN/m^2).

1-7-AASHTO Reduction in Load Intensity

The following percentage of the live load shall be used in view of the improbity of coincident maximum loading:-

1	One or two lanes	100%
2	Three lanes	90%
3	Four lanes and more	75%

1-8-Impact (AASHTO)

Impact (percentage from live load) shall be included for Group (A), Impact allowances shall not be applied to item Group (B). And shall not be included in loads transferred to footing, nor to those ports of piles or column that are below ground.

Group (A): (Impact shall be included)

1- Superstructure.
2- Pier (with or without bearings regardless of types).
3- The portion above the ground line of concrete or steel piles that support the superstructure.

Group (B): (Impact shall not be included)

1- Abutment, retaining walls piles.
2- Foundation pressure and footings.
3- Side walk load.
4- Culverts.

Impact Formula

$$I=[15.24/ (L+38.1)] \leq 30\%$$

Where

I=impact fraction.

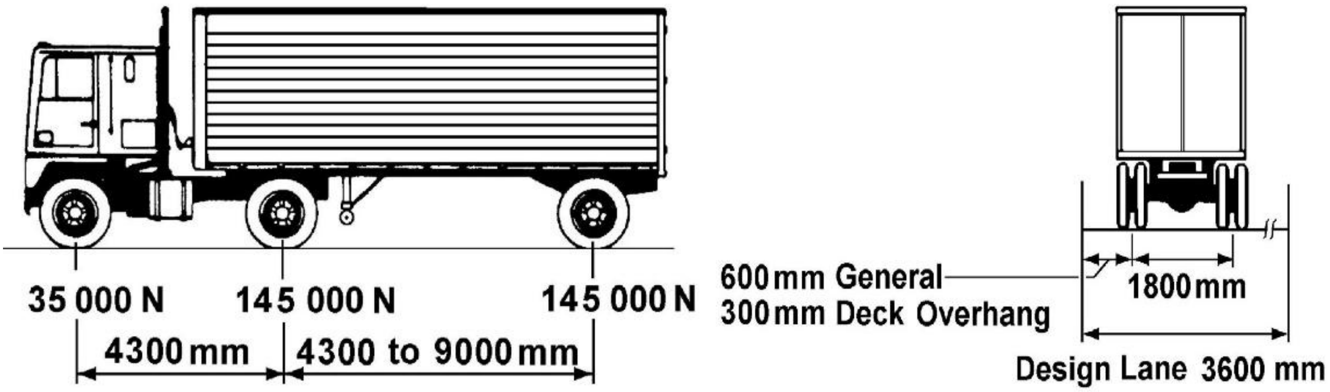
L=length of the portion of the span that is loaded to produce the max. stress in the member.

2-AASHTO-LRFD LOADING

The live load on bridges is defined by AASHTO-LRFD specifications as a vehicular live loading on the roadways of bridges or incidental structures, designated HS-93, is consist one of ***Design Truck, Design Tandem and Design Lane Load***.

2-1-Design Truck

The weights and spacing of axles and wheels for the design truck is as specified below. To produce extreme force effects, the rare axles spacing shall be varied between (4.3 and 9.0m).



AASHTO-LRFD Design Truck

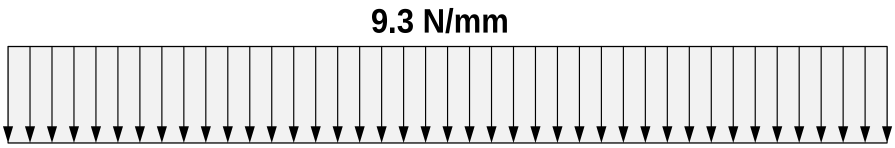
2-2-Design Tandem

The design tandem shall consist of a pair of (110 kN) axles spaced (1.2m) apart. The transverse spacing of wheels shall be taken as (1.8m).

AASHTO-LRFD Design Tandem

2-3-Design Lane Load

Uniformly distributed load of (9.3 N/mm) in the longitudinal direction. Transversely, the design lane load is assumed to be uniformly distributed over a width of (3.0m).



AASHTO-LRFD Design Lane Load

3-BRITISH STANDARDS (BS-5400 PART 2) (1978 OR 2002)

Types of live loads due to vehicle and pedestrian:-

3-1-Primary live load

Vertical live loads considered as static load due to directly to the mass of traffic without impact. For primary live load, two types of loading must be considered:-

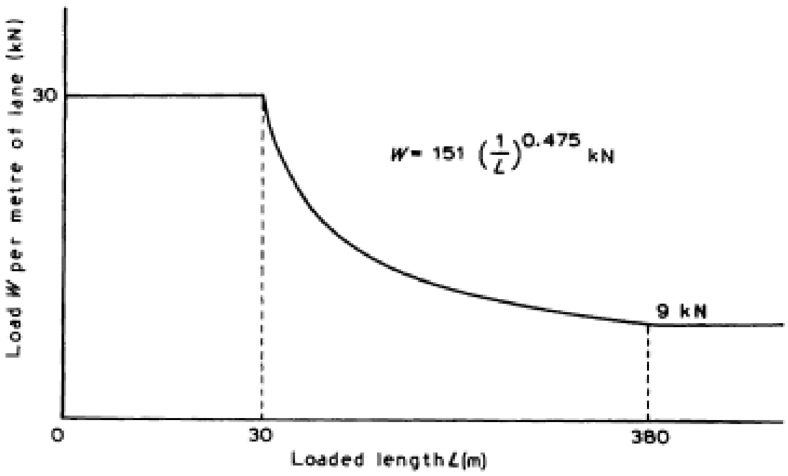
a- HA-Loading

b- HB-Loading

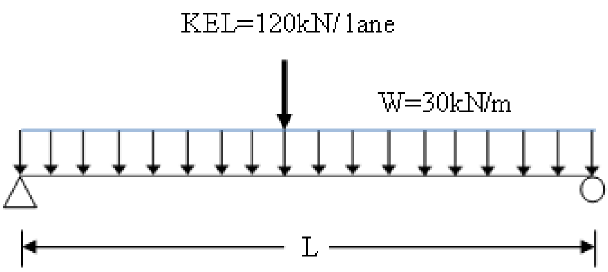
3-1-1-HA-Loading

Consisting combined of (UDL) & (KEL). The (UDL) shall be taken as (30kN) per linear meter of national lane (design lane) for loading length Up to (30m), and for loaded length excess of (30m) it shall derived from equation:-

(W=151(1/L)$^{0.475}$ kN), But not less than (9kN/m)



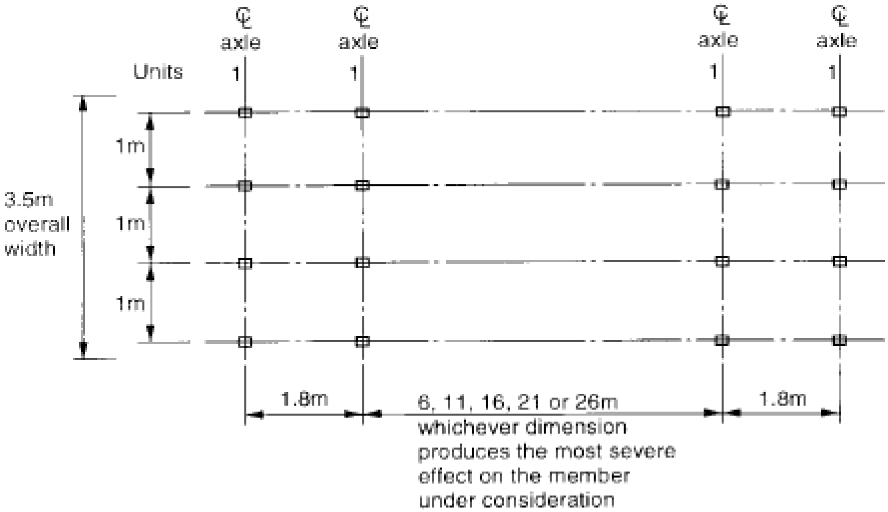
Loading Curve for HA-UDL



Where:
L=loaded length in (m).
W=load per meter of lane in (kN).
The nominal Kinfe Egde Load (NEL) per design lane shall be taken as (120kN).

3-1-2- HB-Loading

Consisting of a series of axle loads (Vehicle) as shown below.



Dimensions of HB vehicle

Normally, W=25Units (x10^{kN} per axle) ⇨ Total w=25x4x10=1000^{kN}

No. of axles

Increase to 45 units ....Total w=45x4x10=1800^{kN}

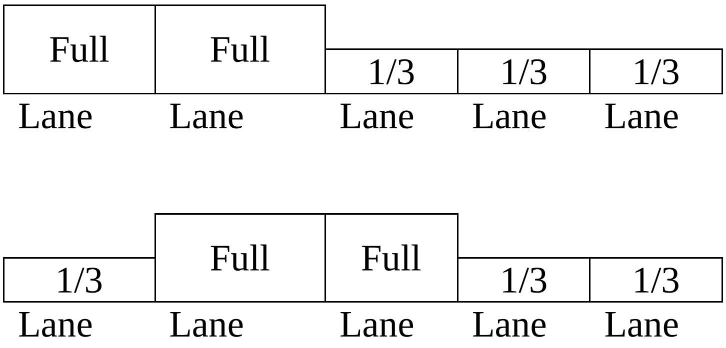
3-1-3-Number of Design lanes

Carriageway widths of (4.6m) or more: Design lanes shall be taken to be not less than (2.3m) nor more than (3.8m) wide. The carriageway shall be divided into the least possible number of design lanes having widths as follows: -

Carriageway width (m)	Number of design lanes
4.6^{m} up to and including 7.6^{m}	2
above 7.6^{m} and including 11.4^{m}	3
above 11.4^{m} and including 15.2^{m}	4
above 15.2^{m} and including 19.0^{m}	5
above 19.0^{m} and including 22.8^{m}	6

3-1-4-Application of HA loading (UDL)

Full (UDL) and (KEL) shall be applied to two national (design) lanes in the appropriate parts of the influence line for the element or member under consideration and **ONE THIRD (UDL) and (KEL)** loads shall be similarly applied to all other design lanes.
The (KEL) shall be applied at one point only in the loaded length of each design lane.



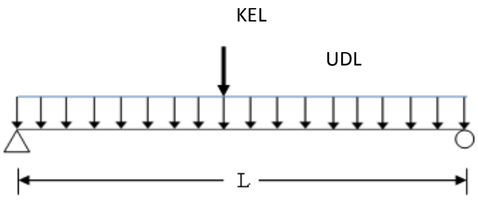
Application of HA-loading

3-2- Secondary Live load

Live load due to changes in speed or direction of the vehicle traffic.

4-IRAQ SPECIFICATION-LOADING

Iraq loading consists of:-
a- Civilian loading (HA-loading): Uniformly distributed load (UDL) plus Knife edge load (KEL).



b- Military loading.

4-1- Civilian loading (HA-loading)

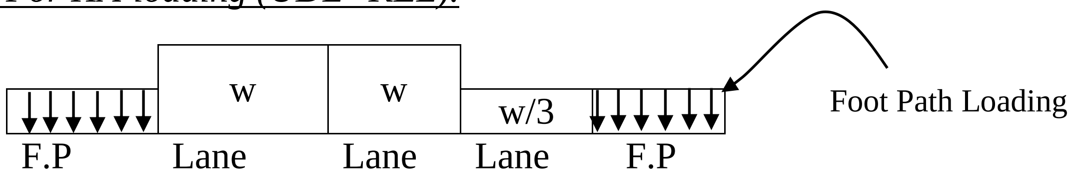
Is the old British standard loading (British Standards: 135-1957). This load is variable (360kN /lane for loaded length of (0.914m to 6.04 kN /lane) for loaded length of 900m)… see page 3 from Iraq standards. The (KEL) is (122.46 kN) per lane of width equal to (3.05m) and over; and equal to (4018kN) per lane of width equal to (3.05m) and less.

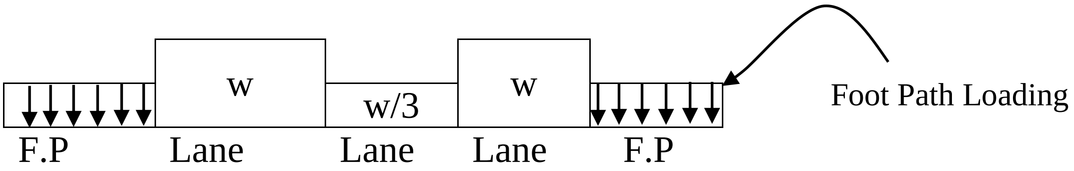
4-2- Military loading

a- Tracked Vehicle: a 90^{Ton} tank (class100).
b- wheeled vehicle: consist of a loaded trailer weighing 115 ^{Ton} (class100).

4-3-Application of Iraq specification loading

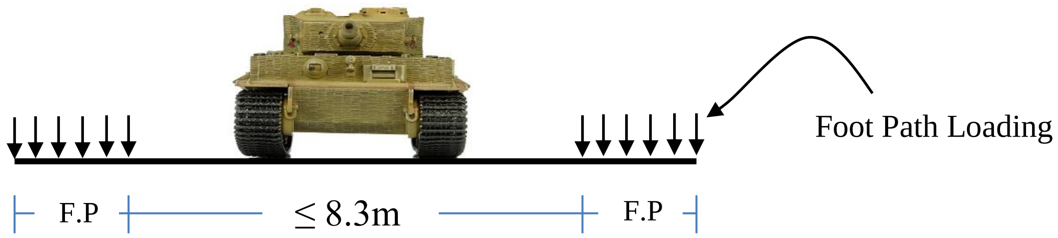
4-3-1-For HA-loading (UDL+KEL).



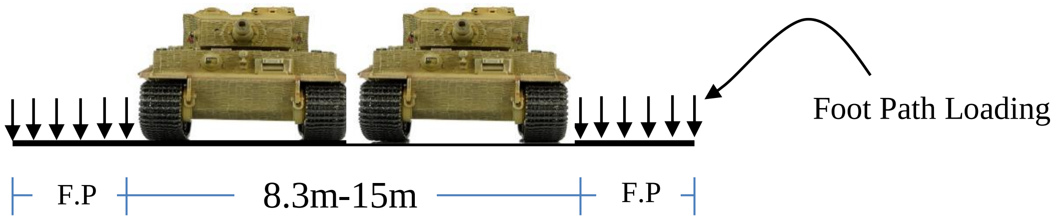


4-3-2-For military loading

For bridge width ≤ 8.3m → One military loading.

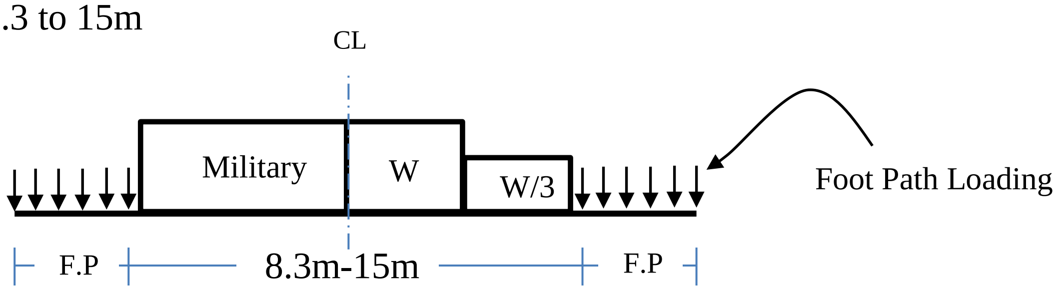


For bridge width from 8.3m to 15m→two military loading.



Note: The combination between HA-loading and military loading is as follows:-

For width 8.3 to 15m



4-4-Impact (see Tables of Iraq standards)

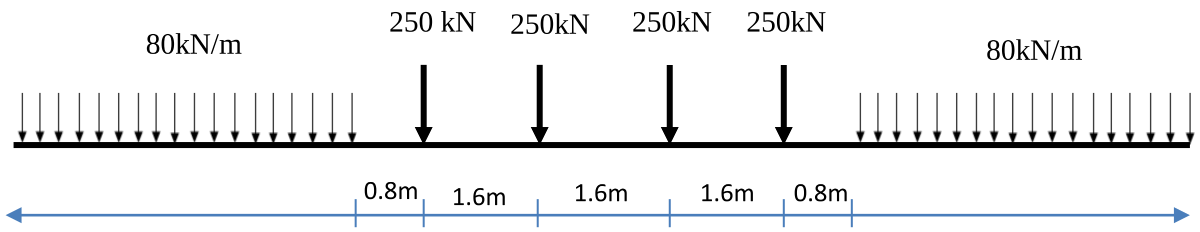
The impact is applied only to the military loading occupying one lane. It may be noted that, the impact for trucked Vehicle=1/2 impact for wheeled vehicle.

4-5-Longitudinal force due to military loading

(30%) of the heaviest single military load on the structure under consideration, applied in the direction of travel of deck level, without any increase for impact effect.

5-IRAQ SPECIFICATION FOR RAILWAY BRIDGES

Railway Bridges shall designed to carry UIC (International Union of Railways) Loads (This loading is similar to the type RU-Loading given in BS-5400)

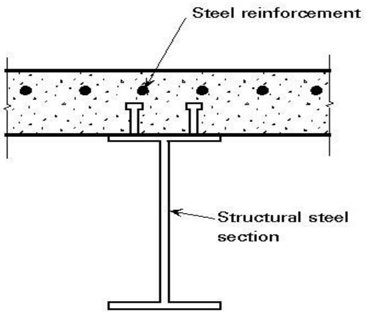


Bridges floor systems

Floors for steel highway bridges and reinforced concrete bridges are usually "reinforced concrete". The use of other types, such as steel grid, steel plate and timber, depends upon dead load, traffic, and the location of the structure. Floors should have a transverse slope and if possible, a longitudinal slope to provide adequate drainages. Transverse slope should be (1.0-2.0%) and preferably more. Adequate drains should be placed at suitable locations to prevent water from collecting on the deck. Exclusive of the main carrying members, floor system can be classified as follows:-

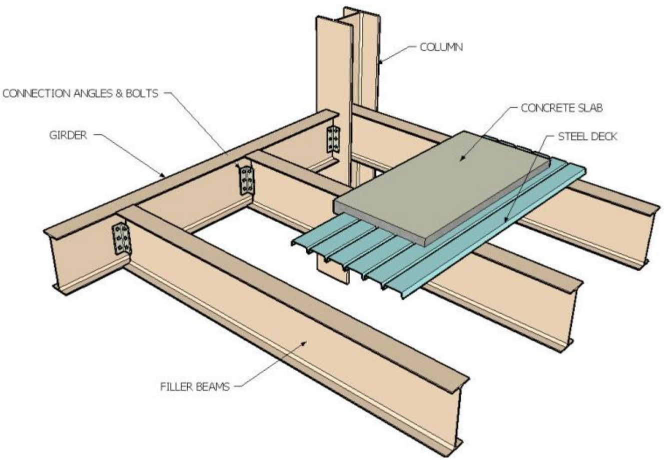
1-One Element System

A transverse reinforced concrete slab supported on longitudinal or main stringers or girders, (Ex. Composite section).



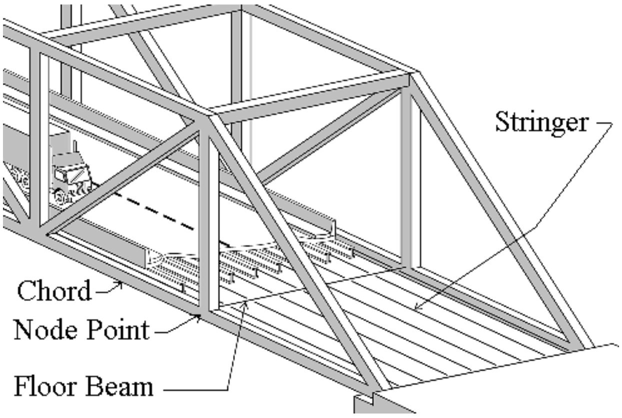
2- Two Element System

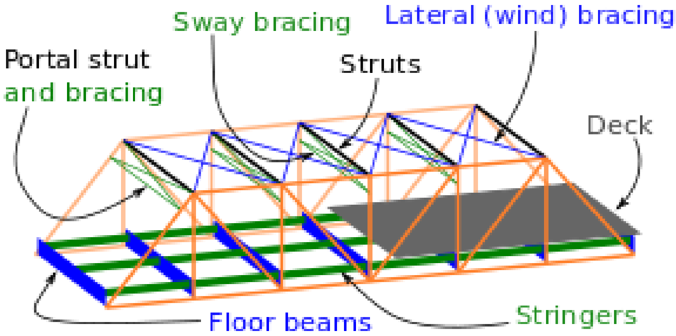
A longitudinal reinforced concrete slab supported on transverse floor beam, supported by girders, (Ex. Composite section, Truss bridge).

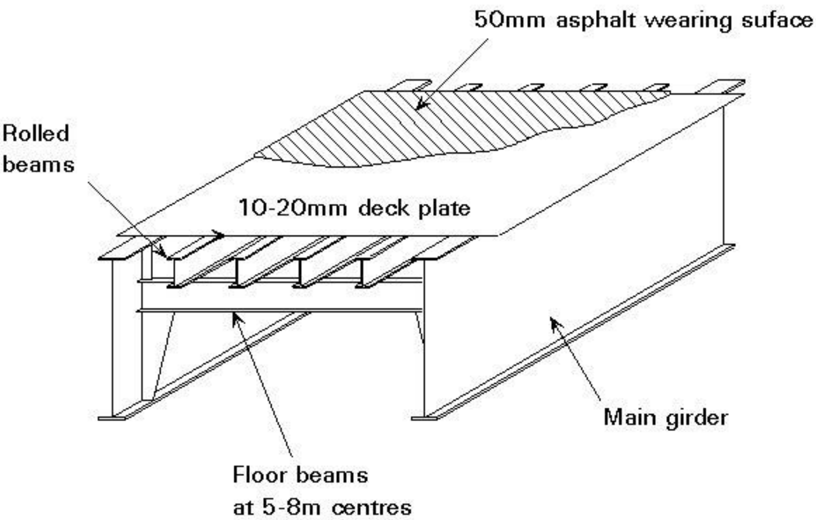


3-Three Element System

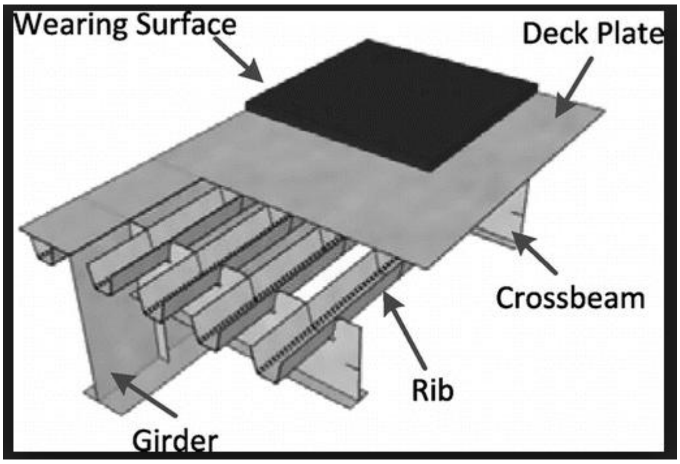
A transverse reinforced concrete slab, on longitudinal stringer, supported by floor beams, supported by girders, (Ex. Truss bridge).







4-Grid Floor



5-Orthotropic plate Floor (Orthotropic Steel Deck)

Deck plate acting compositely in both, longitudinally and transversely direction.