LOADS ON BRIDGE

ACCORDING AASHTO LRFD

Presented by :

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LOADS ON BRIDGE

- Loads on Bridges
- Typical Loads
  - Dead Load
  - Live Load
    - Live Load of Vehicle
    - Pedestrian Load
    - Dynamic Load Allowance
- Other Loads
  - Fatigue
  - Wind
  - Earthquake
  - …
- Load and Resistance Factor Design

Live Load of Vehicle:

- Design Lane
- AASHTO HL93 Loads
  - Truck
  - Tandem
  - Uniform Load
- LL Combinations
- LL Placement
  - Influence Line
  - Design Equation
  - Design Charts
- Multiple Presence
- Distribution to Girders

- DD = downdrag (wind)
- **DC = dead Load of structural and nonstructural components**
- **DW = dead load of wearing surface**
- EH = earth pressure (horizontal)
- EL = secondary forces such as from posttensioning
- ES = earth surcharge load (vertical)
- EV = earth pressure (vertical)
- BR = breaking force of vehicle
- CE = centrifugal force of vehicle (at curves)
- CR = creep of concrete
- CT = vehicle collision force (on bridge or at piers)
- CV = vessel collision force (bridge piers over river)
- EQ = earthquake
- FR = friction
- IC = ice
- **IM = dynamic load of vehicles**
- **LL = live load of vehicle (static)**
- LS = live load surcharge
- **PL = pedestrian load**
- SE = settlement
- SH = shrinkage of concrete
- TG = load due to temperature differences
- TU = load due to uniform temperature
- WA = water load/ stream pressure
- WL = wind on vehicles on bridge
- WS = wind load on structure

DEAD LOAD

Dead loads shall include the weight of all components of the structure, appurtenances and utilities attached thereto, earth cover, wearing surface, future overlays, and planned widenings.

- Dead load includes the self weight of:
  - structural components such as girder, slabs, cross beams, etc…
  - nonstructural components such as medians, railings, signs, etc…
- But does **not** include the weight of wearing surface (asphalt)
- We can estimate dead load from the material's density

Material	Density (kg/m^3)
Concrete (Normal Weight.)	2400
Concrete (Lightweight)	1775-1925
Steel	7850
Aluminum Alloy	2800
Wood	800-960
Stone Masonry	2725

- It is the weight of the wearing surface (usually asphalt) and utilities (pipes, lighting, etc…)
- Different category is needed due to large variability of the weight compared with those of structural components (DC)
  - Asphalt surface may be thicker than designed and may get laid on top of old layer over and over
- Density of asphalt paving material = 2250 kg/m^3
- Average Thickness of asphalt on bridge = 9 cm

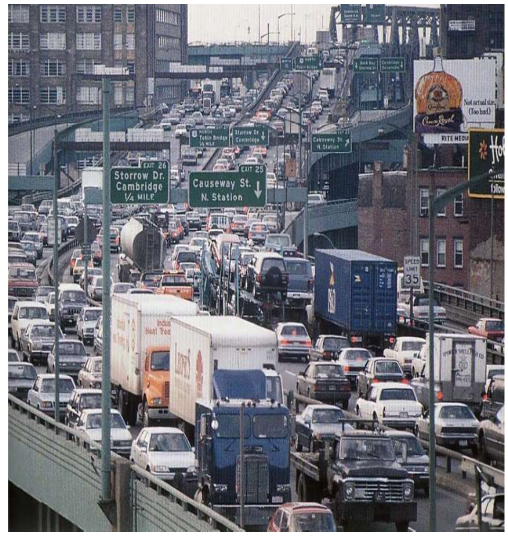
LIVE LOADS

Gravity Loads: LL and PL:

Vehicular 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

- 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)



**.Number of Design Lanes*

Unless specified otherwise, the width of the design lanes should be taken as 3.65M. The number of design lanes should be determined by taking the integer part of the ratio w/3.65M, where w is the clear roadway width in feet between curbs, barriers, or both. Possible future changes in the physical or functional clear roadway width of the bridge should be considered.
In cases where the traffic lanes are less than 3.65M wide, the number of design lanes shall be equal to the number of traffic lanes, and the width of the design lane shall be taken as the width of the traffic lane.
Roadway widths from 6M to 7.2M shall have two design lanes, each equal to one-half the roadway width.

**Multiple Presence of Live Load*

The provisions of this Article shall not be applied to the fatigue limit state for which one design truck is used, regardless of the number of design lanes.

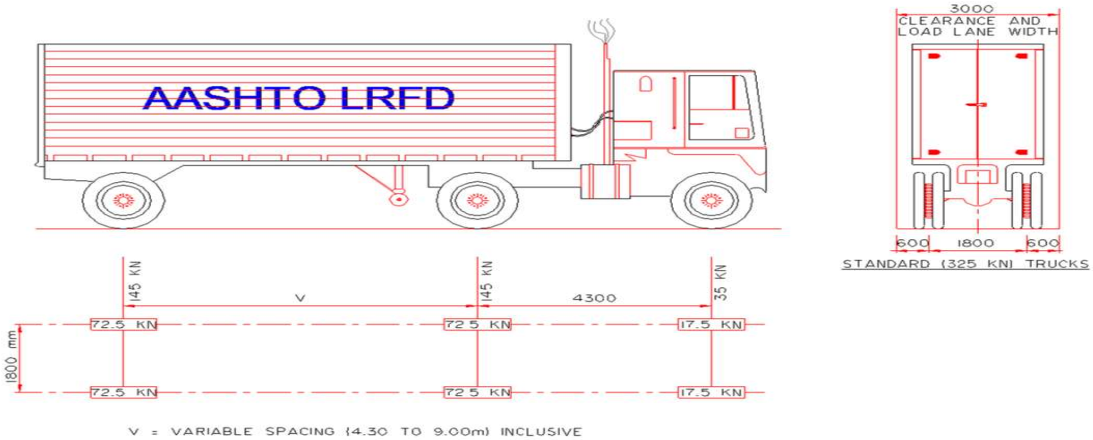
- shall be used when investigating the effect of one lane loaded, and
- may be used when investigating the effect of three or more lanes loaded.

Number of Loaded Lanes	Multiple Presence Factors, m
1	1.20
2	1.00
3	0.85
>3	0.65

***Design Vehicular Live Load**

Vehicular live loading on the roadways of bridges or incidental structures, designated HL-93, shall consist of a combination of the:

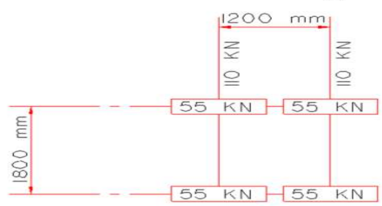
- **Design truck or design tandem, and**
- **Design lane load.**



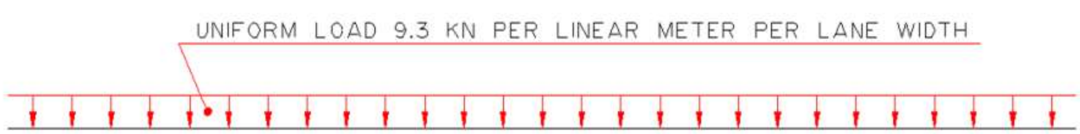
Distribution of the AASHTO LRFD Truck Load

❑ Traffic Live Load (LL):

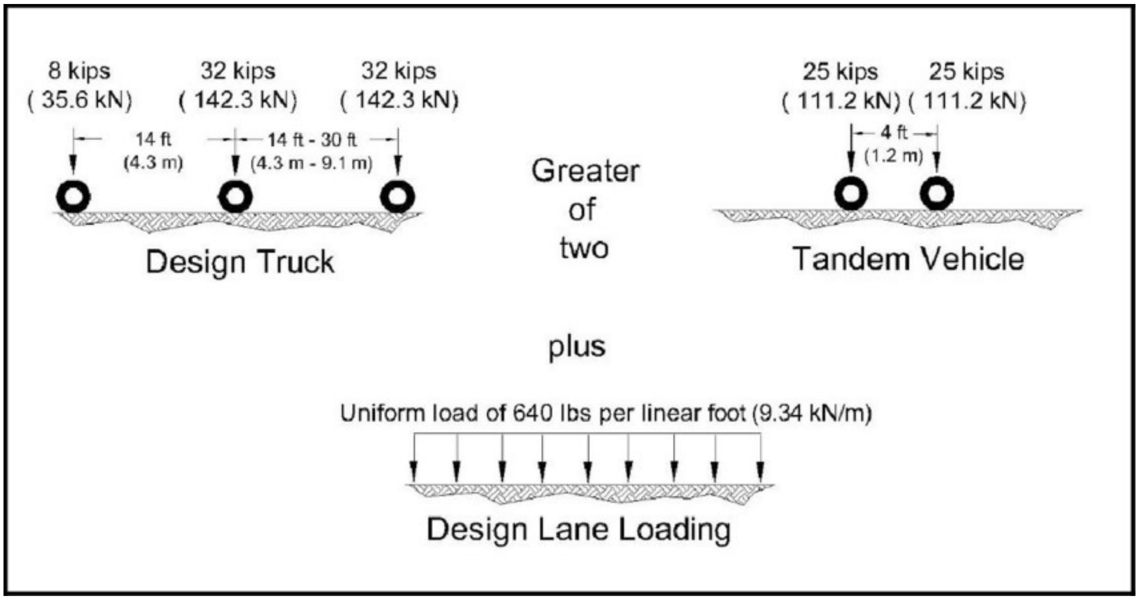
- Number of traffic lanes = width of carriageway / standard lane width.
- Standard lane width is 3.65m.
- A combination of either the AASHTO LRFD Truck or tandem load coincident with the lane load is applied on the bridge deck.



Distribution of the AASHTO LRFD Tandem Load



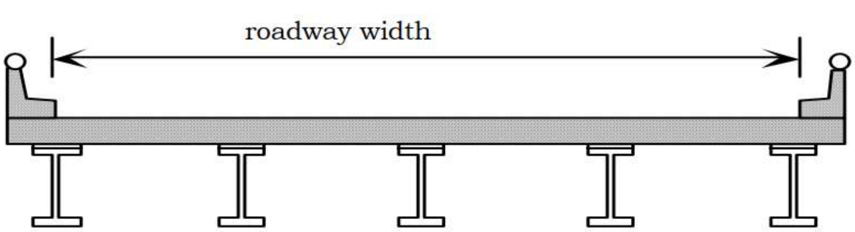
Distribution of the AASHTO LRFD Lane Load



Case	AASHTO LRFD			
Load Case	Case 1 325kN Truck + 9.3kN/m Lane		Case 2 220kN Tandem + 9.3kN/m Lane	
	Truck	Lane	Tandem	Lane
Dynamic Load Allowance	1.33	1.0	1.33	1.0

Load Cases for traffic live loads on the bridge deck .

- Number of Lane must be an integer (1,2,3,…) – there is no fraction of lane (no 2.5 lanes, for example)
- For roadway width from 6 m to 7.2 m, there should be 2 design lanes, each equal ½ of the roadway width



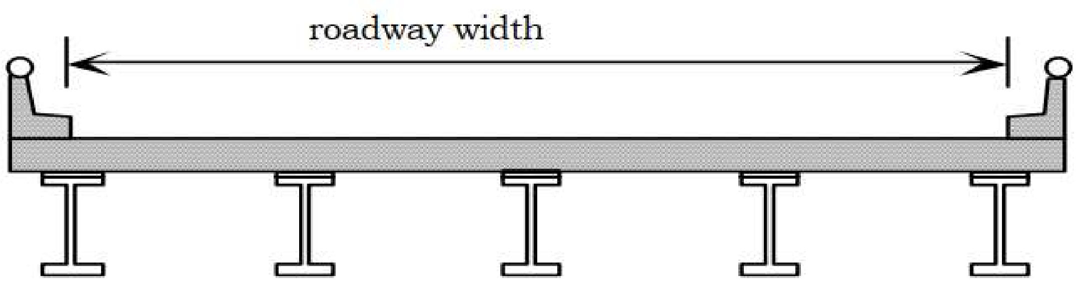
LIVE LOAD COMBINATIONS

- 3 ways to add the design truck, design tandem, and uniform load together
  - Combination 1: one HS20 truck on top of a uniform lane load per design lane
  - Combination 2: one Design Tandem on top of a uniform lane load per design lane
  - Combination 3: (for negative moments at interior supports of continuous beams) place two HS20 design truck, one on each adjacent span but not less than 15 m apart (measure from front axle of one truck to the rear axle of another truck), with uniform lane load. Use 90% of their effects as the design moment/ shear
- The loads in each case must be positioned such that they produce maximum effects (max M or max V)
- The maximum effect of these 3 cases is used for the design

LIVE LOAD PLACEMENT

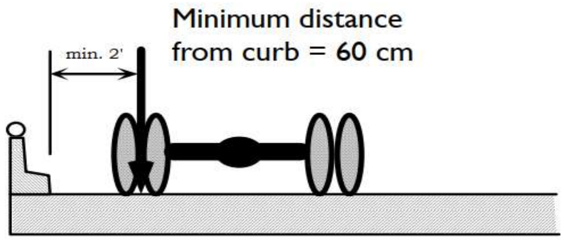
Need to consider two dimensions

1-Transversly for design of Slab and Overhangs



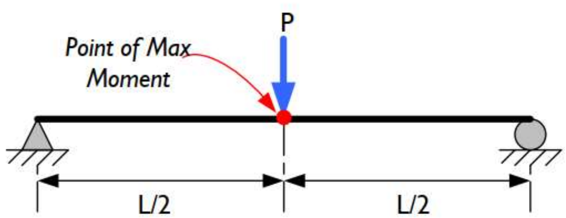
2-longitudnaly for design of main Girders

- The design truck or tandem shall be positioned transversely such that the center of any wheel load is not closer than:
  - 30 cm from the face of the curb or railing for the design of the deck overhang
  - 60 cm from the edge of the design lane for the design of all other components



- Note that if the sidewalk is not separated by a crashworthy traffic barrier, must consider the case that vehicles can be on the sidewalk

- Need to place the LL along the span such that it produces the maximum effect
- For simple 1-point loading, the maximum moment occurs when the load is placed at the midspan



- However, truck load is a group of concentrated loads. It is not clear where to place the group of loads to get the maximum moment
- **REMEMBER:** MAXIMUM MOMENT DOES NOT ALWAYS OCCURS AT MIDSPAN !!!

Tire Contact Area

The tire contact area of a wheel consisting of one or two tires shall be assumed to be a single rectangle, whose width is 20.0 in. and whose length is 10.0 in.

Tire width $= P/0.8$

Tire length $= 6.4\gamma(1 + IM/100)$

where:

γ	=	load factor
IM	=	dynamic load allowance percent
P	=	design wheel load (kip)

PEDISTERIAN LIVE LOAD

- Use when has sidewalk wider than 60 cm
- Considered simultaneously with truck LL

- Pedestrian only: 3.6 kN/m^2
- Pedestrian and/or Bicycle: 4.1 kN/m^2

- No IM factor (Neglect dynamic effect of pedestrians)

DYNAMIC LOAD ALLOWANCE IM

- Sources of Dynamic Effects
  - Hammering effect when wheels hit the discontinuities on the road surface such as joints, cracks, and potholes
  - Dynamic response of the bridge due to vibrations induced by traffic
- Actual calculation of dynamic effects is very difficult and involves a lot of unknowns
- To make life simpler, we account for the dynamic effect of moving vehicles by multiplying the static effect with a factor

- This IM factor in the code was obtained from field measurements

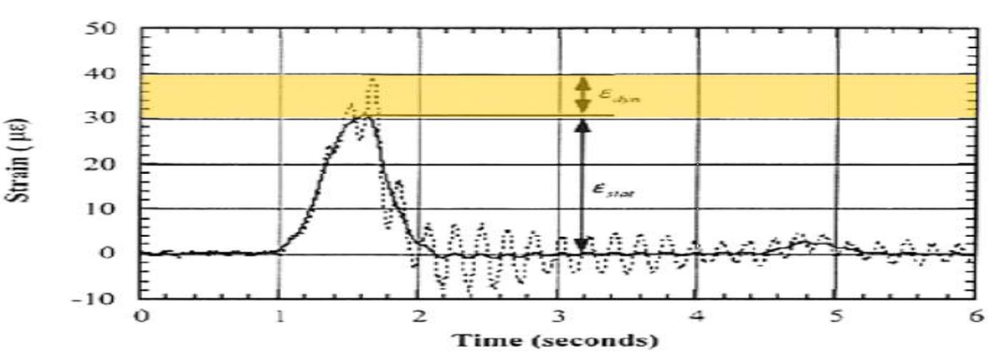


Figure 3.3. Dynamic and Static Strain under a Truck at Highway Speed.

- Add dynamic effect to the following loads:
  - Design Truck
  - Design Tandem
- But NOT to these loads:
  - Pedestrian Load
  - Design Lane Load

Table 3.6.2.1-1 (modified)

Component	IM
Deck Joint All limit states	75%
All other components above ground Fatigue/ Fracture Limit States **All Other Limit States**	 15% **33%**
Foundation components below ground	0%

* Reduce the above values by 50% for wood bridges

MULTIPLE PRESINCE OF LL

- We've considered the effect of load placement in ONE lane
- But 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

Number of Loaded Lane	Multiple Presence Factor "m"
1	1.20
2	1.00
3	0.85
> 3	0.65

- We take care of this by using Multiple Presence Factor
- 1.0 for two lanes and less for 3 or more lanes
- This is already included (indirectly) into the GDF Tables in AASHTO code so we <u>do not</u> need to multiply this again
- Use this only when GDF is determined from other analysis (such as from the lever rule, computer model, or FEM)

DISTIBUTION OF LL TO GIRDER

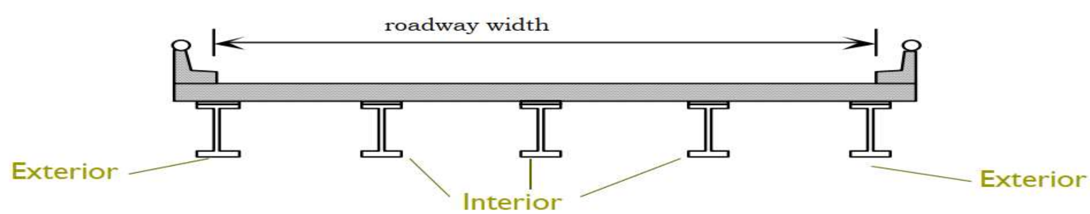
- A bridge usually have more than one girder so the question arise on how to distribute the lane load to the girders

- Two main methods
  - Using AASHTO's table: for typical design, get an approximate (conservative) value
    - No need to consider multiple presence factor

  - Refined analysis by using finite element method
    - Need to consider multiple presence factor

AASHTO DISTIBUTION GIRDER FACTOR

- DFs are different for different kinds of superstructure system
- DFs are different for interior and exterior beam

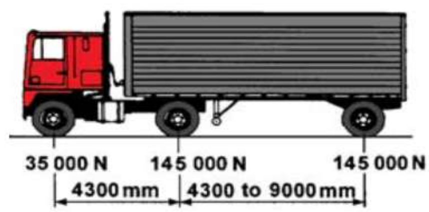


- DFs are available for one design lane and two or more design lanes (the larger one controls)
- Must make sure that the bridge is within the range of applicability of the equation

- Factors affecting the distribution factor includes:
  - Span Length (L)
  - Girder Spacing (S)
  - Modulus of elasticity of beam and deck
  - Moment of inertia and Torsional inertia of the section
  - Slab Thickness (t_s)
  - Width (b), Depth (d), and Area of beam (A)
  - Number of design lanes (N_L)
  - Number of girders (N_b)
  - Width of bridge (W)

FATIGUE LOAD

- Repeated loading/unloading of live loads can cause fatigue in bridge components
- Fatigue load depends on two factors
  - Magnitude of Load
    - Use HS-20 design truck with 9m between 145 kN axles for determination of maximum effects of load



  - Frequency of Occurrence:
    - Use $ADTT_{SL}$ = average daily truck traffic in a single lane

ADT
Average Daily Traffic
(All Vehicles/ 1 Direction)
From Survey (and extrapolate to future)
Max ~ 20,000 vehicles/day

% of Truck in Traffic

ADTT
Average Daily Truck Traffic
(Truck Only/ 1 Direction)

Fraction of Truck Traffic in a Single Lane (p)

$ADTT_{SL}$
Average Daily Truck Traffic
(Truck Only/ 1 Lane)

Table C3.6.1.4.2-1

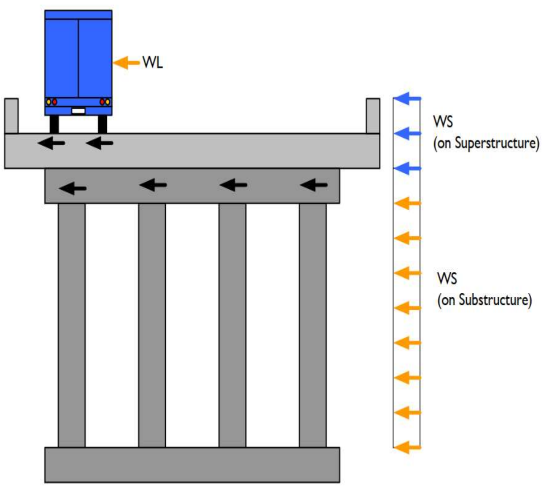
Class of Hwy	% of Truck
Rural Interstate	0.20
Urban Interstate	0.15
Other Rural	0.15
Other Urban	0.10

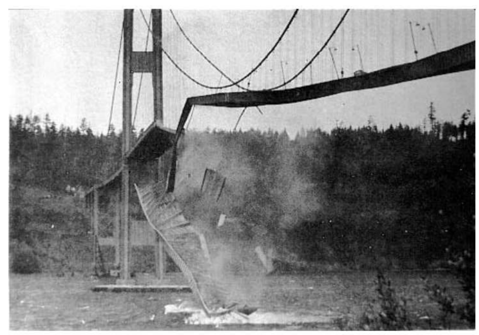
Table 3.6.1.1.2-1

Number of Lanes Available to Trucks	p
1	1.00
2	0.85
3 or more	0.80

WIND LOAD

- Horizontal loads
- There are two types of wind loads on the structure
  - WS = wind load on structure
    Wind pressure on the structure itself
  - WL = wind on vehicles on bridge
    Wind pressure on the vehicles on the bridge, which the load is transferred to the bridge superstructure
- Wind loads are applied as static horizontal load
- For small and low bridges, wind load typically do not control the design
- For longer span bridge over river/sea, wind load on the structure is very important
  - Need to consider the aerodynamic effect of the wind on the structure (turbulence) → wind tunnel tests
  - Need to consider the dynamic effect of flexible long-span bridge under the wind → dynamic analysis





- Tacoma Narrows Bridge (Tacoma, Washington, USA)
  - The bridge collapsed in 1940 shortly after completion under wind speed lower than the design wind speed but at a frequency near the natural frequency of the bridge
  - The "resonance" effect was not considered at the time

According to AASHTO LRFD

Wind Loads:

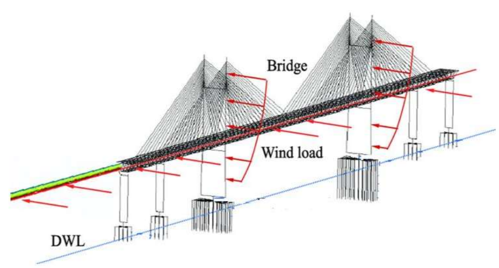
Wind loads shall be applied to the bridge superstructure as well as the moving vehicles assuming a design base wind Velocity of 160 km/hr. at a height of 10m above the ground surface.

Wind Pressure on Structures (WS):

SUPERSTRUCTURE COMPONTENT	WINDWARD LOAD, MPa	LEEWARD LOAD, MPa
Trusses, Columns, and Arches	0.0024	0.0012
Beams	0.0024	NA
Large Flat Surfaces	0.0019	NA

Wind Pressure on Vehicles (WL):

When vehicles are present, the design wind pressure shall be applied to both structure and vehicles. Wind pressure on vehicles shall be represented by an interruptible, moving force of 1.46 KN/m' acting normal to, and 1800 mm above, the roadway and shall be transmitted to the structure.



Sketches for Wind Loads

$$P_D = P_B\left(\frac{V_{DZ}}{V_B}\right)^2 = P_B\frac{V_{DZ}^2}{25\,600}$$

$$V_{DZ} = 2.5\,V_0\left(\frac{V_{10}}{V_B}\right)\ln\left(\frac{Z}{Z_o}\right)$$

CONDITION	OPEN COUNTRY	SUBURBAN	CITY
V_0 (km/hr.)	13.2	17.6	19.3
Z_0 (mm)	70	1000	2500

EARTHQUAKE

- Horizontal load
- The magnitude of earthquake is characterized by return period
  - Large return period (e.g. 500 years) → strong earthquake
  - Small return period → (e.g. 50 years) → minor earthquake
- For large earthquakes (rarely occur), the bridge structure is allowed to suffer significant structural damage but must not collapse
- For small earthquakes (more likely to occur), the bridge should still be in the elastic range (no structural damage)
- Earthquake must be considered for structures in certain zones
- Analysis for earthquake forces is taught in Master level courses

- The January 17, 1995 Kobe earthquake had its epicenter right between the two towers of the Akashi-Kaikyo Bridge
- The earthquake has the magnitude of 7.2 on Richter scale
- The uncompleted bridge did not have any structural damages
- The original planned length was 1990 meters for the main span, but the seismic event moved the towers apart by almost a meter!

According to AASHTO LRFD

Earthquake Loads (EQ):

- We can apply earthquake with dynamic method "Response spectrum method"
- The general procedure shall use:
  - The peak ground acceleration coefficient (PGA) at 0.0 sec and
  - The short-period spectral acceleration coefficient (SS) at 0.2 sec
  - The long-period spectral acceleration coefficients (S1) at 1.0 sec
- Value of PGA, Ss and S1 shall be determined from charts shown in AASHTO LRFD.
- Sites shall be classified by their stiffness as determined by the shear wave velocity as shown in the table.

Site Class	Soil Type and Profile
A	Hard rock with measured shear wave velocity, $\bar{v}_s > 5{,}000$ ft/s
B	Rock with 2,500 ft/sec < $\bar{v}_s$ < 5,000 ft/s
C	Very dense soil and soil rock with 1,200 ft/sec < $\bar{v}_s$ < 2,500 ft/s, or with either $\bar{N}$ > 50 blows/ft, or $\bar{s}_u$ > 2.0 ksf
D	Stiff soil with 600 ft/s < $\bar{v}_s$ < 1,200 ft/s, or with either 15 < $\bar{N}$ < 50 blows/ft, or 1.0 < $\bar{s}_u$ < 2.0 ksf
E	Soil profile with $\bar{v}_s$ < 600 ft/s or with either $\bar{N}$ < 15 blows/ft or $\bar{s}_u$ < 1.0 ksf, or any profile with more than 10.0 ft of soft clay defined as soil with $PI > 20$, $w > 40$ percent and $\bar{s}_u$ < 0.5 ksf
F	Soils requiring site-specific evaluations, such as: • Peats or highly organic clays (H > 10.0 ft of peat or highly organic clay where H = thickness of soil) • Very high plasticity clays (H > 25.0 ft with PI > 75) • Very thick soft/medium stiff clays (H >120 ft)

Exceptions: Where the soil properties are not known in sufficient detail to determine the site class, a site investigation shall be undertaken sufficient to determine the site class. Site classes E or F should not be assumed unless the authority having jurisdiction determines that site classes E or F could be present at the site or in the event that site classes E or F are established by geotechnical data.

where:

$\bar{v}_s$ = average shear wave velocity for the upper 100 ft of the soil profile
$\bar{N}$ = average Standard Penetration Test (SPT) blow count (blows/ft) (ASTM D1586) for the upper 100 ft of the soil profile
$\bar{s}_u$ = average undrained shear strength in ksf (ASTM D2166 or ASTM D2850) for the upper 100 ft of the soil profile
PI = plasticity index (ASTM D4318)
w = moisture content (ASTM D2216)

❑ Earthquake Loads (EQ):

- ❖ The elastic seismic coefficient for ***m***th move of vibration (C_{sm}) shall be taken as:

$C_{sm} = A_S + (S_{DS} - A_S)(T_m/T_0)$ For $T_S < T_0$

$C_{sm} = S_{DS}$ For $T_0 \le T_m \le T_S$

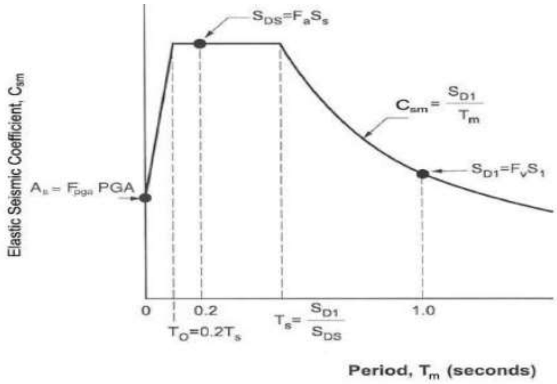
$C_{sm} = S_{D1}/T_m$ For $T_S < T_m$

In which:

$$A_S = F_{pga} * PGA$$
$$S_{SD} = F_a * S_S$$
$$S_{D1} = F_V * S_1$$
$$T_S = S_{D1}/S_{DS}$$
$$T_0 = 0.2 * T_s$$

Acceleration Coefficient, S_{D1}	Seismic Zone
$S_{D1} \le 0.15$	1
$0.15 < S_{D1} \le 0.30$	2
$0.30 < S_{D1} \le 0.50$	3
$0.50 < S_{D1}$	4

Seismic Zone



Site Class	Peak Ground Acceleration Coefficient (PGA)[1]				
	$PGA <$ 0.10	$PGA =$ 0.20	$PGA =$ 0.30	$PGA =$ 0.40	$PGA >$ 0.50
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F[2]	*	*	*	*	*

F_{pga} Factor

Site Class	Spectral Acceleration Coefficient at Period 0.2 sec (S_S)[1]				
	$S_S <$ 0.25	$S_S =$ 0.50	$S_S =$ 0.75	$S_S =$ 1.00	$S_S >$ 1.25
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F[2]	*	*	*	*	*

F_a Factor

Site Class	Spectral Acceleration Coefficient at Period 1.0 sec (S_1)[1]				
	$S_1 <$ 0.1	$S_1 =$ 0.2	$S_1 =$ 0.3	$S_1 =$ 0.4	$S_1 >$ 0.5
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F[2]	*	*	*	*	*

F_V Factor

EARTH LOADS

Earth pressure shall be considered as a function of the :

- type and unit weight of earth,
- water content,
- soil creep characteristics,
- degree of compaction,
- location of groundwater table,
- earth-structure interaction,
- amount of surcharge,
- earthquake effects,
- back slope angle, and
- wall inclination.

Type of Backfill	Values of Δ/H	
	Active	Passive
Dense sand	0.001	0.01
Medium dense sand	0.002	0.02
Loose sand	0.004	0.04
Compacted silt	0.002	0.02
Compacted lean clay	0.010	0.05
Compacted fat clay	0.010	0.05

❑ Earth Pressure (EH):

Earth pressure loads on abutment walls and retaining walls are calculated based on the following soil parameters of the backfilling material as per geotechnical recommendation: Angle of internal Friction of backfill soil (Ø), Bulk Density of backfill soil, Coefficients of Lateral Earth Pressure (K_a, K_p, K_o). (using Rankine theory)

$$K_a = \frac{1-\sin(\phi)}{1+\sin(\phi)} \qquad K_p = \frac{1+\sin(\phi)}{1-\sin(\phi)}$$

$$K_o = 1-\sin(\phi)$$

❑ Live Load Surcharge (LS):

A live load surcharge shall be applied where vehicular load is expected to act on the surface of the backfill within a distance equal to one-half the wall height behind the back face of the wall. The increase in horizontal pressure due to live load surcharge may be estimated as:

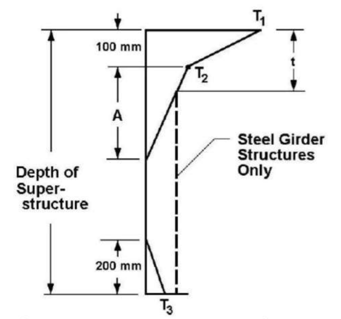
$$\Delta_p = k_a \times \gamma_s \times g \times h_{eq} \times 10^{-9}$$

TEMPERATURE EFFECT

❑ Temperature effect :

The bridge is designed for the following thermal effects:

- Uniform increase or decrease of temperature (TU) = ±30°C.
- Temperature gradient (TG) across the depth of the bridge deck as shown in figure.
- Value of T_3 shall be taken as 0°C, unless the site specific study is made to determine an appropriate value $\ngtr$ 3°C.



Sketch of temperature Gradient

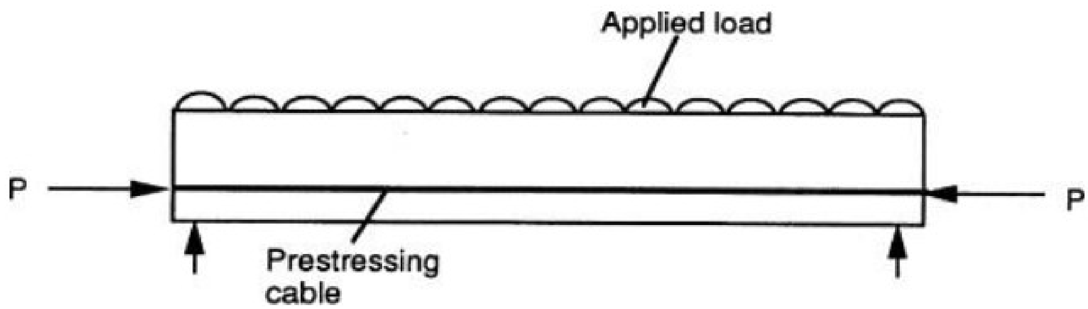
Zone	T_1 (°C)	T_2 (°C)
1	30	7.8
2	25	6.7
3	23	6.0
4	21	5.0

SETTLEMENT LOAD

The worst cumulative effect of possible long term differential settlement of individual bridge foundations is considered in the analysis and design.
The geotechnical report indicates values of differential settlement between the bridge foundations.

PRE-STRESSING LOAD

- Usually in bridges we used post tension system and can be cast in-situ or pre-cast.
- There are some samples for pre-tensioned girder with dimensions, tendons and spans.



CENTREFUGALE FORSE

It occurs due to curvature of the bridge and speed of the vehicles, and taken as:

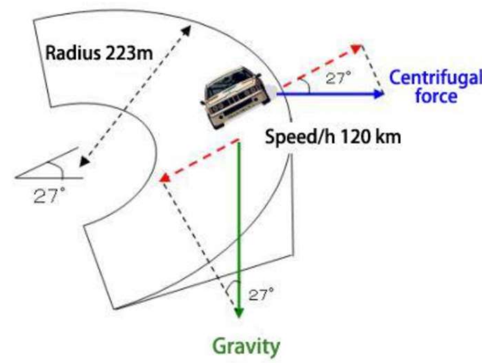
CE= C x design truck x No. of lanes x Reduction Factor

$$C = f * \frac{v^2}{g * R}$$

Where,

- V= Highway design speed in (m/sec.)
- f = 4/3
- g= Gravitational acceleration.
- R= Radius of curvature of traffic lane.

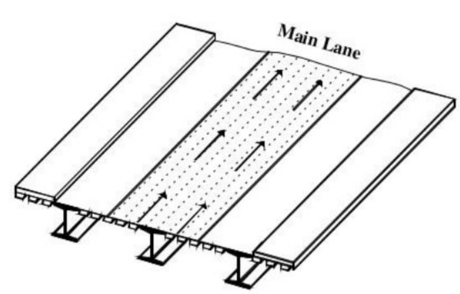
- The centrifugal force shall be applied horizontally at 1.8m above the roadway surface.



Sketch for Centrifugal Force

BRAKING FORSE

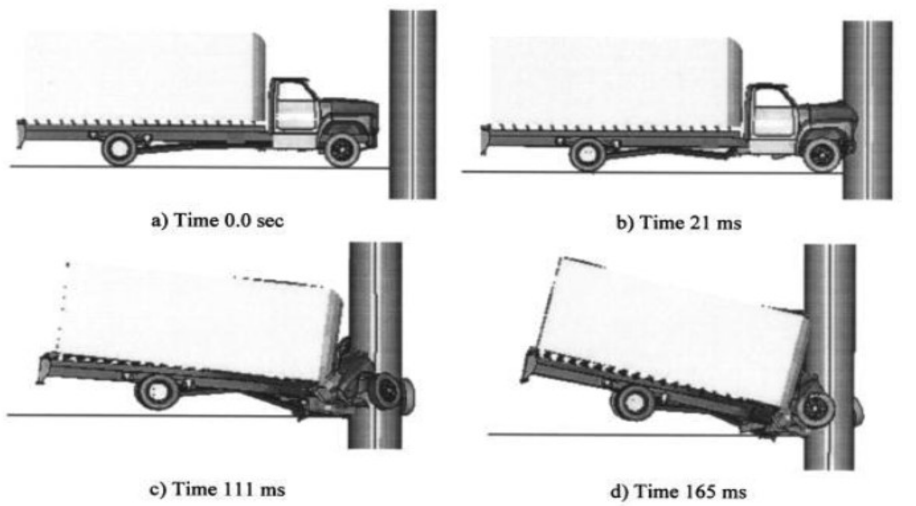
- Braking force to be used for the design is equal to the greater of:
  - BR_1 = 0.25 x design truck x Number of lanes x Reduction Factor
  - BR_2 = 0.05 x [(design truck x Number of lanes x Reduction Factor) + (lane load x length of bridge x Number of lanes x Reduction Factor)]
- The center of gravity of the braking force is assumed to be located at 1.8 m above the roadway surface.



Braking Force

VEHICULAR COLLISION FORCE

- Abutments and piers located within a distance of 9.0m to the edge of roadway shall be investigated for collision.
- Its assumed to act at a distance of 1.50 m above ground with value 2670 KN.



Vehicular Collision Force

❑ Effect of Creep and Shrinkage of Concrete:

❖ Time dependant deformations due to creep:

The Creep coefficient of concrete is calculated by the following equation,

$$\Psi(t,ti) = 1.9 \times K_s \times K_{hc} \times K_f \times K_{td} \times t_i^{-0.118}$$

$$\varepsilon_{prestressing} = \frac{P_{jacking}}{A \times E_c}$$

$$\varepsilon_{creep} = \psi(t, t_i) \times \varepsilon_{prestressing} \qquad \varepsilon_{creep} = \alpha \times t_{eq}$$

❖ Time dependant deformations due to Shrinkage:

The Shrinkage strain of concrete is calculated by the following equation,

$$\varepsilon_{sh} = -K_s \times K_{hc} \times K_f \times K_{td} \times 0.48 \times 10^{-3}$$

$$\varepsilon_{sh} = \alpha \times t_{eq}$$

$K_s = 1.45 - 0.0051 \times \frac{V}{S} \geq 1$

V =volume per unit length of a concrete deck

S = Surface in contact with freely air

$K_{hc} = 1.56 - 0.008 \times H$

H = Average Ambient relative humidity

$K_f = \frac{35}{7 + f'_{ci}}$

$K_{td} = \frac{t}{61 - 0.58 \times f'_{ci} + t}$

t = Defined as age of concrete between time of loading for creep calculation, and time being considered for analysis of creep effects.

A = cross section area of the concrete bridge deck

$E_c = 4800 \times \sqrt{f'_c}$

α= 10.8×10^{-6} /°C, Coefficient of thermal expansion of concrete.