3. Loads on Bridges Components

3.1. General Loads on Highway Bridge Components

Bridges must be designed to safety resist multitude loads that might act on them, singly or in combinations togethers as illustrated in Figure 3-1. These loads can be classified into two broad categories:

- Gravity loads.
- Transverse loads.

Gravity load acts vertically downward and includes dead loads such as components weight and live loads such as vehicular weight. While transverse loads are assumed to act horizontally and include such loads as wind and seismic, braking forces, earth pressure, water pressure and ice pressure as well debris and collision forces. Some of these loads are classified as permanent loads because they always sustain on the bridge such as dead loads; and others such as live loads, are classified as transient loads.

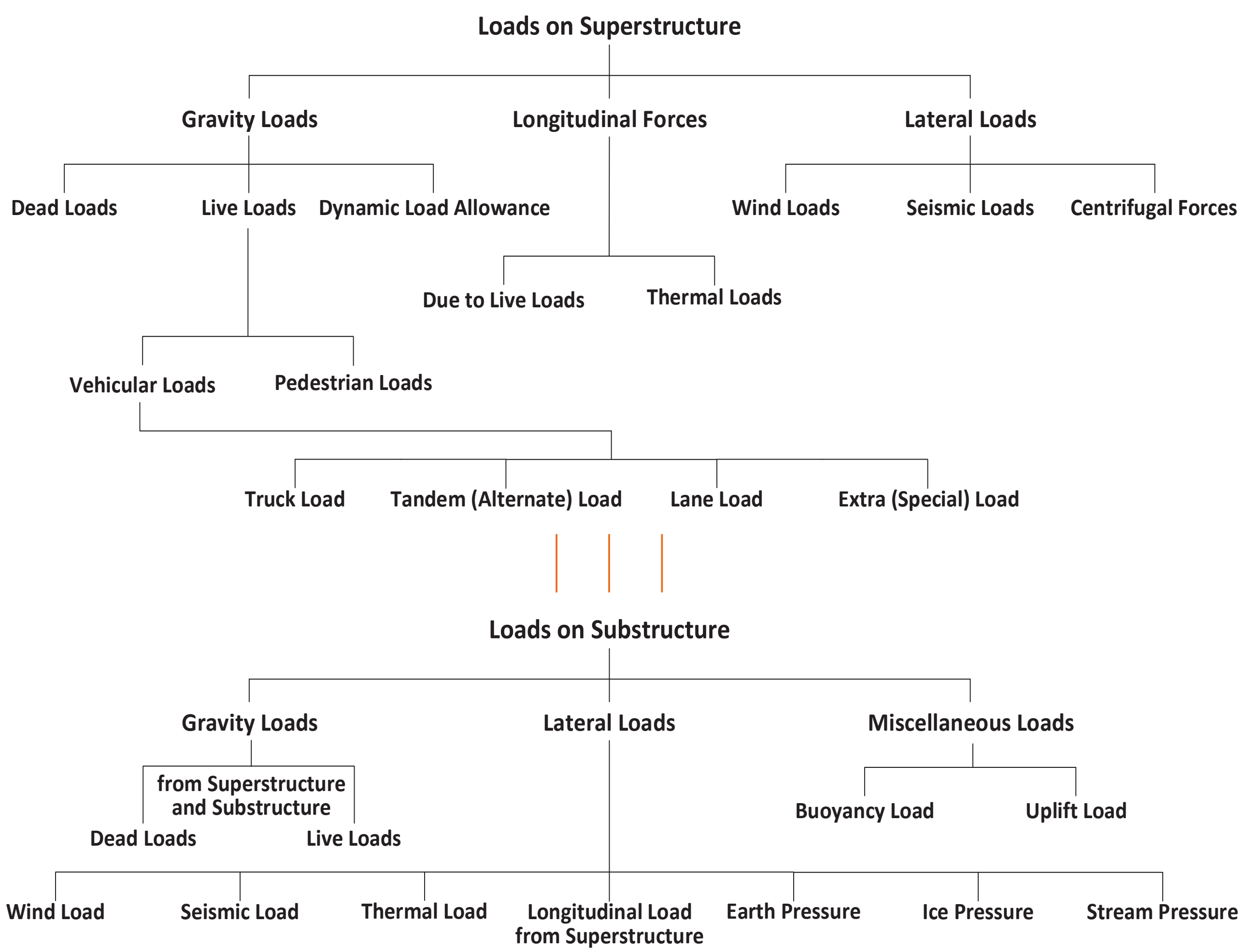

Figure 3-1: Loads on Bridge Structures

3.1.1. Gravity Loads on Deck Slab

A typical designed deck slab should support the following loads:

- Its own dead weight.
- Integral wearing surface (nonstructural concrete layer).
- Railings, parapets, barriers, curbs, and any other attachments.
- Future wearing surface (asphalt layer).
- Facilities, directional signs, and other services.
- Vehicular live load.
- Vehicular dynamic load allowance.

3.1.2. Gravity Load on Girders

A typical designed girder should support, in minimum, gravity loads from following items:

- All the loads come from deck slab.
- Its own dead weight including the haunch.
- Permanent or stay-in-place (SIP) forms that support the deck during construction.
- Diaphragms and as applicable cross frames.
- Intermediate and bearing stiffeners if built-up steel girders are used.
- Construction loads.

3.2. Dead Loads on Bridge Superstructure

Dead loads on highway bridge superstructures include the following:

- Weight of all structural components and nonstructural attachments (DC).
- Weight of wearing surfaces and utilities (DW).

Calculations of these loads are pertaining to the deck slab and its supporting girders that shown in Figure 1.2 and Figure 1.3 previously. The deck may be of reinforced concrete, steel grid (open or filled); while the girders may be of different properties reinforced concrete, prestressed concrete, steel or wood. However, the dead load of components can be determined from their section properties and the unit weight of their materials that can be found in Table 3.1 below.

The unit weight of reinforcement amount is generally taken as $(0.8\ \mathrm{kN/m^3})$ greater than the unit weight of plain concrete which generally equals $(23.2\ \mathrm{kN/m^3})$. So, in the absence of more precise information, take the unit weight of reinforced concrete (Υ_c) equals to $(24\ \mathrm{kN/m^3})$.

Table 3-1: Unit Weights of Materials [AASHTO LRFD Table 3.5.1-1]

Material		Unit Weight (Υ) kN/m^3
Aluminum Alloys		28
Bituminous Wearing Surface		22.5
Cast Iron		72
Cinder Filling		9.6
Compacted Sand, Silt or Clay		19.25
Concrete	Lightweight	17.75
	Sand lightweight	19.25
	Normal weight with $f_c' \leq 35$ MPa	23.2
	Normal weight with $35 < f_c' \leq 105$ MPa	$22.4 + 0.023f_c'$
Loose Sand, Silt or Gravel		16
Soft Clay		16
Rolled Gravel, Macadam or Ballast		22.5
Steel		78.5
Stone Masonry		27.25
Wood	Hard	9.6
	Soft	8
Water	Fresh	10
	Salt	10.25
Item		Weight/Unit Length ($\boldsymbol{w/L}$) kN/m
Transit Rails, Tires and Fastening / Track		3

3.2.1. Maximum Moment and Shear Force for Dead Load

The maximum values of bending moment and shear force due to dead loads on the section can be determined from Table 3-1 equations:

Table 3-2: Maximum Bending Moment and Shear Force Due to Dead Loads

Type of Span	Effective Length ($\boldsymbol{L}$) mm	Bending Moment ($\boldsymbol{M}$) N.mm	Shear Force ($\boldsymbol{V}$) N
Simple	center/center of supports	$+wL^2/8$	$wL/2$
Continuous	center/center of supports	$+wL^2/24$	$wL/2$
		$-wL^2/12$	
Cantilever	center of support/free end	$-wL^2/2$	wL

where:

w: continuous dead load on the section.

L: effective length of span.

3.3. Vehicular Live Load

The vehicular live loading on the roadways of bridges or incidental structures is defined by AASHTO specifications, designated as HL-93 where HL means highway loading and 93 refers to year of officially approved 1993, shall consist of a combination of the (Figure 3-2):

- **Design Truck**: it is the HS20-44 truck as defined previously. To produce extreme force effects, the rare axles spacing shall be varied between (4.3 and 9.0 m) as Figure 2.10 shows.
- **Design Tandem**: a pair of axles have load of (110 kN) spaced (1.2 m) apart. The transverse spacing of wheels is (1.8 m).
- **Design Lane Load**: uniformly distributed load of (9.3 kN/m) in the longitudinal direction over a width of (3.0 m).

The tandem load, also known as the alternate military loading, is specified to simulate military loading and typically governs design of spans approximately shorter than (12 m).

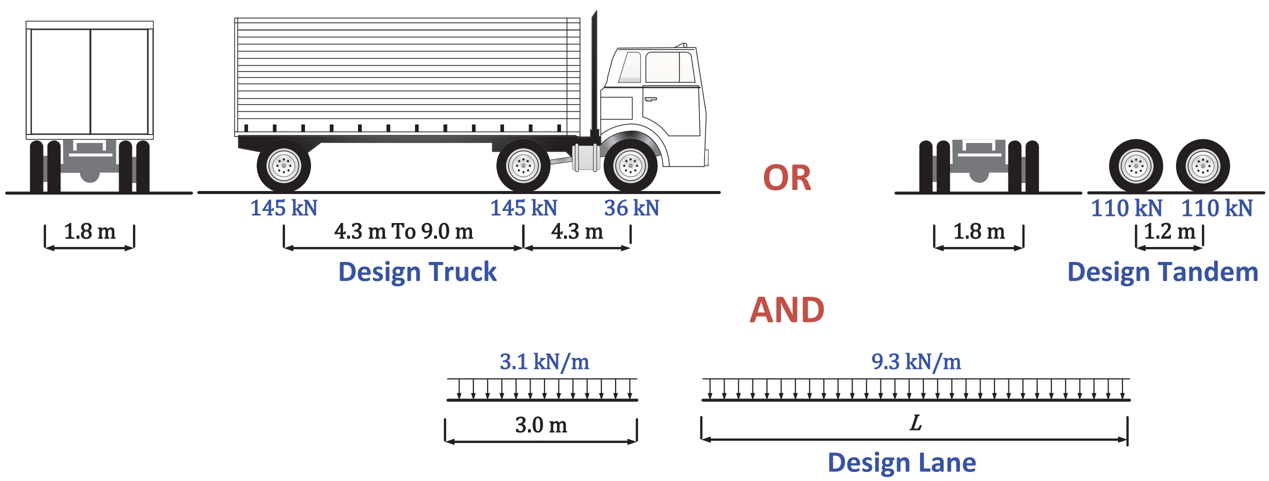

Figure 3-2: HL-93 Vehicular Live Load According to AASHTO LRFD Specifications

3.3.1. Maximum Moment and Shear Force for Lane Load

The maximum bending moment or shear force induced by lane load can be determined by the same manner of calculation of the moment and shear from distribute deal load. Table 3-2 above has the required equations.

3.3.2. Maximum Moment and Shear Force for Moving Load

The maximum bending moment or shear does not depend on the moving loads magnitudes only. However, the position of the moving load is more considerable. The critical position of the moving load needs to be determined by influence lines application.

So, the maximum moment caused by a moving load on simple span can be computed instantaneously when the center of the span is at the middle distance between the resultant (R) of the moving load and its nearest axle load as shown in Figure 3-3.

To find the maximum bending moment of moving load (M_{Mo}) as truck (M_{Tr}) or tandem (M_{Ta}), follow that:

- Find the distance ($\bar{x}$) between the resultant (R) of moving load and its nearest axle load.
- Then, neglect (R) and assume its nearest axle load lies at point (o) of distance ($\bar{x}/2$) from the center of the span.
- Determine the positions of the other front and rear axles of the moving load on the span.
- Compute the supports reactions, then make a cut at point (o) to find the moment therein.

The maximum shear force (V_{Tr}) or (V_{Ta}) can be computed instantaneously on a support when the entire moving load is inside the span and its rear axle is closest to that support.

- $L \geq 12\text{m}$ $\qquad M_{Mo} = M_{Tr}$
- $L \geq 8.5\text{ m}$ $\qquad V_{Mo} = V_{Tr}$

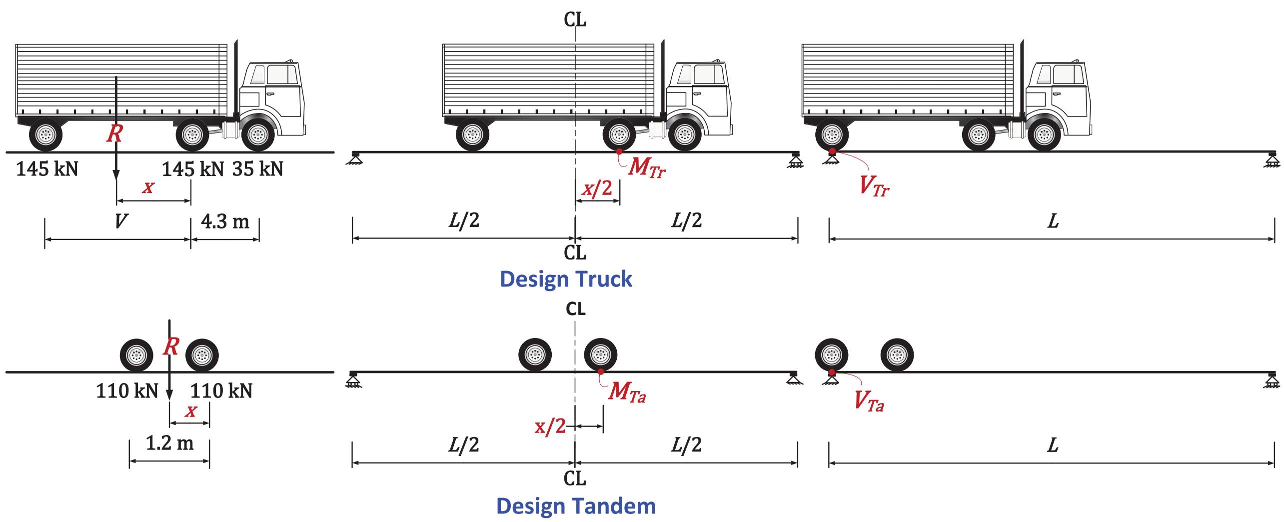

Figure 3-3: Maximum Moment and Shear Locations under Moving Load on Simple Spans

3.3.3. <u>Approximate Maximum Moment for Moving Load</u>

The maximum bending moment can be approximately calculated with acceptable results by positing the larger load from near axles to the resultant on the center line of the simple beam as in shown in Figure 3-4.

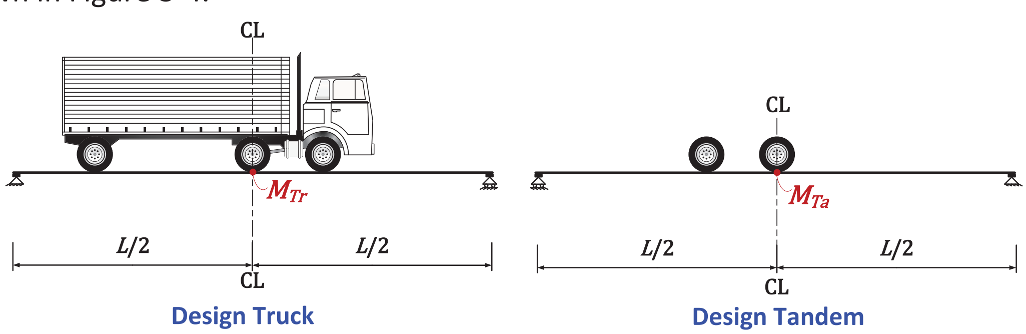

Figure 3-4: Approximate Maximum Moment under Moving Load on Simple Spans

3.3.4. Vehicular Dynamic Load Allowance

When a moving vehicle across a bridge at a specific speed, stresses are produced greater than ones when the vehicle remains static on the bridge.

The static effects of the design truck or tandem, other than centrifugal and braking forces on superstructure and other bridge portions above the ground level shall be increased by the percentage specified by AASHTO for dynamic load allowance (DLA). The (DLA) factor (IM) to be applied to the static load shall be taken as: $(1 + IM)$. In contrast, the (IM) shall not be applied to pedestrian loads or to the design lane load.

Table 3-3: Dynamic Load Allowance [AASHTO LRFD Table 3.6.2.1-1]

Component		DLA (IM)
Deck Joints	All Limit States	75%
All Other Components	Fatigue and Fracture Limit State	15%
	All Other Limit States	33%

3.3.5. Multiple Presence of Live Load

The multiple presence factor (m) is needed to investigate the position of vehicular Live Load, thereby, the design lane width (3.6 m) is greater than the truck width (3.0 m). So, the (m) factor is depending on number of loaded lanes (N_L) on the roadway of the bridge.

The (m) factor to be applied to the vehicular Live load shall be taken as: $m(Q_{Mo} + IM)$. Possible future changes in the physical or functional clear roadway width of the bridge should be considered during determination of lanes. Roadway widths $(6.0 - 7.2\text{ m})$ shall have two design lanes, each equal to one-half the roadway width. Thus, (N_L) is:

- $N_L = 1$ $[3.0 \leq w < 6.0\text{ m}]$

  $= 2$ $[6.0 \leq w \leq 7.2\text{ m}]$

  $= INT(w/12)$ $[w > 7.2\text{ m}]$ N_L

  $w = W - 2(W_e)$

where:

w: the clear roadway width.

W: overall bridge width.

W_e: distance between the inside face of the curb and the edge of the deck.

Table 3-4: Multiple Presence Factor [AASHTO LRFD Table 3.6.1.1.2-1]

Number of Loaded Lanes (N_L)	Multiple Presence Factor (m)
1	1.20
2	1.00
3	0.85
> 3	0.65