2. Loads on Bridge Structures

2.1. General Loads on Components

Bridges must be designed to safety resist multitude loads that might act on them, singly or in combinations togethers as illustrated in Figure 2.1. These loads can be classified into two broad categories:

- Gravity loads.
- Lateral loads.

Gravity load act vertically downward and include dead loads such as components weight and live loads such as vehicular weight. While lateral 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 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.

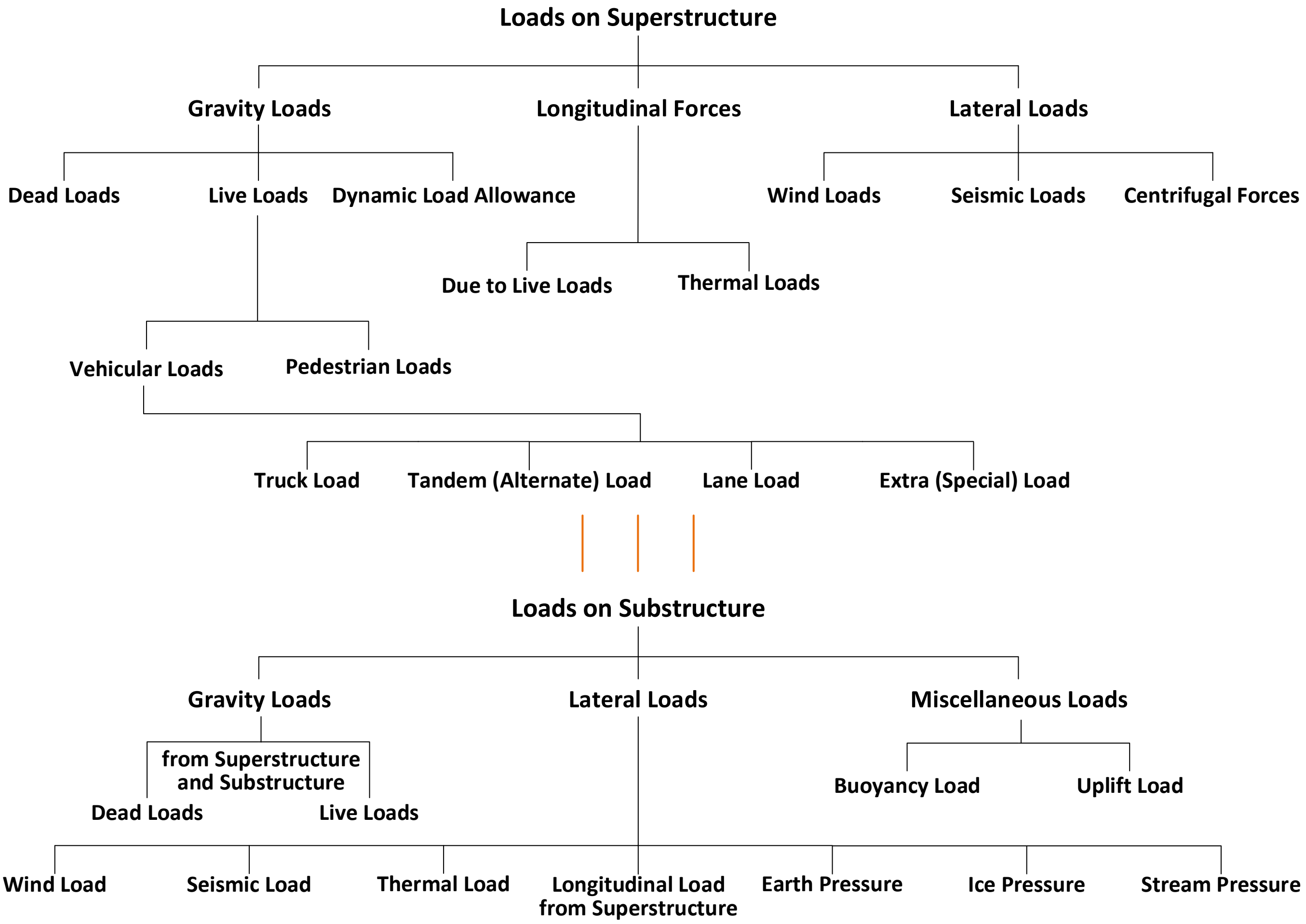

Figure 2.1: Loads on Bridge Structures

2.2. 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 related to the weights of deck slab and its supporting girders (if they are presence) as shown in Figures 1.2 and 1.3 above. The deck may be of reinforced concrete, steel grid (open or filled) or wood; 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 depending on the unit weight of their materials that can be found in Table 2.1 below.

The unit weight of reinforcement amount is generally taken as 0.005 kcf plus the unit weight of plain concrete which generally equals 0.145 kcf. So, in absence of more precise information, take the unit weight of reinforced concrete (Υ_c) = 0.150 kcf.

Table 2.1: Unit Weights of Materials [AASHTO LRFD 2017 Table 3.5.1-1]

Material		**Unit Weight (Υ) kcf**
Aluminum Alloys		0.175
Bituminous Wearing Surface		0.140
Cast Iron		0.450
Cinder Filling		0.060
Compacted Sand, Silt or Clay		0.120
Concrete	Lightweight	0.110
	Sand lightweight	0.120
	Normal weight with $f_c' \leq 5.0$ ksi	0.145
	Normal weight with 5.0 < f_c' 15.0 ksi	$0.140 + 0.001f_c'$
Loose Sand, Silt or Gravel		0.100
Soft Clay		0.100
Rolled Gravel, Macadam or Ballast		0.140
Steel		0.490
Stone Masonry		0.170
Wood	Hard	0.060
	Soft	0.050
Water	Fresh	0.0624
	Salt	0.0640
Item		**Weight/Unit Length (w/L) klf**
Transit Rails, Tires and Fastening / Track		0.200

2.2.1. Dead Load on Deck Slab

The deck slab has to support its own dead weight plus the live load. The dead weight of deck slab depends on its thickness which is related to the span length in the slab bridges type. Whereas in the case of typical slab-girder in beam bridges type, the deck slab thickness depends on the girder spacing.

The deck slab almost includes integral wearing surface which is nonstructural layer with typical thickness of 0.5 in. Thus, the total or overall thickness of the deck slab which should be used for dead load calculations is greater than its structural thickness; while the strength calculations are relating just to the structural thickness.

2.2.2. Dead Load on Girders

A bridge girder has to support its own dead weight as well as the dead weight of the tributary area of the deck slab it supports. Also, the girder has to support the dead weight of some essential items that might not be obvious to the junior engineers. A typical designed girder should support, in minimum, dead load from following items:

- Tributary area of the deck slab including the wearing surface.
- Future wearing surface layer.
- Girder own wight including the haunch.
- Traffic barriers including parapet and railing.
- Permanent or stay-in-place (SIP) deck forms to support concrete slab during construction.
- Diaphragms and as applicable cross frames.
- Intermediate and bearing stiffeners if built-up steel girders are used.
- Construction loads.

Example 2.1:

A 75 ft simple span beam bridge of concrete deck slab and four supporting steel girders spaced at 10 ft on centers has the cross section shown below. The deck is 8½ in. thick cast from 4.5 ksi concrete and contains ½ in. thick integral wearing surface. The steel girders are made of Gr. 50 [F_y = 50 ksi and F_u = 60 ksi] steel built to act compositely with deck using 4 in. long and ¾ in. diameter headed shear studs welded to the girder. Calculate the unfactored gravity loads act on an interior girder. Assume the following dead weights: 25 lb/ft^2 of deck due to future wearing surface; 200 lb/ft of girder length due to SIP forms, cross frames and detailing; and 353 lb/ft due to traffic barrier.

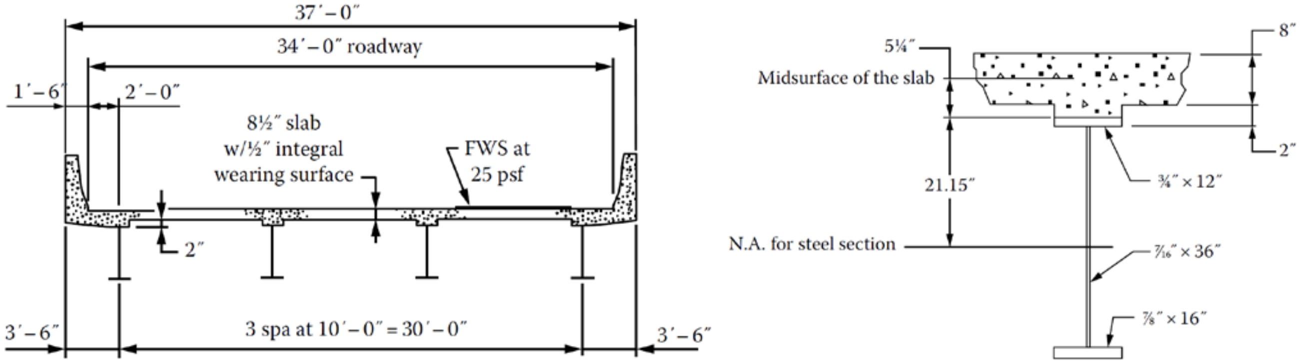

Figure 2.2: Bridge cross section for Example 2.1

Solution 2.1:

Components of dead loads:

1. Deck slab:

$$w_d = h_d . b_f . \Upsilon_c$$

$$b_f = \text{tributary width of slab} = \text{spacing between the girders} = 10\text{ ft}$$

$$w_d = (8.5/12)(10)(0.15) = 1.063\text{ kip/ft}$$

2. Haunch:

$$w_h = h_h . b_h . \Upsilon_c$$

$$h_h = 2 - 0.75 = 1.25\text{ in}$$

$$w_h = (1.25/12)(12/12)(0.15) = 0.016\text{ kip/ft}$$

3. Steel girder:

$$w_g = A_g . \Upsilon_s$$

$$A_g = A_{f,top} + A_w + A_{f,bot} = 0.75(12) + 0.4375(36) + 0.875(16) = 38.75\text{ in}^2$$

$$w_g = (38.75/144)(0.49) = 0.132\text{ kip/ft}$$

4. Traffic barriers:

$$w_p = w_{ba} . N_{ba}/N_g$$

$$w_{ba} = 0.353\text{ kip/ft}$$

$$w_p = 0.353(2)/4 = 0.177\text{ kip/ft}$$

5. Estimated dead weight of stay-in-place forms, stiffeners, cross frames, and detailing:

$$w_{misc} = 0.200\text{ kip/ft}$$

6. Future wearing surface:

$$w_{ws} = q_{ws} . b_{ws}$$

$$q_{ws} = 0.025\text{ kip/ft}^2$$

$$b_{ws} = b_f = 10\text{ ft}$$

$$w_{ws} = 0.025(10) = 0.25\text{ kip/ft}$$

Total dead weight due to DC and DW:

$$\begin{aligned} w_{DC} &= w_d + w_h + w_g + w_p + w_{misc} \\ &= 1.063 + 0.016 + 0.132 + 0.177 + 0.200 = 1.588\text{ kip/ft} \end{aligned}$$

$$w_{DW} = w_{ws}$$
$$= 0.25 \text{ kip/ft}$$

Dead load shears in girders:

$$V_{DC} = w_{DC}.L/2 = 1.588(75)/2 = 59.550 \text{ kip}$$
$$V_{DW} = w_{DW}.L/2 = 0.250(75)/2 = 9.375 \text{ kip}$$

Dead load moments in girders:

$$M_{DC} = w_{DC}.L^2/8 = 1.588(75)^2/8 = 1116.563 \text{ kip-ft}$$
$$M_{DW} = w_{DW}.L^2/8 = 0.250(75)^2/8 = 175.781 \text{ kip-ft}$$

Example: 2.2

Cross section of a highway bridge shown in above, having a single span of 85 ft. It consists of an 8½ in. thick reinforced concrete deck (including ½ in. thick integral wearing surface) cast from 4500 psi concrete. The deck is supported on and acts compositely with AASHTO–PCI Type IV precast, prestressed concrete girders having a compressive strength of 6000 psi, which spaced at 7 ft 8 in. on centers. The cross-sectional area of each girder is 789 in^2. The parapets weigh 353 lb per linear ft. Assume the dead load due to future wearing surface (FWS) as 35 lb/ft^2. Calculate the gravity loads for design of an interior girder of the bridge.

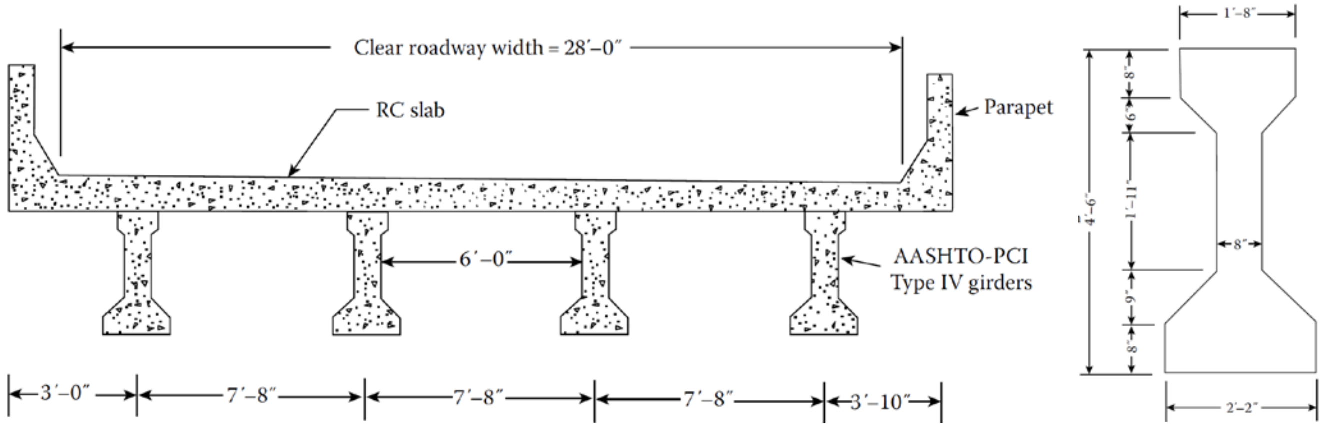

Figure 2.3: Bridge cross section for Example: 2.2

Solution 2.2:

Components of dead loads:

1. Deck slab:

$$w_d = h_d.b_f.\Upsilon_c$$
$$b_f = \text{tributary width of slab} = \text{spacing between the girders} = 7.67 \text{ ft}$$
$$w_d = (8.5/12)(7.67)(0.15) = 0.815 \text{ kip/ft}$$

2. Concrete girder:

$$w_g = A_g.\Upsilon_s$$
$$A_g = 789 \text{ in}^2$$
$$w_g = (789/144)(0.15) = 0.822 \text{ kip/ft}$$

3. Traffic barriers:

$$w_p = w_{ba}.N_{ba}/N_g$$
$$w_{ba} = 0.353 \text{ kip/ft}$$
$$w_p = 0.353(2)/4 = 0.177 \text{ kip/ft}$$

4. Future wearing surface:

$$w_{ws} = q_{ws}.b_{ws}$$
$$q_{ws} = 0.035 \text{ kip/ft}^2$$
$$b_{ws} = b_f = 7.67 \text{ ft}$$
$$w_{ws} = 0.035(7.67) = 0.268 \text{ kip/ft}$$

Total dead weight due to DC and DW:

$$w_{DC} = w_d + w_g + w_p$$
$$= 0.815 + 0.822 + 0.177 = 1.814 \text{ kip/ft}$$
$$w_{DW} = w_{ws}$$
$$= 0.268 \text{ kip/ft}$$

Dead load shears in girders:

$$V_{DC} = w_{DC}.L/2 = 1.814(75)/2 = 59.550 \text{ kip}$$
$$V_{DW} = w_{DW}.L/2 = 0.268(75)/2 = 9.375 \text{ kip}$$

Dead load moments in girders:

$$M_{DC} = w_{DC}.L^2/8 = 1.814(85)^2/8 = 1638.269 \text{ kip-ft}$$
$$M_{DW} = w_{DW}.L^2/8 = 0.268(85)^2/8 = 242.038 \text{ kip-ft}$$

Example: 2.3

Determine the dead weight of the reinforced concrete T-beam bridge interior beam using Figure 2.4 shown below and the bridge data given: span length 50 ft, beam spacing 10 ft, concrete strength 4.5 ksi, minimum yield strength of steel = 60 ksi, future wearing surface load = 0.03 ksf and barrier (curbs and parapet) load 0.505 klf.

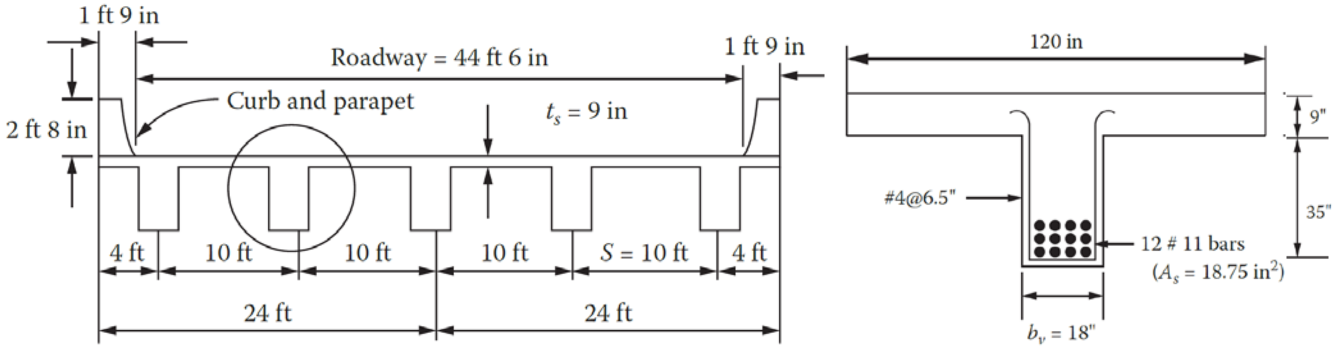

Figure 2.4: Bridge cross section for Example: 2.3

Solution 2.3

$$M_{DC} = 619.69 \text{ kip-ft}$$
$$M_{DW} = 93.75 \text{ kip-ft}$$