Bridge Design - Loads and Load Combinations

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PDH: 4

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Module 3: Loads and Load Combinations

Learning Objectives

By the end of this section, you will be able to:

- **Identify** and categorize permanent and transient loads required for bridge design under AASHTO LRFD and California Amendment standards.
- **Calculate** dead loads, earth pressures, and vehicular forces for both superstructure and substructure components.
- **Select** appropriate load distribution factors and combinations to determine the controlling limit states for structural members.

Executive Summary: Bridge design is an iterative process where member sizes are a function of loads, and loads (such as structural weight) are a function of member sizes. Establishing a clear load path is fundamental to ensuring forces are effectively transferred from the deck, through the girders and bents, and into the foundation soil matrix. This module details the application of permanent loads (DC, DW, EH) and transient loads (LL, WS, EQ) as specified by the AASHTO LRFD Bridge Design Specifications and the California Amendments, providing the technical basis for standard bridge engineering practice.

Introduction

Properly identifying bridge loading is fundamental to the design of each component. Design is iterative; engineers must proportion members based on experience and then adjust for actual loads and geometry. This module focuses on loads specified in the AASHTO LRFD Bridge Design Specifications and the California Amendments (CA). It is important to note that not every load listed will apply to every bridge.

Load Path

The Engineer must provide a clear load path for every force acting on the structure.

Truck Loading Pathway

- **Deck Slab**: Axle loads are divided into wheels or tandems and carried by the deck slab.
- **Girders**: The load transfers from the deck to the girders, changing direction from transverse to longitudinal.
- **Bents and Abutments**: Girders span between these supports, transferring the longitudinal load into transverse bent cap beams.
- **Columns and Foundation**: Bent caps transfer loads to columns (primarily axial members), then to footings, piles, and finally the soil matrix.

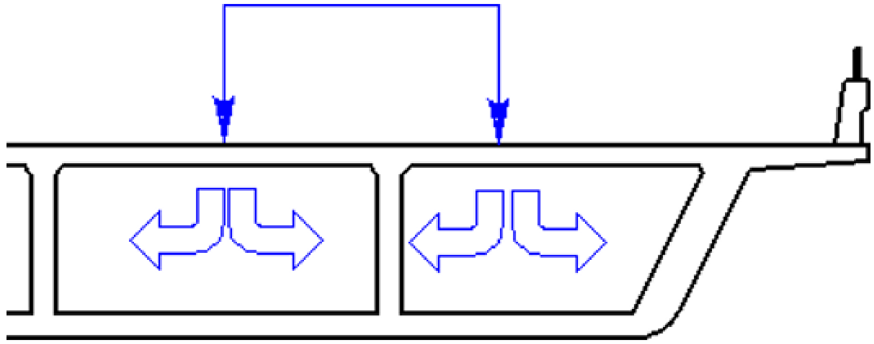

Figure 3.1-1: Truck Load Path from Deck Slab to Girders

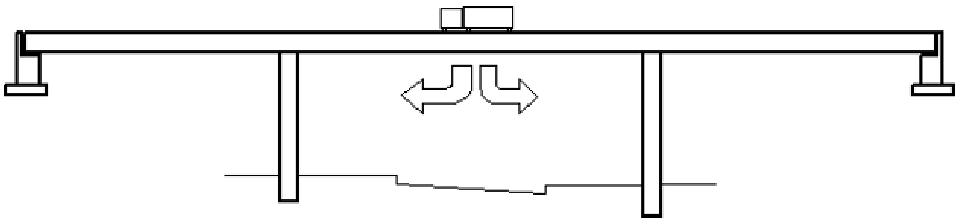

Figure 3.1-2: Truck Load Path from Girders to Bents

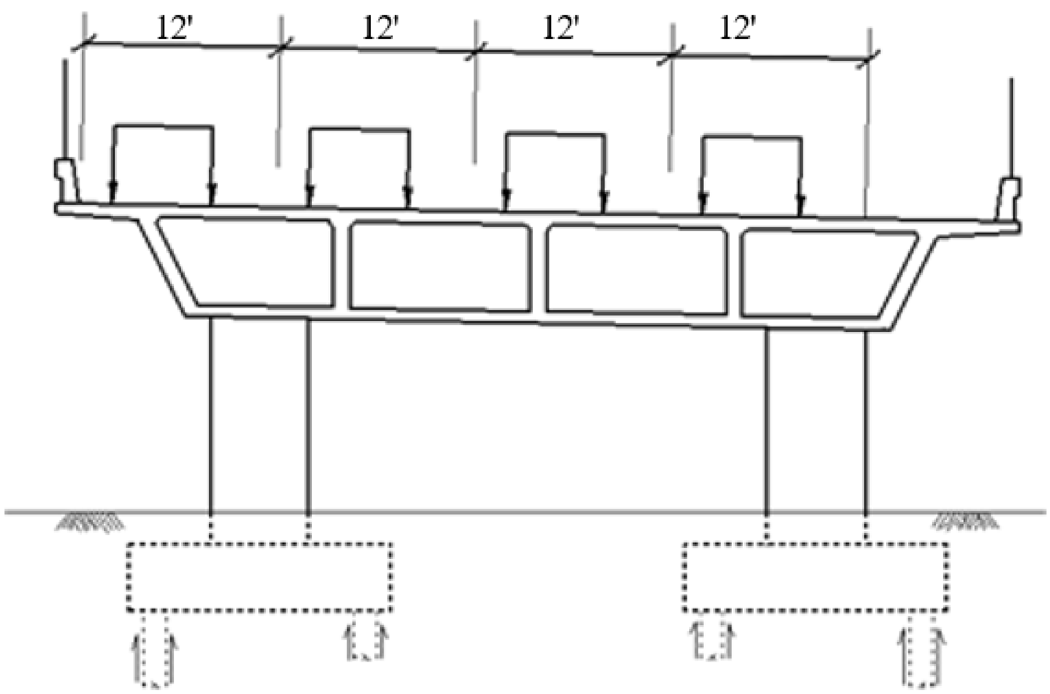

Figure 3.1-3: Truck Load on Bent Cap

Load Definitions

Permanent Loads

Permanent loads are defined as loads and forces that are either constant or varying over a long time interval upon completion of construction.

- **DC**: Dead load of structural components and nonstructural attachments.
- **DW**: Dead load of wearing surfaces and utilities.
- **EH/EV**: Horizontal and vertical earth pressure loads.
- **PS**: Secondary forces from post-tensioning.
- **Other loads**: Downdrag (DD), earth surcharge load (ES), creep (CR), shrinkage (SH), and construction effects (EL).

Transient Loads

Transient loads vary over short time intervals and do not remain on the bridge indefinitely.

- **Vehicular Forces**: Live load (LL), dynamic load allowance (IM), braking force (BR), centrifugal force (CE), and live load surcharge (LS).
- **Environmental Forces**: Wind loads on structure (WS), wind on live load (WL), water loads/stream pressure (WA), earthquake (EQ), and ice loads (IC).
- **Other Transient Loads**: Pedestrian live loads (PL), uniform temperature (TU), temperature gradient (TG), settlement (SE), friction (FR), and vehicular/vessel collisions (CT, CV).

Permanent Load Application with Examples

The following structure is used as an example throughout this chapter to determine individual loads.

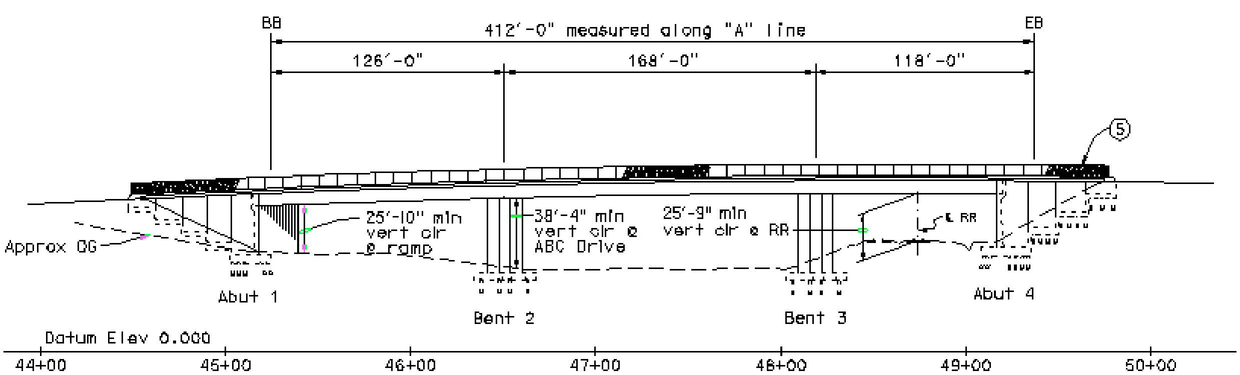

Figure 3.3-1: Elevation View of Example Bridge

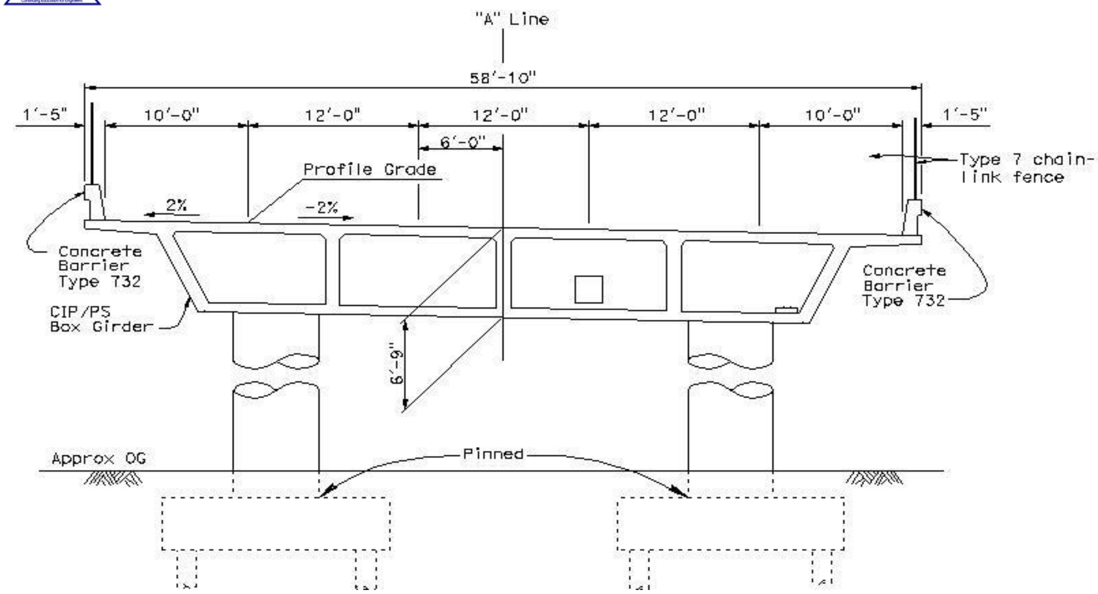

Figure 3.3-2: Typical Section View of Example Bridge

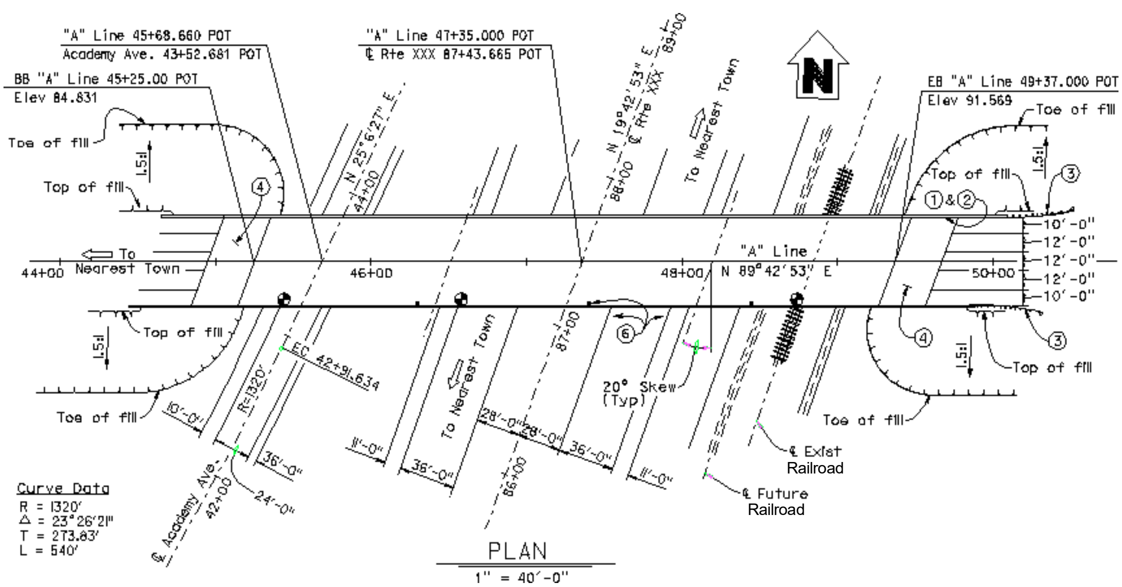

Figure 3.3-3: Plan View of Example Bridge

Dead Load of Components, DC

DC loads are gravity loads based on structural member geometry and material unit weight.

- **Modeling**: Generally calculated by modeling properties in programs such as CTBRIDGE.
- **Concrete Density**: Normal weight concrete is assigned a density of **150 pcf**, which includes reinforcing steel and lost formwork.

⚠️ **Safety Constraint**: Be aware of "double counting" DC loads. For example, bent cap weight included in a longitudinal frame analysis must not be included again in a transverse analysis.

Example Calculation (Barrier): For a Type 732 barrier (A = 2.73 ft²) and normal concrete density (0.15 kcf): $w_{\text{barrier}} = 2.73 \cdot 0.15 = 0.41$ kip/ft Total weight of two barriers (including fence weight) = **0.86 kip/ft**.

Dead Load of Wearing Surfaces and Utilities, DW

- **Wearing Surfaces**: Designed for a thickness of 3 in. of asphalt concrete, resulting in a **35 psf** load.
- **Utilities**: The example utility weight is assumed to be **0.100 kip/ft**.

Downdrag, DD

DD (negative skin friction) can add permanent load on piles. The geotechnical engineer is responsible for determining this additional load.

Horizontal Earth Pressure, EH

EH affects the design of abutments, footings, piles, and wing walls.

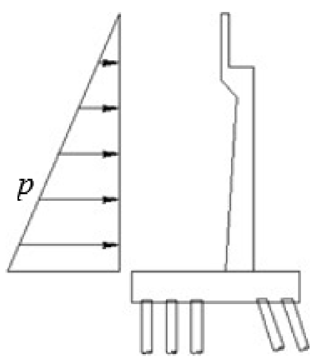

Figure 3.3-4: Abutment 1 with EH Load

Equation 3-1: Pressure Calculation

$$p = k_a \cdot \gamma_s \cdot z$$

Where:

- **p** = pressure against wall (ksf)
- **ka** = active earth pressure coefficient
- **γs** = density of soil (pcf)
- **z** = depth below ground surface (ft)

