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Bridge Deck Design

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Module 1: Introduction

Learning Objectives

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

- **Identify** the primary structural functions and load distribution mechanisms of a bridge deck.
- **Select** appropriate deck types based on project-specific constraints such as weight, durability, and cost.
- **Evaluate** the benefits of composite action between the deck and the steel superstructure.

Executive Summary: The bridge deck is a critical structural element that supports vertical vehicular loads and distributes them to the superstructure while providing lateral stability and bracing; selection depends on a balance of initial cost, life-cycle durability, and weight requirements.

Deck Fundamentals and Selection Criteria

The selection of a bridge deck system is a multi-faceted decision-making process. Designers must evaluate several deck types, including:

- **Concrete deck slabs.**
- **Metal grid decks.**
- **Orthotropic steel decks.**
- **Wood decks** and other specialized systems.

Design Factors

The optimal deck choice is driven by several key variables:

- **Specific Application:** The intended use and environment of the bridge.
- **Financial Constraints:** Both **initial cost** and long-term **life cycle cost**.
- **Performance:** Overall **durability** and the total **weight** of the system.
- **Regulatory Requirements:** Specific mandates or preferences from the bridge owner.

⚠ Safety Constraint: You must refer to the **AASHTO LRFD Bridge Design Specifications (5th Edition, 2010), Section 9: Decks and Deck Systems** for all specific design requirements and code-mandated limits for various deck types.

Structural Functions of the Deck

The bridge deck serves as the first point of contact for vehicular loads and performs several vital structural roles:

Load Distribution

- **Vertical Loads:** The deck supports vehicular vertical loads and distributes them to the steel superstructure.
- **Transverse Bending:** Vehicular wheel loads cause local **flexural bending** as the slab spans across the girders in the transverse direction.
- **Continuity:** To ensure efficient load paths, the deck is typically continuous along both the span length and the span width.

Composite Action

In most modern applications, the deck is made **composite** with the steel superstructure through positive attachment, such as **shear connectors**.

- **Strength and Stiffness:** When composite, the deck acts as part of the **top flange** of the section.
- **Longitudinal Stress:** Composite decks must be designed for longitudinal stresses caused by flexure along the span.

System Stability

- **Continuous Bracing:** Positive attachment to the girders provides continuous bracing for the top flange in the finished structure.
- **Lateral Diaphragm:** The deck acts as a horizontal diaphragm, transferring lateral loads (e.g., **wind** or **seismic**) to the bridge supports.

💡 **Design Tip:** Utilize the deck's capacity as a horizontal diaphragm to simplify the lateral load path, but ensure that the connections to the girders are sufficient to transfer these loads without damaging the slab.

Checkpoint Quiz

1. Which structural role does the bridge deck play when it is positively attached to the steel girders?

- a) It acts only as a wearing surface.
- b) It provides continuous bracing to the bottom flange.
- c) It provides stability to the overall system and continuous bracing to the top flange.
- d) It eliminates the need for any longitudinal reinforcement.

Answer: (c). When a deck is positively attached to the girders, it provides continuous bracing to the top flange in the finished structure and enhances the stability of the overall bridge system.

2. When a deck is designed as a composite section with the steel superstructure, it effectively serves as:

- a) Part of the web of the girder.
- b) Part of the top flange, contributing to strength and stiffness.
- c) A sacrificial layer only.
- d) The primary source of seismic damping.

Answer: (b). In composite construction, the deck acts as an integral part of the top flange of the supporting members, allowing its properties to be utilized for both strength and stiffness.

3. What is the primary factor that causes local flexural bending in the transverse direction of the deck?

- a) Longitudinal thermal expansion.
- b) Vehicular wheel loads.
- c) Wind loads on the bridge railing.
- d) Self-weight of the steel girders.

Answer: (b). Transverse flexural bending occurs as the slab spans over the girders, primarily caused by the local application of vehicle wheel loads.

Module 2: Concrete Deck Slabs

Learning Objectives

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

- **Identify** the primary design requirements for concrete deck slabs, including minimum thickness and applicable limit states.
- **Evaluate** the differences between the Traditional (Equivalent Strip) and Empirical design methods.
- **Select** appropriate precast or cast-in-place construction techniques based on project constraints.
- **Calculate** minimum negative flexure reinforcement and crack control requirements for serviceability.

Executive Summary: Reinforced concrete deck slabs are the most common deck type for steel bridges, designed using either traditional flexural theory or empirical arching action models; they require a minimum thickness of 7 inches and specific reinforcement detailing to ensure durability against vehicular loads, collisions, and environmental corrosion.

Design Fundamentals

Reinforced concrete deck slabs are the standard choice for steel bridge superstructures. They are typically constructed using mild steel reinforcement in both longitudinal and transverse directions, though post-tensioning may be utilized for enhanced performance.

Design Requirements

- **Limit States:** Decks must be designed for dead and live loads at **Service and Strength limit states**.
- **Vehicular Collision:** AASHTO requires design for collision with railing systems at the **Extreme Event limit state**.
- **Fatigue:** Multi-girder bridges do not require investigation of the fatigue limit state for concrete decks.
- **Thickness:** The minimum concrete thickness is **7 inches**, excluding sacrificial wearing surfaces, unless specifically approved by the owner.

⚠ Safety Constraint: If the deck thickness is less than $1/20$ of the design span, you must consider using prestressing steel in the span direction to control cracking.

Traditional Design Method (Equivalent Strip Method)


The Traditional Design Method is based on the flexure of the deck in the transverse direction. It assumes the deck behaves as a transverse strip supporting truck axle loads.

Analysis Procedure

- **Beam Analog:** Treat the transverse strip as a continuous or simply supported beam with pinned supports at girder centerline webs.
- **Assumptions:** Deflection is assumed to be zero for the design procedure.
- **Widths:** Use distinct equivalent widths for overhangs, positive moment regions, and negative moment regions.
- **Live Load:** Analyze using classical beam theory with moving axle loads, including multiple presence factors and dynamic load allowance.

Reinforcement Design

- **Primary:** Perpendicular to traffic if supported by main girders.
- **Negative Moment Location:** For steel girders, design at **one-quarter of the flange width** from the support centerline.
- **Bottom Distribution Reinforcement:** Required in the secondary direction.

 **Calculation Note:** Calculate bottom distribution reinforcement as a percentage of primary reinforcement:

Equation:

$$Percentage = \frac{220}{S^{0.5}} \leq 67\%$$

Where:

- **Percentage** = bottom distribution reinforcement as a percentage of primary reinforcement, % (Maximum 67%)
- **S** = effective span length, ft



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