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Structural Behavior of Steel

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Module 1: Design Fundamentals

Learning Objectives

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

- **Identify** the relationship between AASHTO LRFD Specifications and fundamental structural behavior.
- **Evaluate** the role of engineering judgment in the application and extension of code provisions.
- **Analyze** how external factors such as fabrication and maintenance influence the selection of bridge systems.

Executive Summary: While the AASHTO LRFD Specifications provide a comprehensive framework for bridge design, they are not exhaustive; a deep understanding of fundamental structural behavior is required to properly interpret, apply, and extend these rules to complex engineering challenges.

Overview of Steel Bridge Behavior

The behavior of steel structures is an intricate field of study. This module serves as a technical guide to the **AASHTO (2010) Load and Resistance Factor Design (LRFD) Specifications** (5th Edition with 2010 Interims). The primary focus is the **structural form and function** of bridge systems and members, with a specific emphasis on **strength limit states**.

System Selection and Integration

Selecting the most cost-effective bridge structural system requires balancing fundamental behavior with practical project constraints. Designers must consider:

- **Economic Factors:** Overall material, fabrication, shipping, and construction costs.
- **Lifecycle Factors:** Maintenance requirements and long-term durability.
- **Interdependent Modules:** Steel bridge behavior is inextricably linked to:
    - **Load Models:** Physical loadings and actions the structure must resist.
    - **Structural Analysis:** Methods used to predict overall system response and individual component requirements.
    - **Limit States:** Serviceability, fatigue, redundancy, fracture control, and constructability.

The Role of Engineering Judgment

As noted by J.A.L. Wadell in 1916, no set of specifications can cover every possible scenario in bridge design. The science of bridge engineering is sufficiently profound that specifications cannot govern the scientific proportioning of every part of every structure.

⚠ **Safety Constraint:** Engineers must not rely solely on a literal reading of the code. AASHTO LRFD provisions often require a broad understanding of fundamental behavior to ensure proper interpretation and safe extension of the rules to unique design conditions.

💡 **Design Tip:** Use the AASHTO Specifications as a rigorous baseline, but always apply engineering judgment to settle points that the specifications do not thoroughly cover.

Scope of the Module

This guide integrates AASHTO provisions with recent advances from the **AISC (2010) Specification for Structural Steel Buildings** and modern research developments. It aims to bridge the gap between theoretical behavior and practical code application for the following components:

- Steel system strength.
- Individual member strength and stability.
- Interpretation of strength limit states.

Checkpoint Quiz

1. **According to the text, why is engineering judgment considered essential despite the comprehensive nature of the AASHTO LRFD Specifications?**
    a) Because the specifications are updated too frequently to be reliable.
    b) Because no specification can cover the entire field or all parts of every structure.
    c) Because the specifications only apply to rolled I-sections.
    d) Because the specifications are intended for buildings, not bridges.

Answer: (b). The science of bridge design is so intricate that it is impossible for any code to cover all aspects; judgment is required to handle points not thoroughly covered by rules.

2. **Which of the following factors is described as being "inextricably tied" to steel bridge behavior?**
    a) Architectural aesthetics.
    b) Local zoning laws.
    c) Physical loadings and structural analysis.
    d) Historical bridge naming conventions.

Answer: (c). The text states that behavior is tied to physical loadings (actions), load models, and the analysis of structural systems to predict responses.

Module 2: Behavior and Structure Types

Learning Objectives

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

- **Classify** steel highway bridges based on span length and structural behavior.
- **Evaluate** the technical limits and efficiency of various stringer systems, including rolled I-sections and welded plate girders.
- **Analyze** the fundamental behavior of complex systems such as box-girders, trusses, arches, and cable-supported bridges.

Executive Summary: Bridge classification by span length is the most relevant method for understanding structural behavior. While stringer systems dominate shorter spans (up to 400 ft), reaching longer distances requires a transition to "open" webs and axially-loaded components found in trusses, arches, and cable-supported systems.

Rolled I-Section Stringer Systems

For spans less than 100 feet, **rolled I-section members** are typically the most economical choice. At these lengths, simplicity, standardization, and speed of construction outweigh structural efficiency in cost-benefit analyses.

Technical Constraints and Extensions

- **Span Limits:** Simple-span I-beams start to face flexibility and vibration issues as the span-to-depth ratio (**L/Dtotal**) exceeds 25.
- **Continuity:** Performance can be extended to **L/Dtotal** ratios of approximately 35 by establishing continuity through:
    - Composite action with concrete decks.
    - Use of continuous spans.
    - Making I-beams integral with substructure piers.

General I-Section Stringer Systems

Overview

Welded plate I-girders become attractive at the upper range of rolled I-beam spans and are highly effective for longer distances.

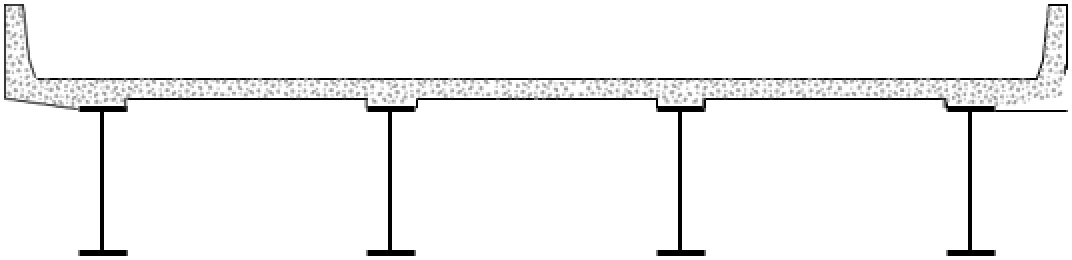

Figure 1: Typical composite rolled I-beam or welded I-girder bridge cross-section.

Deck Design and Spacing

- **Empirical Design:** AASHTO Article 9.7.2 allows empirical design for cast-in-place slabs with girder spacing (**S**) up to 13.5 feet or **S/ts** = 18.
- **Girder Spacing Efficiency:** Wider spacing can eliminate entire girder lines, cross-frames, and bearings. While this increases deck thickness, it often reduces overall labor and material costs.
- **Shear Lag and Effective Width:** Modern provisions (AASHTO 2010) use the **full tributary width** for resistance calculations, as studies show slab thickness has a negligible relationship with effective width in ordinary stringer systems.

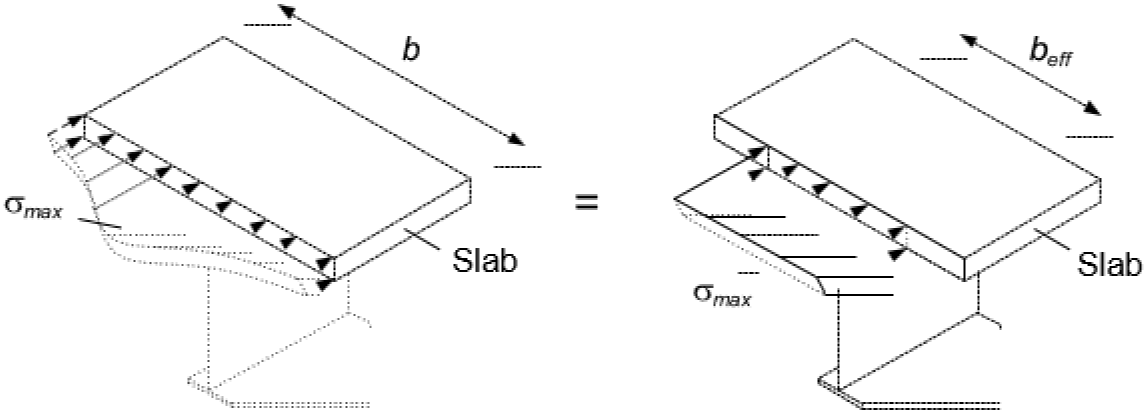

Figure 2: Effect of Shear lag.

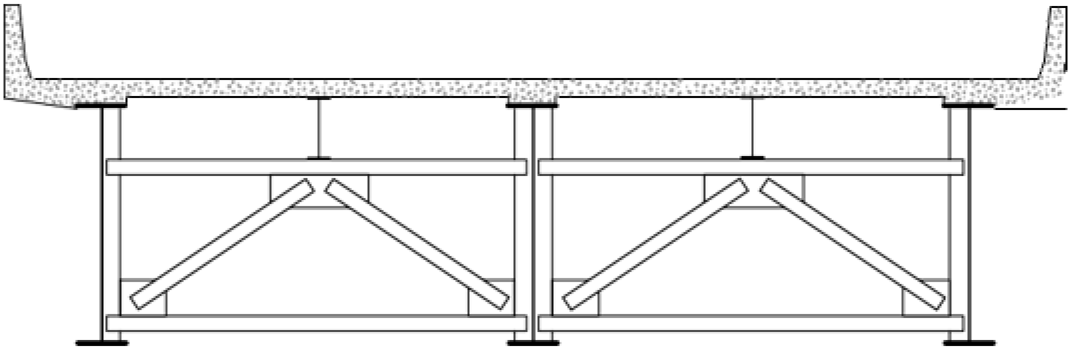

Figure 3: Typical composite I-girder substringer system.

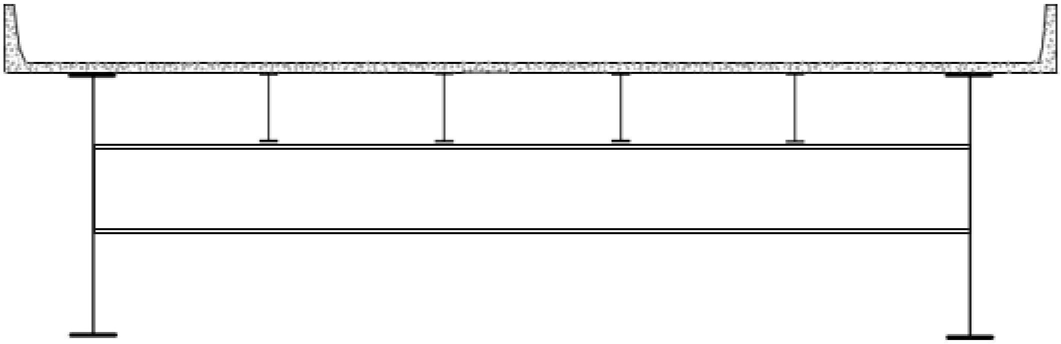

Figure 4: Two-girder system with floor beams and stringers.

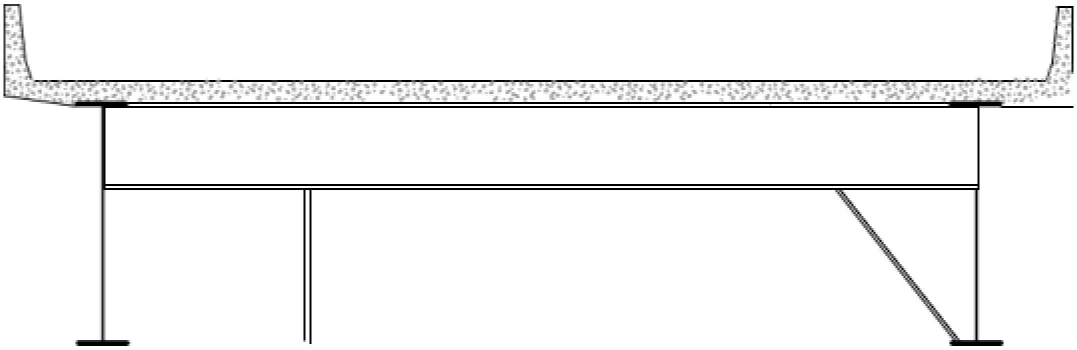

Figure 5: Two-girder system with cross-girders.