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## Bridge Design - Steel Plate Girders

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## Module 1: Steel Plate Girders

### Learning Objectives

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

- **Evaluate** span and framing configurations to optimize the structural efficiency of steel plate girder bridges.
- **Calculate** section proportions for webs and flanges in accordance with AASHTO LRFD specifications.
- **Determine** factored moments, shears, and support forces for strength, service, and fatigue limit states.

*Executive Summary:* Steel I-sections represent the most effective solid section for resisting bending and shear in short to medium span bridges. Successful design requires a rigorous application of composite action principles, balancing structural steel grades (typically ASTM A 709) with concrete deck slab properties. Professionals must meticulously manage span arrangements, girder spacing, and limit state requirements—including strength, serviceability, fatigue, and constructibility—to ensure long-term structural integrity and economic viability.

### Introduction

Girder bridges are structurally the simplest and most commonly used for short to medium spans. Steel I-sections are highly effective for resisting bending and shear. This module focuses on straight composite steel-concrete plate girder bridges, presenting design considerations for span arrangement, framing, and section proportioning.



**Figure 1.1-1:** Central Viaduct in San Francisco


## Structural Materials

### Structural Steel

Commonly used structural steels include **ASTM A 709** or **AASHTO M 270** (Grades 36, 50, 50S, 50W, HPS 50W, HPS 70W, and 100/100W).

### Concrete

Concrete with a 28-day compressive strength of  $f'_c = 3.6$  ksi is standard for deck slab construction.

 **Calculation Note:** For normal weight concrete ( $f'_c = 3.6$  ksi), use a modular ratio  $n = \frac{E}{E_c} = 8$

### Modular Ratio Application

- **n:** Used for transient loads applied to short-term composite sections.
- **3n:** Used for permanent loads applied to long-term composite sections (to account for concrete creep).

## Span and Framing Arrangement

### Span Configuration

Optimizing span arrangement is critical for cost-effectiveness.

- **Preferences:** Three- and four-span continuous systems are preferred over two-span systems due to lower negative moments.
- **Efficiency:** End span lengths should be approximately **70% to 80%** of interior span lengths.
- **Constraint:** Avoid configurations that result in uplift due to live load plus impact.

### Girder Spacing

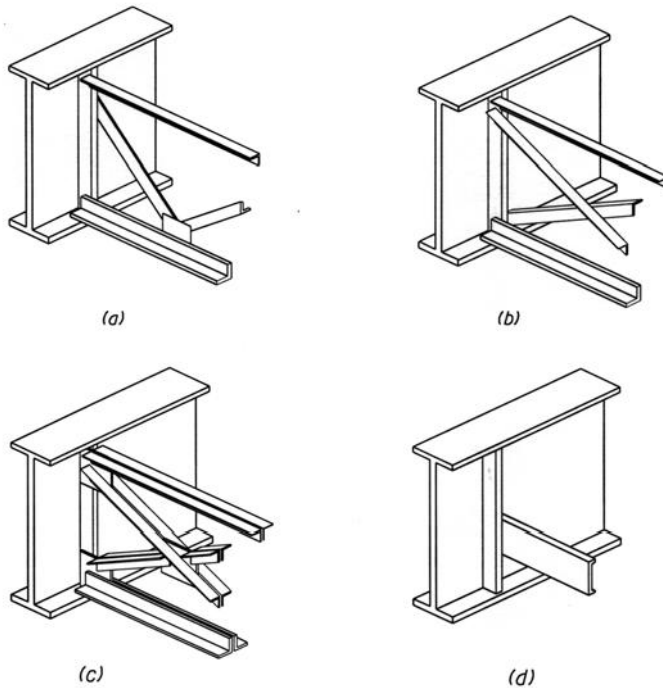
- **Economic Range:** 11 ft. to 14 ft.
- **Short Spans (< 140 ft.):** 10 ft. to 12 ft. preferred.
- **Long Spans (> 140 ft.):** 11 ft. to 14 ft. recommended.
- **Metal Deck Forms:** Limit spacing to approximately 16 ft.

### Diaphragms and Cross Frames

Intermediate cross frames provide bracing against **lateral torsional buckling** during erection and concrete placement. End cross frames transmit lateral wind and seismic loads to the bearings.

## Spacing and Orientation

- **Traditional Limit:** 25 ft. (AASHTO Standard).
- **Modern LRFD:** Requires **rational analysis** for all construction stages and final conditions.
- **Skewed Bridges:** Place parallel to skew up to 20 degrees; normal to girders for skews > 20 degrees.



**Figure 1.3-1:** Typical Diaphragms and Cross Frames

**⚠ Safety Constraint:** Diaphragms/cross frames must be as deep as practicable. They shall be at least **0.5** of the beam depth for rolled beams and **0.75** of the girder depth for plate girders.

## Lateral Bracing

Avoid bottom chord lateral bracing if possible, as it creates **fatigue-sensitive details**. Instead, size flanges sufficiently to preclude the need for extra bracing.

## Field Splice Locations

Locate splices near points of **dead load contraflexure** and section changes. Spacing should exceed 50 ft.

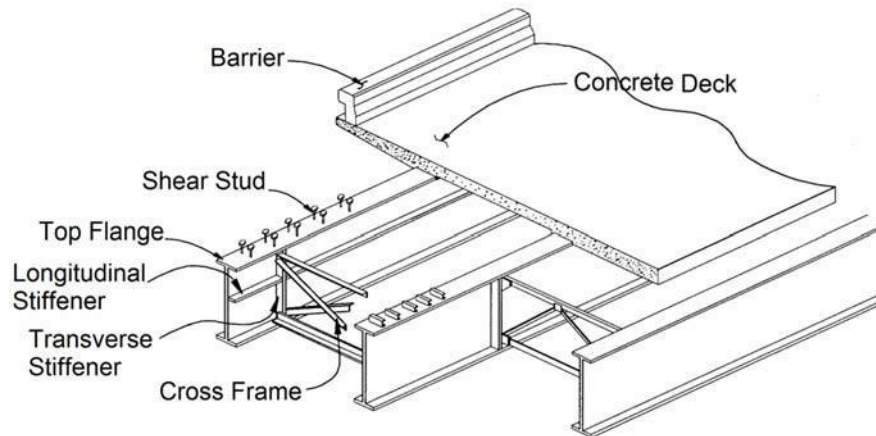
- **Shipping limits:** Length < 125 ft.; Weight < 40 tons.
- **Method:** Field splices should always be **bolted**. Welded field splices are prohibited.

## Section Proportion

### Depth to Span Ratios

Standard minimum ratios for the steel portion:

- **Simply Supported:** 0.033
- **Continuous:** 0.027



**Figure 1.4-1:** Components of Typical I-Girder Bridge

## Webs

Webs primarily provide shear strength. To prevent distortion from welding, web thickness should not be less than **0.5 inch**.

⚠ **Safety Constraint:** Maintain the following depth-to-thickness ratios ( $\frac{D}{t_w}$ ):

- **Without Longitudinal Stiffeners:**  $\frac{D}{t_w} \leq 150$
- **With Longitudinal Stiffeners:**  $\frac{D}{t_w} \leq 300$

## Flanges

Flanges provide bending strength and should be at least **12 inches** wide.

💡 **Design Tip:** Maintain constant flange width throughout the girder length and change thickness instead of width at splices to optimize fabrication.

### Proportion Limits (AASHTO 6.10.2.2)

1.  $\frac{b_f}{2t_f} \leq 12$
2.  $b_f \geq \frac{D}{6}$
3.  $t_f \geq 1.1t_w$
4.  $0.1 \leq \frac{I_{yc}}{I_{yt}} \leq 10$

#### Where:

- **bf** = Full width of flange (in)
- **tf** = Thickness of flange (in)
- **tw** = Web thickness (in)
- **D** = Web depth (in)
- **I<sub>yc</sub>** = Moment of inertia of compression flange about vertical axis (in<sup>4</sup>)
- **I<sub>yt</sub>** = Moment of inertia of tension flange about vertical axis (in<sup>4</sup>)

### Structural Modeling and Analysis

Girders are typically modeled as beam elements. Stiffness assumptions:

- **Non-composite:** Steel section only.
- **Long-term composite:** 3n properties for permanent loads.
- **Short-term composite:** n properties for transient loads.

### Design Limit States

Design must satisfy:

- **Strength I/II:** Ultimate load capacity.
- **Service II:** Control of elastic/permanent deflections.
- **Fatigue I/II:** Resistance to crack initiation.
- **Constructibility:** Stability during the bridge build.



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