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Mechanical Properties of Bridge Steels

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Module 1: Introduction

Learning Objectives

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

- **Identify** the unique performance requirements that distinguish bridge steels from general structural steels.
- **Evaluate** the environmental and loading factors that necessitate the use of ASTM A 709 specifications.
- **Select** appropriate material properties to address fatigue, fracture, and corrosion limit states in bridge design.

Executive Summary: Bridge steels require more stringent performance standards than building steels due to exposure to outdoor temperature swings, millions of fatigue cycles, and corrosive chlorides; they must specifically satisfy Fatigue and Fracture limit states and often provide enhanced atmospheric corrosion resistance.

Design Fundamentals for Bridge Steels

Structural steels utilized in bridge engineering are subject to rigorous performance demands that exceed those of typical building applications. While all structural steels must meet baseline **strength and ductility** requirements, bridge materials must be resilient against specific environmental and mechanical stressors.

Critical Environmental and Loading Factors

- **Thermal Variations:** Materials must perform reliably across relatively large temperature changes in an outdoor environment.
- **Cyclic Loading:** Components are subjected to millions of cycles of live loading over their service life.
- **Corrosive Exposure:** Structures are frequently exposed to environments containing chlorides and other corrosive agents.

Essential Limit States

- **Fatigue and Fracture:** Unlike general applications, bridge steels must provide adequate service life regarding the **Fatigue and Fracture limit state**.
- **Enhanced Corrosion Resistance:** In many applications, steel must provide atmospheric corrosion resistance to function effectively without expensive protective coatings.

Course Scope and Material Focus

This module is developed from a **structural engineer's perspective**, prioritizing the performance aspects of structural steel over theoretical metallurgy.



Primary Material Specifications

- **ASTM A 709:** The core focus remains on steel plate and rolled shape products available under this specification.
- **Ancillary Products:** This course also introduces related components including **bolts, castings, cables, and stainless steels** commonly used in bridge connections.
- **Standards Governance:** Detailed references are provided for both **AASHTO and ASTM** standards to ensure code compliance.

Performance Assessment Methodology

1. **Stress-Strain Behavior:** Analysis of various steel grades to understand strength and ductility.
2. **Fracture Toughness:** Application of the **Charpy vee-notch (CVN)** test to determine fracture resistance in the field.
3. **Weathering Steel Classification:** Methodologies for determining atmospheric corrosion resistance for un-coated applications.

💡 **Design Tip:** When designing for bridge applications, always verify if the specific environment (such as high-chloride coastal areas) requires corrosion resistance that exceeds the standard ASTM A 709 "weathering" properties.

⚠️ **Safety Constraint:** Engineers shall ensure that selected materials satisfy the **Fatigue and Fracture limit state** as defined by current AASHTO standards, as these requirements are typically more stringent than those for general structural applications.



Checkpoint Quiz

1. Which factor is a primary reason bridge steels require higher fracture toughness than general structural steels?

- a) Higher initial cost of materials.
- b) Exposure to millions of cycles of live loading.
- c) The need for a specific aesthetic finish.
- d) Reduction in the required yield strength.

Answer: (b). Bridge structures are unique because they must endure constant, repetitive live loads over decades. This creates a high risk for the **Fatigue and Fracture limit state**, where small cracks could propagate and lead to brittle failure. To prevent this, bridge steels are engineered with higher fracture toughness—a material's ability to resist the growth of a crack—ensuring safety under these cyclic loading conditions.

2. According to the text, the ASTM A 709 specification is the primary focus for which of the following products?

- a) Concrete reinforcement bars.
- b) Steel plate and rolled shapes.
- c) Aluminum bridge railings.
- d) Timber deck connectors.

Answer: (b). ASTM A 709 is the standard specifically established to cover the carbon and high-strength low-alloy steel structural shapes, plates, and bars used in the construction of bridges. While other ASTM standards exist for general construction, A 709 incorporates additional requirements—such as mandatory Charpy V-Notch impact testing—to ensure the plates and shapes can handle the specific environmental and mechanical stresses of a bridge.



Module 2: Product Specifications

Learning Objectives

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

- **Contrast** the roles and membership structures of ASTM and AASHTO in governing bridge steel standards.
- **Select** appropriate steel grades and fastener types based on yield strength, atmospheric corrosion resistance, and product category.
- **Evaluate** the application of specialty materials, including HPS, stainless steel, and ductile iron, for specific bridge components.

Executive Summary: In the U.S., bridge steel is governed by dual standards from ASTM and AASHTO; while these are largely identical, AASHTO maintains independent standards to allow modifications in the public interest. Engineers must navigate a variety of grades—ranging from standard Grade 36 to high-performance and stainless varieties—each with specific mechanical properties and fabrication constraints.

Governance of Structural Steel Standards

Standards for structural steel in the U.S. are published by two primary organizations. While their requirements often overlap, their institutional focuses differ.

- **ASTM (American Society for Testing and Materials):** A non-profit voluntary organization. Subcommittee A01.02 holds primary responsibility for bridge steels, utilizing a membership of experts from industry, government, and academia.
- **AASHTO (American Association of State Highway Transportation Officials):** Develops standards through committees comprised solely of government officials responsible for highway system maintenance.

Dual Standards Rationale

AASHTO maintains independent standards to retain the right to modify ASTM requirements if determined to be in the public's interest. Most bridge owners specify AASHTO adherence in construction documents, though ASTM is also used.

Table 1: Cross reference between AASHTO and ASTM standards for bridge steel products

Product	AASHTO Specifications	ASTM Specifications
Structural Steel for Bridges	M 270 / M 270M	A 709 / A 709M
Structural Stainless Steel		A 1010
Cold-Formed Welded or Seamless Tubing		A 500 Grade B
Hot-Formed Welded or Seamless Tubing		A 501
Pins, Rollers, and Rockers	M 169 M 102 / M 102M	A 108 A 668 / A 668M
Bolts	M 164 M 253	A 307 Grade A or B A 325 A 490 F 1852
Galvanized Structural Bolts	M 232 / M 232M Class C M 298 Class 50	A 153 / A 153M B 695
Anchor Bolts	M 314 - 90	A 307 Grade C F 1554
Nuts	M 291	A 563
Washers	M 293	F 436 F 959
Shear Studs	M 169	A 108
Cast Steel	M 103 / M 103M M 163 / M 163M	A 27 / A 27M A 743 / A 743M
Ductile Iron		A 536
Malleable Castings		A 47 Grade 35018
Cast Iron	M 105 Class 30	A 48 Class 30
Stainless Steel		A 176 A 240 A 276 A 666
Cables		A 510
Galvanized Wire		A 641
Epoxy Coated Wire		A 99
Bridge Strand/ Bridge Rope		A 586 A 603
Wire Rope	M 277	
Seven-Wire Strand	M 203 / M 203M	A 416 / A 416M
High Strength Steel Bar	M 275 / M 275M	A 722 / A 722M

Structural Plate and Rolled Shapes

ASTM A 709 is the standalone specification for main bridge members, established in 1974. The numerical designation indicates the nominal yield strength in ksi.



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