Chapter 6
Steel Bridge Design Handbook

STRUCTURAL BEHAVIOR OF STEEL

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Chapter 6 Emphasis

- Background and guide to AASHTO (2010) Chapter 6
  - Structural form and function of bridge systems & members
  - Strength limit states
- Discussion of recent advances in AASHTO & AISC provisions
- Findings from research developments

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1. Introduction

- Scope
- Cross-References to other Chapters
- Wadell (1916)

  "There are No Bridge Specifications Yet Written, and there Probably Never Will be Any, which will Enable an Engineer to Make a Complete Design for an Important Bridge without Using His Judgment to Settle Many Points which the Specifications Do Not Thoroughly Cover… the science of bridge-designing is such a profound and intricate one that it is absolutely impossible in any specification to cover the entire field and make rules governing the scientific proportioning of all parts of all structures."

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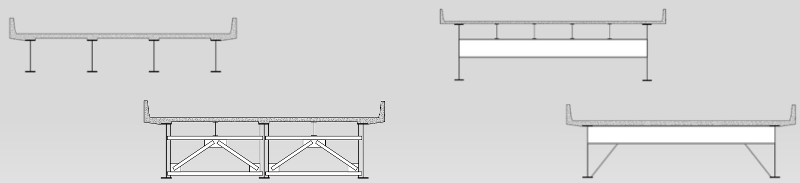
2. Behavior and Structure Types

- I-Section Stringer Systems
  - Framing arrangements



  - Shear lag and slab effective width
  - Fundamental curved and skewed bridge behavior
  - Flange level lateral bracing
  - Integral piers and abutments
  - Temperature movements

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2. Behavior and Structure Types

- Box-Section Stringer Systems
  - Box-girder response to flexure & torsion
  - Importance of top-flange bracing in tub girders

Sfalassà Viaduct in
Calabria, Italy
(1230 ft main span)

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2. Behavior and Structure Types

- Truss Bridges

Ikitsuki Ohashi Bridge, Nagasaki, Japan (1300 ft main span)

Quebec Bridge, Quebec, Canada (1800 ft main span)

La Roize Bridge, France

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2. Behavior and Structure Types

- Arch Bridges

Lupu Bridge, Shanghai, China (1800 ft main span)

New River Gorge Bridge, WV (1700 ft main span)

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2. Behavior and Structure Types

- Cable-Stayed Bridges

Sutong Bridge, Jiangsu, China (3570 ft main span)

Arthur Ravenel Jr. Bridge, Charleston, SC (1550 ft main span)

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2. Behavior and Structure Types

- Suspension Bridges

Alashi Kaikyo Bridge, Japan (6530 ft main span)

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3. Elastic System Analysis, Inelastic Component Resistances

- Restrictions to ensure validity of elastic design
- AASHTO (2010) Article 4.1

  "The primary objective in the use of more sophisticated methods of analysis is to obtain a better understanding of the structural behavior. Such improved understanding may often, but not always, lead to the potential for saving material.... With rapidly improving computing technology, the more refined and complex methods of analysis are expected to become commonplace. Hence, this section addresses the assumptions and limitations of such methods. It is important that the Engineer understand the method employed and its associated limitations."

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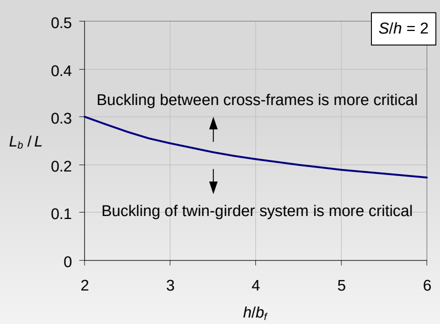
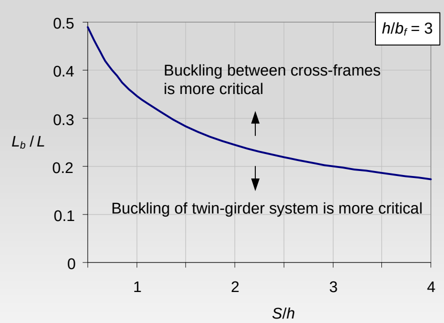
4. Overall System Buckling vs. Individual Member Buckling

- Global buckling of I-girder systems





- Lean-on bracing systems

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4. Overall System Buckling vs. Individual Member Buckling

- Hardy Cross (1952)

"Various sources aid the engineer in determining strength. No one of them is more important than another. Analyses, tests, experience and such intuitive common sense as may be personally developed about structural stability; these are all helpful, but they can also be dangerously misleading. Evidence from the four sources rarely agrees completely. Great engineers are those who can weigh this evidence and arrive at a reasonable answer through judgment as to its dependability…."

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Section 5

MEMBER BEHAVIOR & DESIGN STRENGTH

5.1 Tension Members

- Rolled or built-up tension members
- Eyebars and pin-connected plates
- Strands

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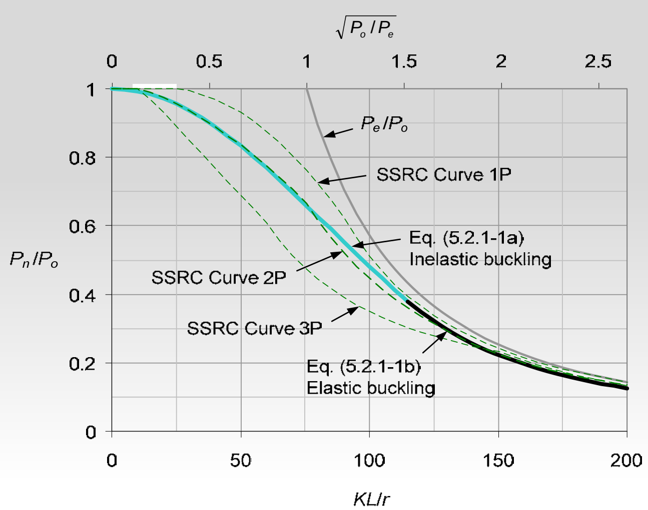
5.2 Compression Members

- Base column strength equations



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5.2 Compression Members (cont'd)

- Flexural buckling & column effective length
- Torsional buckling of doubly-symmetric sections
- Flexural or torsional-flexural buckling of singly-symmetric sections
- Torsional-flexural buckling of general unsymmetric sections
- Differences between AASHTO & AISC torsional-flexural buckling calculations
- Special handling of single-angle compression members

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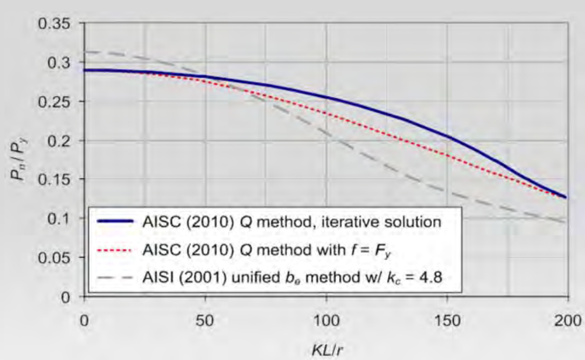
5.2 Compression Members (cont'd)

- Columns with slender elements



- Axial capacity of hybrid slender-web girders
- Axial capacity of composite bridge girders
- Local buckling criteria for solid-web arch ribs

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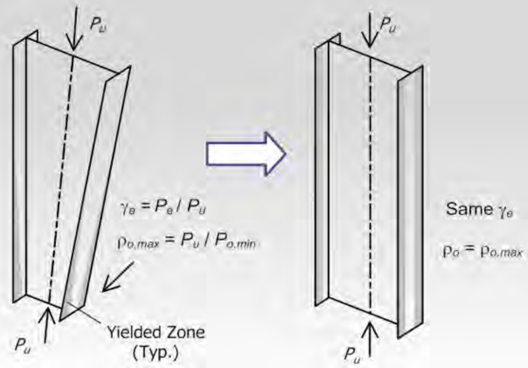
5.2 Compression Members (cont'd)

- Built-up columns composed of two or more shapes
- Columns with tapered and/or stepped sections and/or nonuniform internal axial force



- Composite columns, AISC (2010) & AASHTO (2010)

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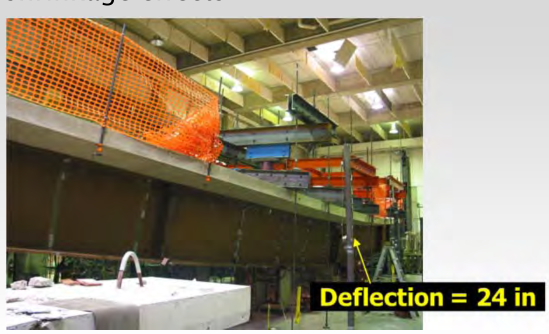
5.3 I-Section Flexural Members

- AASHTO proportioning limits
- Compact composite sections in positive flexure
  - Section classification
  - Flexural resistance
  - Creep & shrinkage effects



- Noncompact sections in postive flexure

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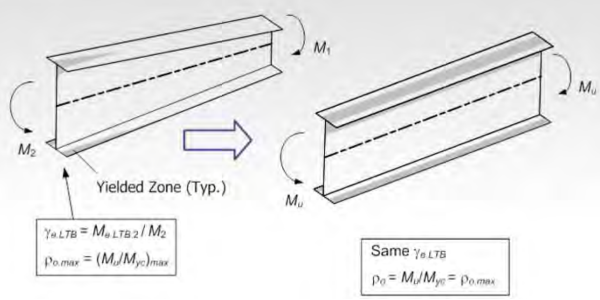
5.3 I-Section Flexural Members

- Composite sections in negative flexure & noncomposite sections
  - Key concepts
  - Moment gradient modifier, C_b, AASHTO & AISC procedures
  - LTB effective lengths
  - Inelastic redistribution in straight non-skewed bridges
  - Stepped, variable web depth & other nonprismatic members



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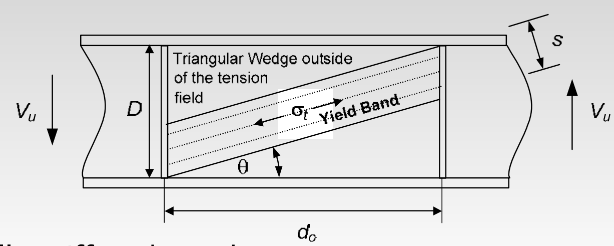
5.3 I-Section Flexural Members

- Combined major-axis bending, minor-axis bending & torsion
  - Key Concepts
  - Calculation of flange lateral bending stresses
- Shear Strength
  - Basler & True Basler tension field resistance



  - Longitudinally-stiffened members
  - Variable web depth members
  - Web transverse stiffener requirements

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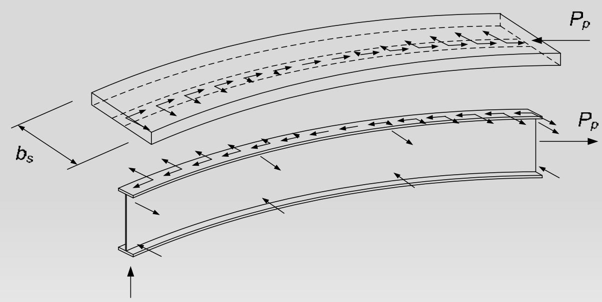
5.3 I-Section Flexural Members

- Shear connectors (horizontally-curved I-girders)



- Net section fracture resistance
- Web bend buckling
- Longitudinal stiffener requirements
- Bearing stiffener requirements
- Transverse web yielding and web crippling strength

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5.4 Box-Section Flexural Members

- Key concepts
- Requirements for simplified analysis & design
- Other general requirements
  - Diaphragm requirements at supports
  - Bearing requirements
  - Top lateral bracing requirements in tub girders
- Proportioning limits
- Composite sections in positive flexure
- Noncomposite sections & composite sections in negative flexure
- Bottom box flange at interior pier sections
- Variable web depth & other nonprismatic members
- Web shear strength
- Shear connectors

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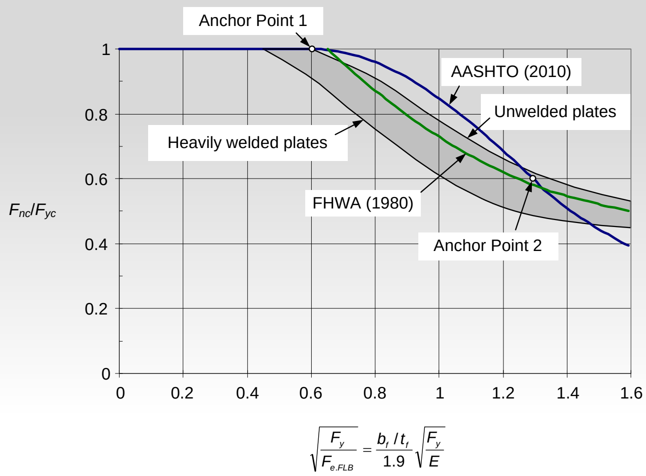
5.4 Box-Section Flexural Members

- Comparison with Wolchuk & Mayrbaurl (1980) proposed specifications for long-span steel box-girder bridges



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5.5 Miscellaneous Flexural Members

- I-section members in weak-axis bending
- Rectangular & circular tubes
- Tees & double-angles in major-axis bending
- Channels in major- and minor-axis bending
- Concrete encased & filled members

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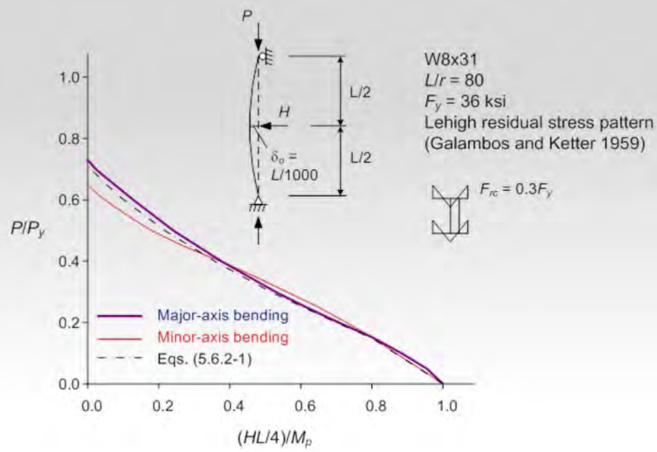
5.6 Combined Flexure & Axial Load

- Key concepts
- In-plane resistance of doubly-symmetric I-section members



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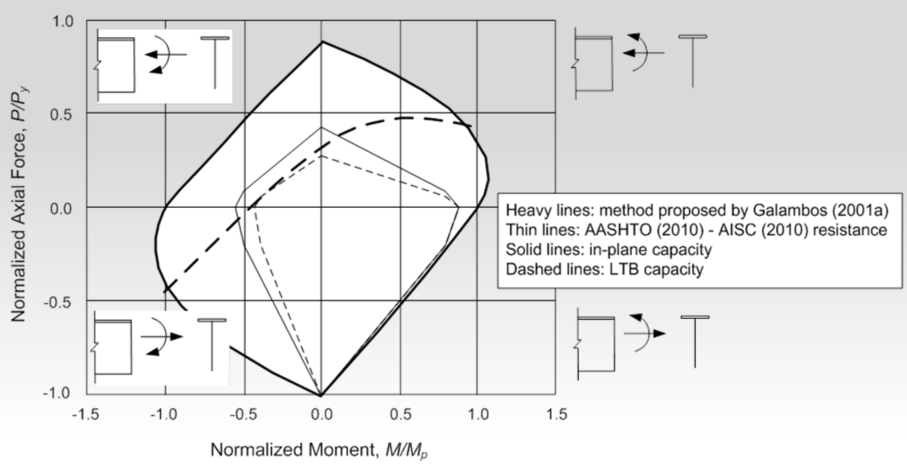
5.6 Combined Flexure & Axial Load

- Singly-symmetric open-section members subjected to axial load & flexure in the plane of symmetry



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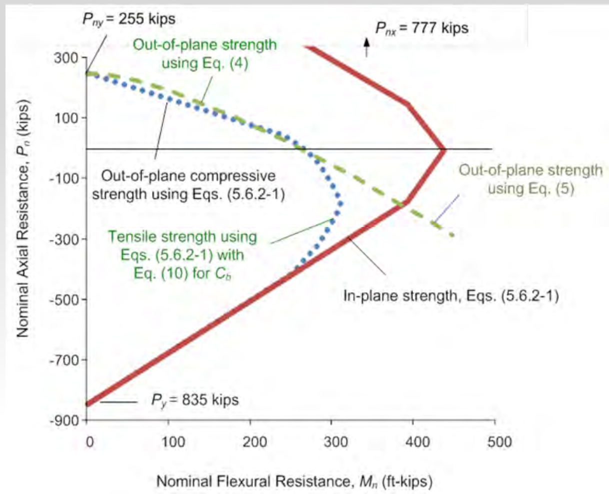
5.6 Combined Flexure & Axial Load

- Out-of-plane strength of doubly-symmetric non-slender element I-section members with $KL_z \leq KL_y$ subjected to axial load & major-axis bending



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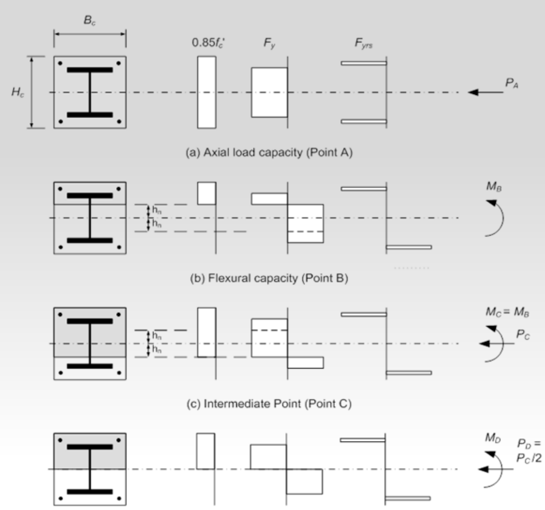
5.6 Combined Flexure & Axial Load

- Other beam-column types, general loading conditions
- Composite members, AASHTO (2010) & AISC (2010)



(a) Axial load capacity (Point A)
(b) Flexural capacity (Point B)
(c) Intermediate Point (Point C)
(d) Balance Point (Point D)

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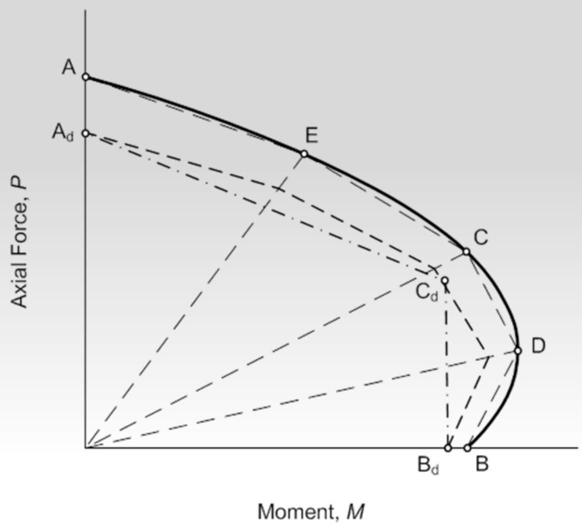
5.6 Combined Flexure & Axial Load

- Composite members, AASHTO (2010) & AISC (2010), cont'd



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References

- Extensive reference list…

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