Stability of Straight Steel Plate Girders in Construction

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Background:

Stability problems during superstructure construction is a rare occurrence, but can have large implications for a bridge project – delays, costs, and more.

Quick check methods are useful for:
- design engineers to check stability during design process.
- contractors to check girders for bidding
- construction engineers to review changes to a scheme

Background:

Stability of plate girders in erection based mostly on L/b ratio:

- L is distance between support points
- b is (compression) flange width

There are several tools available for detailed analysis of girder stability during construction.

Investigate methods for checking stability of plate girders in erection and discuss potential limitations of the methods.

Outline of Topics:

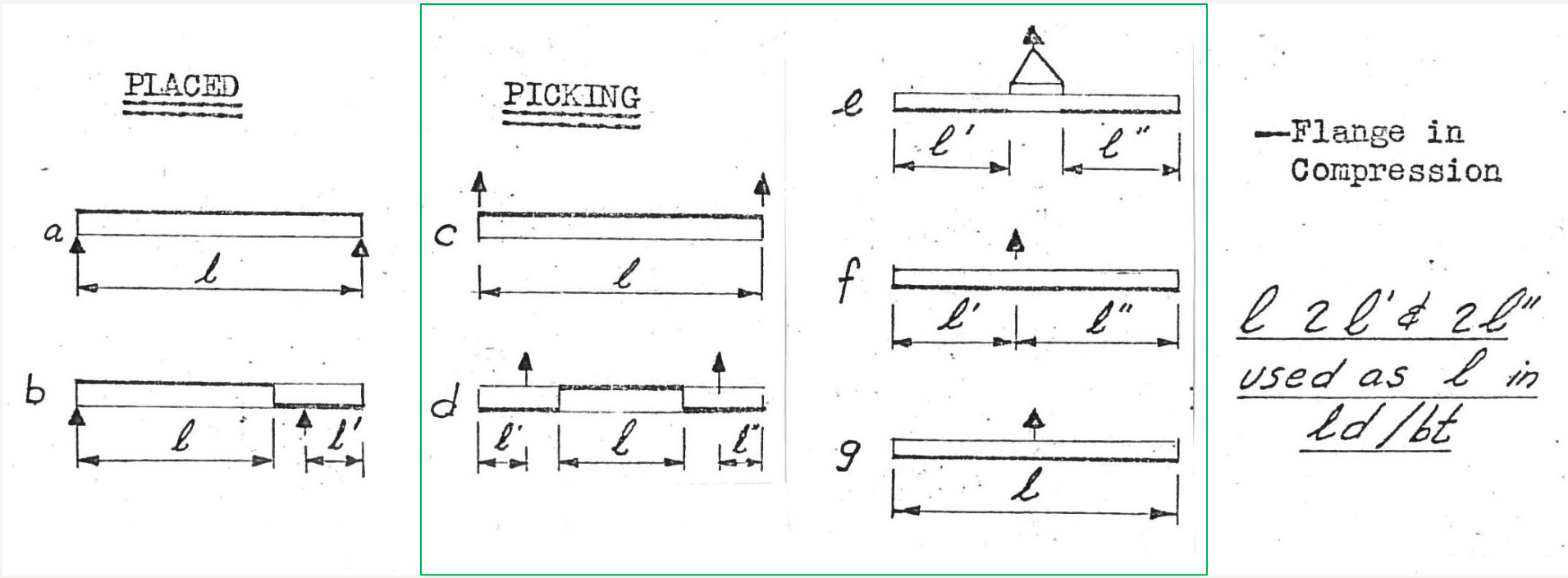
- Conditions during Construction
- Single Plate Girder Analysis Methods
- Equipment for Installing Plate Girders

Conditions during Construction:

- Picking and Placing of Girders
- Restraint at Lifting Points
- Wind Loads

Conditions during Construction:

Picking and Placing of Girders (deVries -1953)



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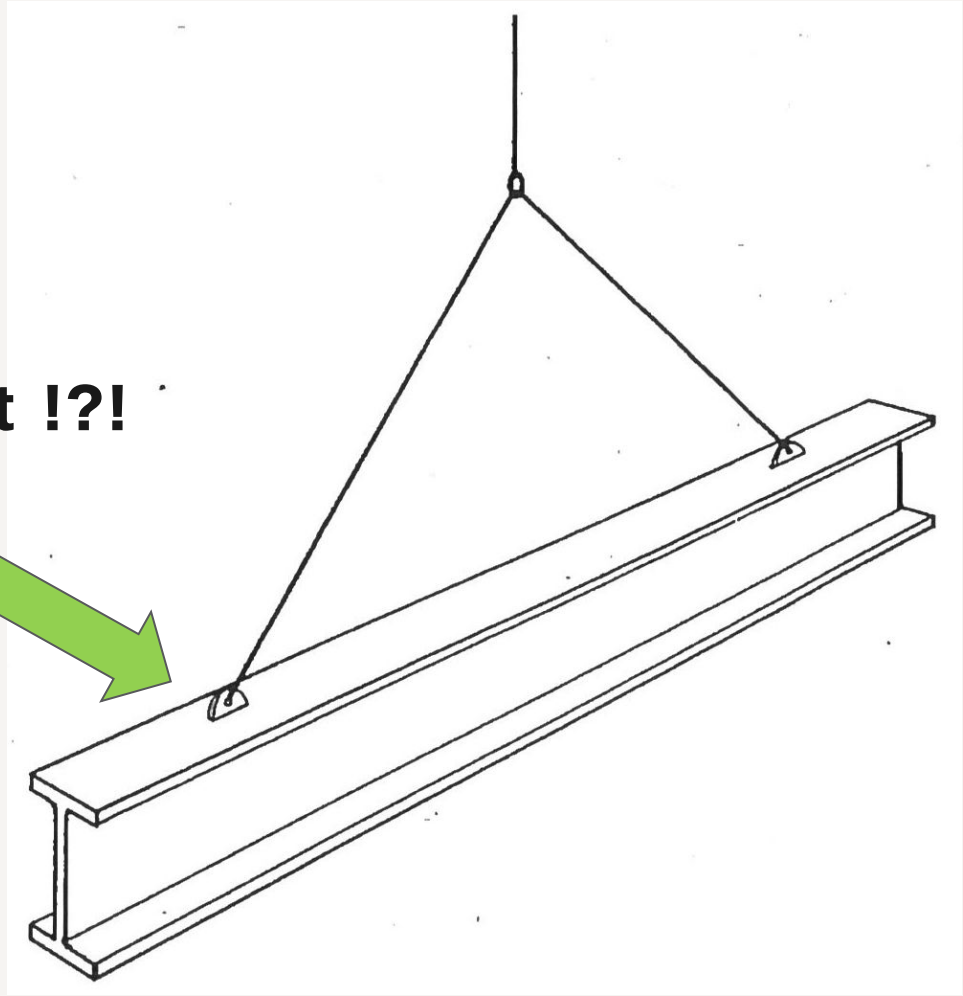
Conditions during Construction:

Restraint of Lifting Points



Conditions during Construction:

Restraint at Lifting Points!!

AASHTO/NSBA Steel Bridge Collaboration
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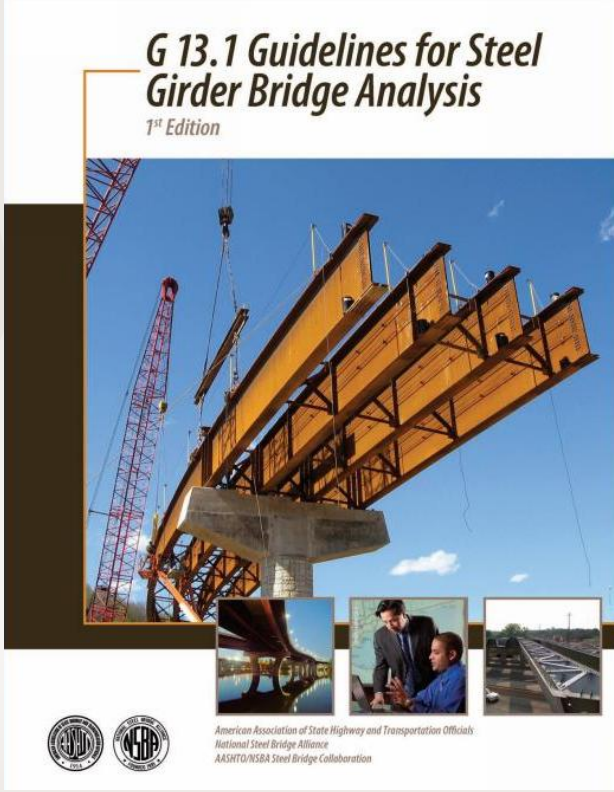
Pages 3-21 to 3-23



Stability of I-Beams under Self-Weight during Lifting
"Engineers should not apply traditional LTB equations and assume an unbraced length equal to the distance between the lifting lugs; this will result in an unconservative prediction in strength."

Conditions during Construction:

Wind Loads

Try to use construction wind loads that are appropriate for the:

- situation
- site location
- duration of the event
- loading combinations

Single Plate Girder Analysis Methods:

- Rule of Thumb
- AASHTO Based Simplified Boundary Formulas
- Hand Calculations with deVries Method
- FE Analysis
- Methods for Restraint Conditions

Single Plate Girder Analysis Methods:

› "Handbook for Construction Engineers"
US Steel Corp, 1983

Rules-of-Thumb:

For Simple Spans
- L/b of 60 or less, OK
- L/b of 60 to 80, may be OK
- L/b of 80 or more, need temporary support

For Cantilevers
- L/b of 30 or less, OK
- L/b of 30 to 40, may be OK
- L/b of 40 or more, need temporary support

Based solely on experience with no theoretical basis
Does not take into account effects of girder geometry
Use with caution!!!!

Single Plate Girder Analysis Methods:

"Convenient Method for On-Site Check of Single Steel I-Girder Stability During Erection"

Qiuhong Zhao, Sean Justin Coffelt, Tao Zou, Baolin Yu, Edwin G. Burdette, and John S. Hastings

Tennessee DOT & Univ. of Tennessee, Knoxville.

Single Plate Girder Analysis Methods:

Upper and Lower Bounds (Zhao et al)

Zhao et al (2010) used AASHTO LRFD code formulas for lateral torsional buckling and load combination Strength IV (1.5D) to refine the rules-of-thumb from Section 2.1 to values for as per Figures 2 and 3 below.

Upper bound:

$$\left(\frac{L}{b}\right)_{max} = \frac{5d}{b} + 57.5 \quad for \; 1.5 \leq \frac{d}{b} \leq 3.5$$

$$= 75 \qquad for \qquad 3.5 \leq \frac{d}{b} \leq 6.0$$

Lower bound:

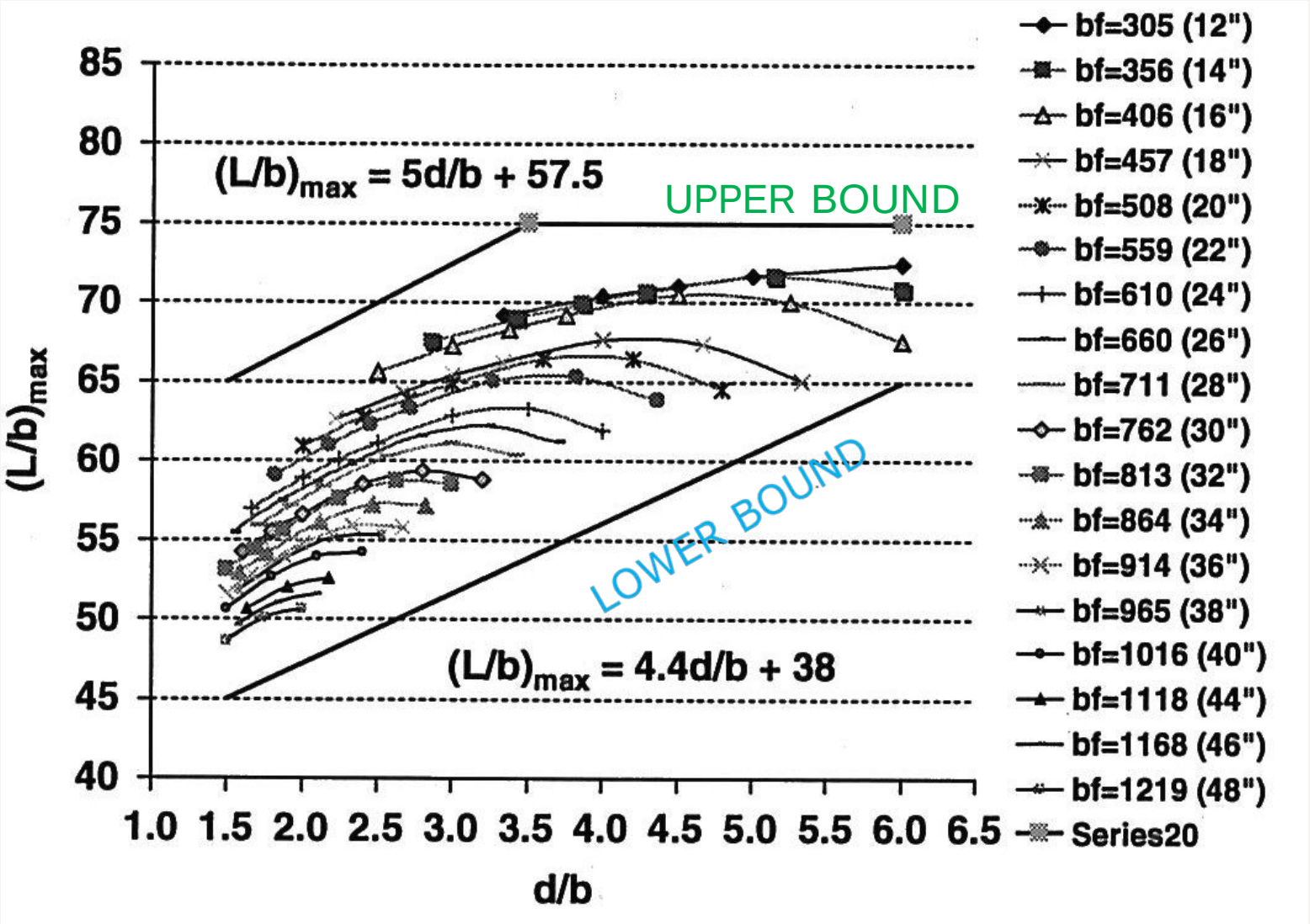
$$\left(\frac{L}{b}\right)_{max} = \frac{4.4d}{b} + 38 \quad for \; 1.5 \leq \frac{d}{b} \leq 6.0$$

Figure 3: Values for Upper & Lower Bounds of $(L/b)_{max}$ Ratio - Simply Supported Girder

The upper bounds identify the limit to which above the value the girder will require some form of temporary bracing to achieve stability. The lower bounds identify the limit to which below the value no check is needed for buckling stability.

Single Plate Girder Analysis Methods:

Envelope for Simply Supported Cases (Zhao et al)



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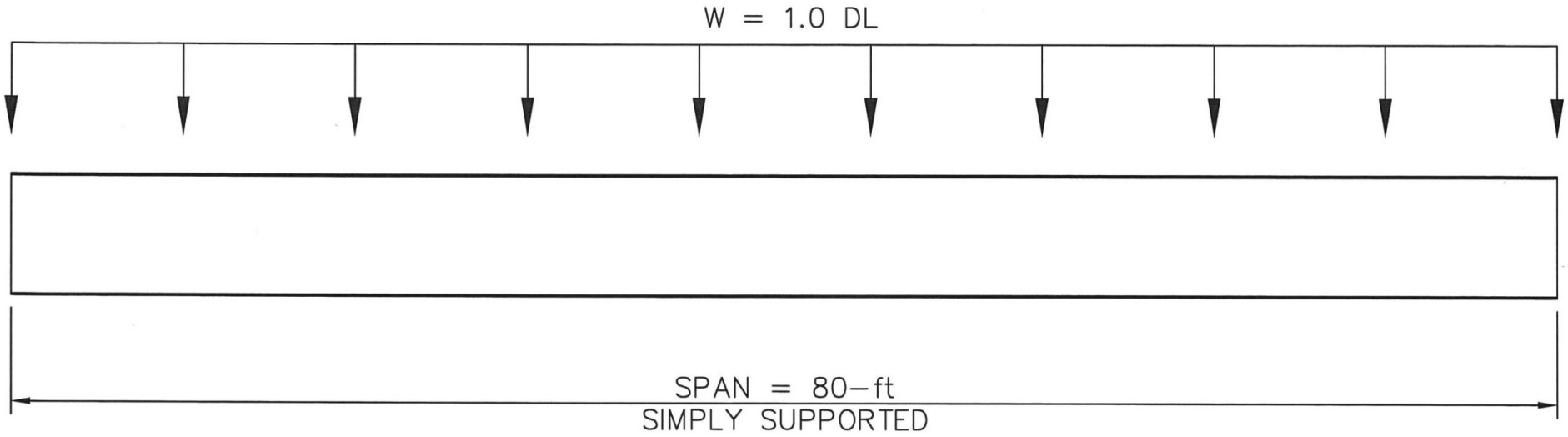
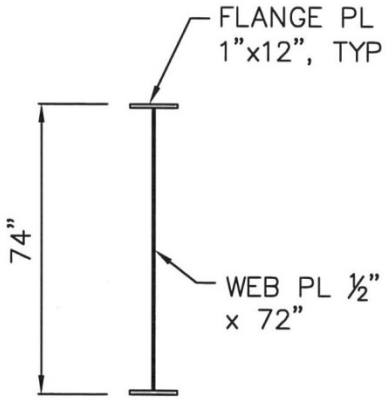
Single Plate Girder Analysis Methods:

Comparison



ELEVATION OF MODEL – PLATE GIRDER



SECTION

SPAN	L/b
80–ft	78.7
90–ft	88.5
100–ft	98.4

Single Plate Girder Analysis Methods:

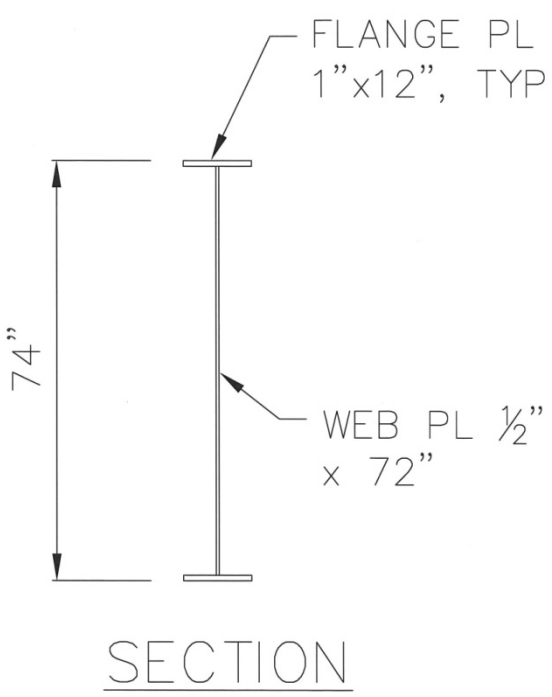
Hand Calculation – deVries Method

$f_{cr} = 24x10^6/(Ld/bt)$

$f_{cr} = 4.05$ ksi

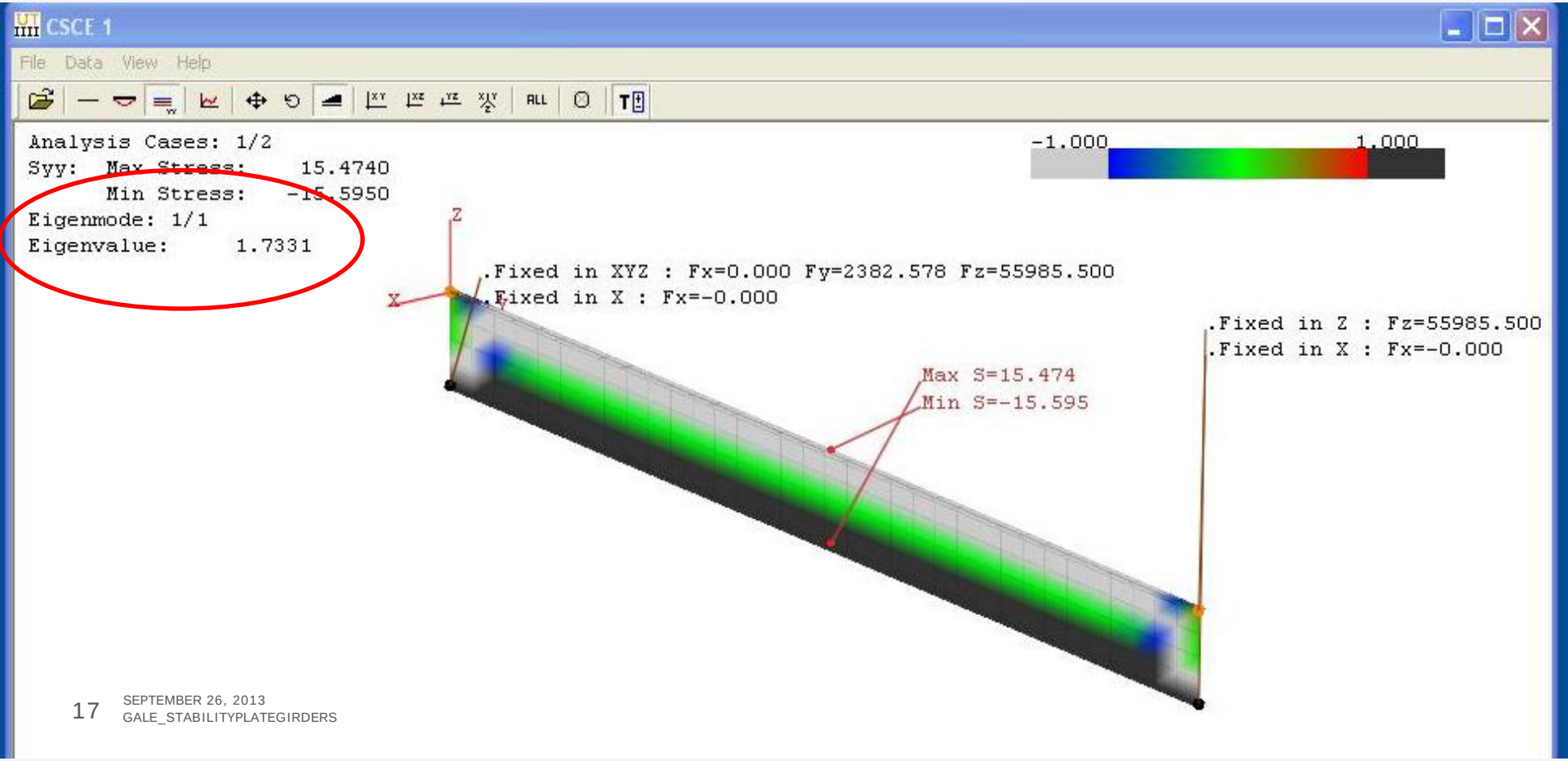
$f_b = 1.93$ ksi (DL Girder only)

OK -> "FOS" =4.05 ksi / 1.93 ksi = 2.10



Single Plate Girder Analysis Methods:

FE Analysis (UT Bridge) Comparison Model



Single Plate Girder Analysis Methods:

Restraint at Lifting Points!!

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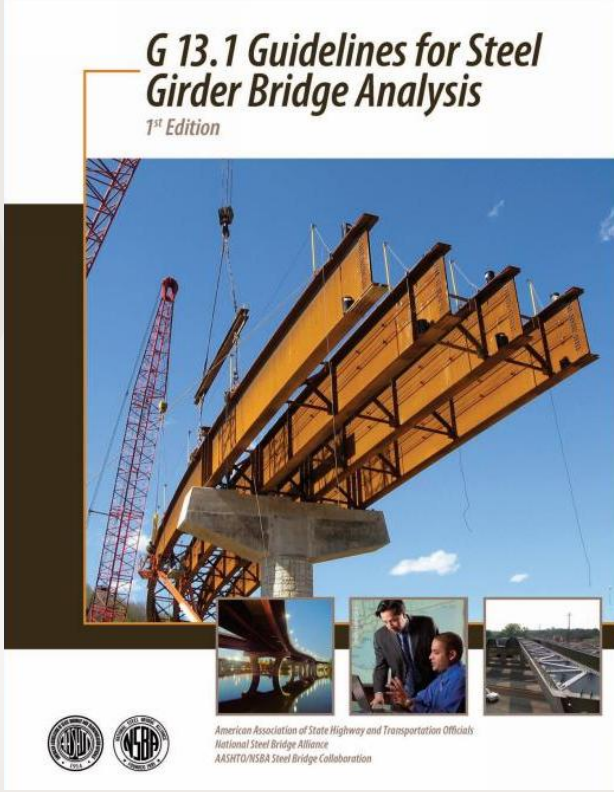

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Single Plate Girder Analysis Methods

Methods that Account for Restraint Conditions

Refer to:

- Guide to Stability Design Criteria for Metal Structures, Sixth edition, 2010, pg 228-230.
- Distortion Buckling of Steel Beams, Esa and Kennedy, 1993.
- Stability of I-beams under self-weight lifting, P.F. Dux and S. Kitipornchai, 1990.

Single Plate Girder Analysis Methods:

Methods for Restraint Conditions

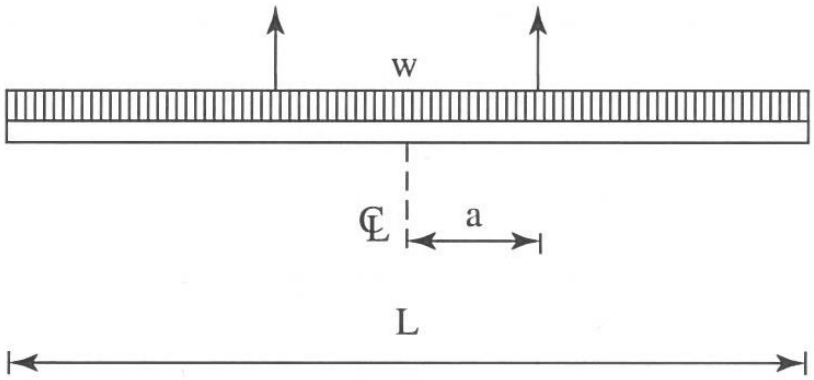

FIGURE 5.14 Doubly symmetric I-section member suspended from two vertical lifting cables.

buckling weight per unit length is approximated by the equation

$$w_{cr} = \frac{C\sqrt{EI_y GJ}}{L^3} \qquad (5.28)$$

Equipment:

- Spreader Beams
- Pier Brackets
- Stiffening Trusses
- Shoring Towers

Spreader Beams and Pier Brackets

Spreader Beam and Cross Frames

Pier Brackets and Permanent Bracing

Stiffening Truss and Cross Frames

Shoring Towers

Summary:

Bridge superstructures are supposed to be checked for constructability during design.

Potentially use L/b and d/b ratios with graphs for quick check to ask: Is further analysis needed?

Many methods available for detailed analysis. Use caution until familiar with the method.

Be wary of necessary restraints at supports and lift points and how this will affect the FOS for both girder picking and placement.

Double Girder Pick

Thank-you!!

Questions?

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