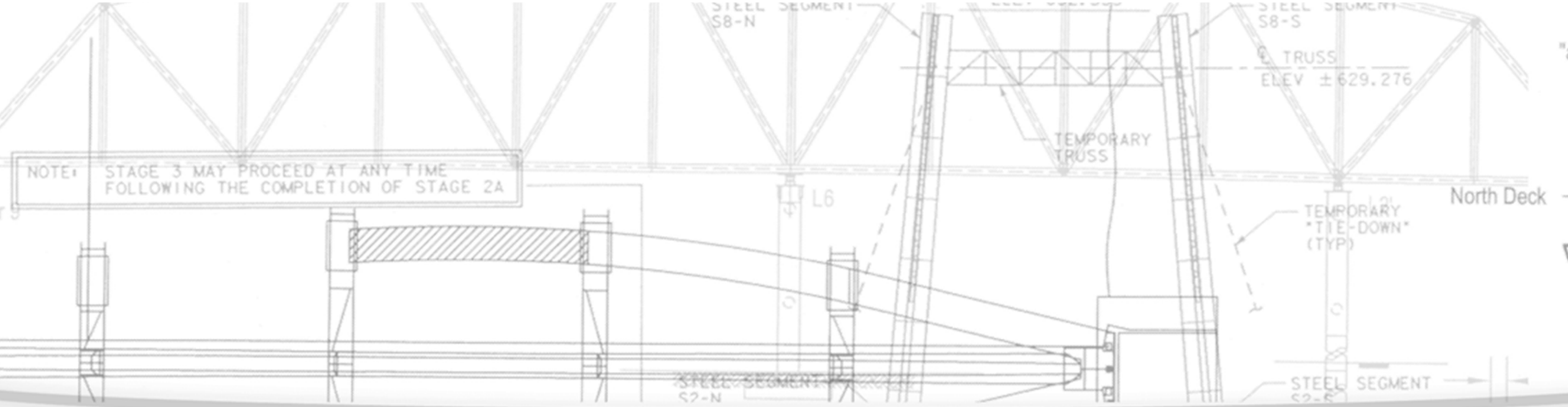


STEEL GIRDER ERECTION

A CONSTRUCTION ENGINEER'S PERSPECTIVE

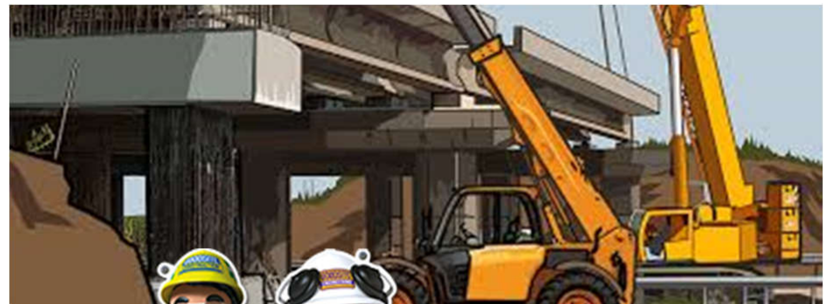
National Steel Bridge Alliance (NSBA)

Presentation Overview

- Contractors and the 3-C's
- Constructibility of Superstructures
- Steel Girder Erection
- Precast Concrete Girder Erection
- Bridge Demolition and/or Re-decking
- Conclusions/Suggestions

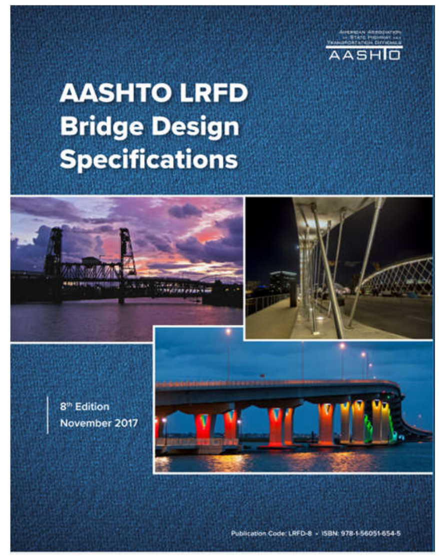
Presentation Overview

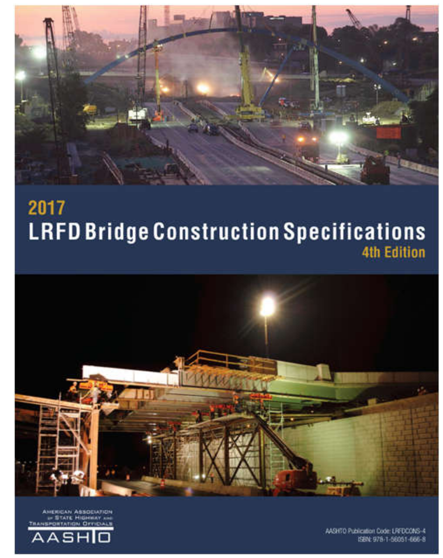
- Contractors and the 3-C's
  - Constructibility
  - Costs
  - Competition
- Constructibility of Superstructures
- Steel Girder Erection
- Precast Concrete Girder Erection
- Bridge Demolition and/or Re-Decking
- Conclusions/Suggestions



Presentation Overview

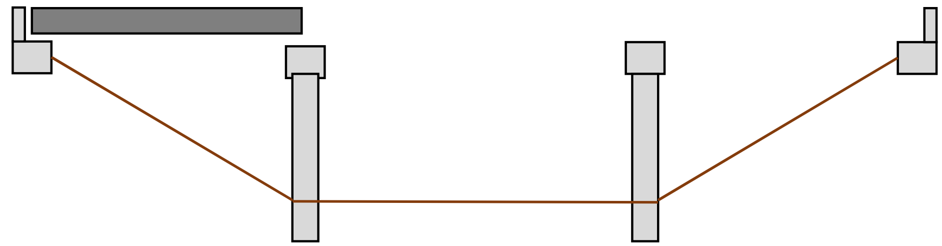
- Contractors and the 3-C's
- Constructibility of Superstructures
  - Review of AASHTO Expectations
  - Review of Minimum Checks
  - Steel/Precast – Similar
- Steel Girder Erection
- Precast Concrete Girder Erection
- Bridge Demolition and/or Re-decking
- Conclusions/Suggestions



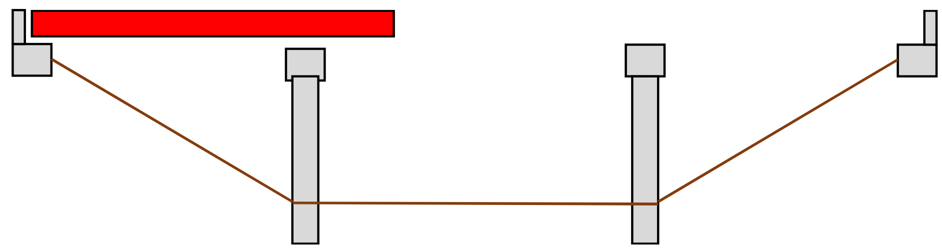


Presentation Overview

- Contractors and the 3-C's
- Constructibility of Superstructures
    - Review of AASHTO Expectations
    - Review of Minimum Checks
    - Steel/Precast – Similar…***but***…Different
        - *Short Span (< 200ft) / Conventional*
- Steel Girder Erection
- Precast Concrete Girder Erection
- Bridge Demolition and/or Re-decking
- Conclusions/Suggestions



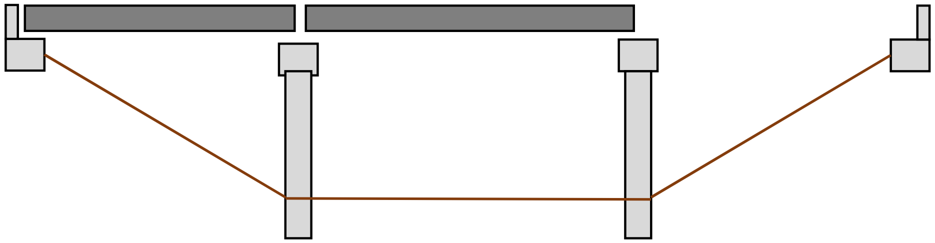
Simple 3-Span Precast Girder Bridge



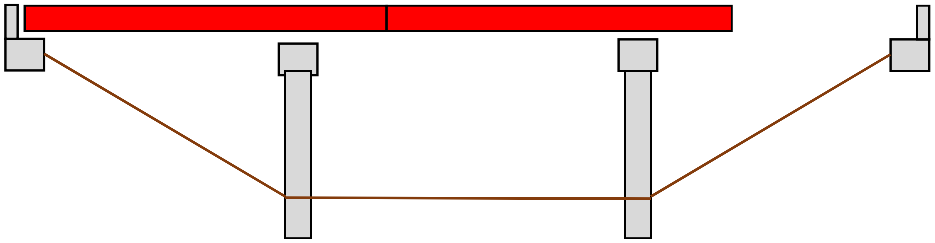
Simple 3-Span Continuous Steel Girder Bridge

Presentation Overview

- Contractors and the 3-C's
- Constructibility of Superstructures
  - Review of AASHTO Expectations
  - Review of Minimum Checks
  - Steel/Precast – Similar…***but***…Different
    - *Short Span (< 200ft) / Conventional*
- Steel Girder Erection
- Precast Concrete Girder Erection
- Bridge Demolition and/or Re-decking
- Conclusions/Suggestions



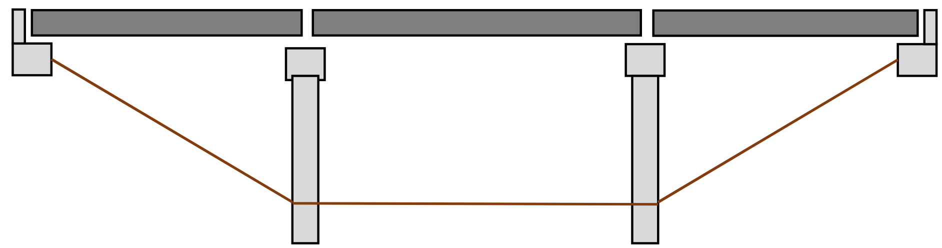
Simple 3-Span Precast Girder Bridge



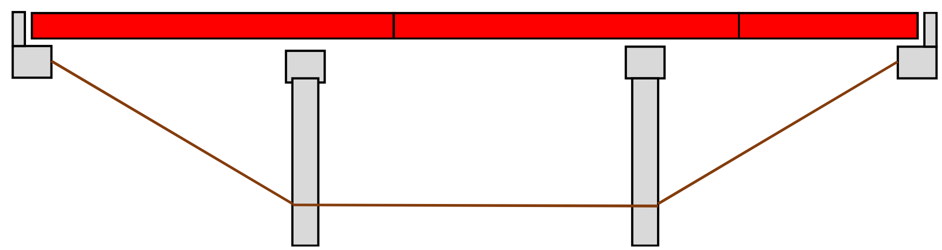
Simple 3-Span Continuous Steel Girder Bridge

Presentation Overview

- Contractors and the 3-C's
- Constructibility of Superstructures
  - Review of AASHTO Expectations
  - Review of Minimum Checks
  - Steel/Precast – Similar…***but***…Different
    - *Short Span (< 200ft) / Conventional*
- Steel Girder Erection
- Precast Concrete Girder Erection
- Bridge Demolition and/or Re-decking
- Conclusions/Suggestions



Simple 3-Span Precast Girder Bridge



Simple 3-Span Continuous Steel Girder Bridge

Presentation Overview

- Contractors and the 3-C's
- Constructibility of Superstructures
  - Review of AASHTO Expectations
  - Review of Minimum Checks
  - Steel/Precast – Similar…***but***…Different
    - *Long Span (> 200-ft) / Complex*
- Steel Girder Erection
- Precast Concrete Girder Erection
- Bridge Demolition and/or Re-decking
- Conclusions/Suggestions

Spliced Precast

Spliced Steel

Presentation Overview

- Contractors and the 3-C's
- Constructibility of Superstructures
- Steel Girder Erection
  - Compression Flange Requirements
  - Picking Girders
  - Staged Construction Evaluation
  - Temporary Works
- Precast Concrete Girder Erection
- Bridge Demolition and/or Re-decking
- Conclusions/Suggestions

Gateway Interchange Flyovers, Johnson County, KS

Presentation Overview

- Contractors and the 3-C's
- Constructibility of Superstructures
- Steel Girder Erection
- Precast Concrete Girder Erection
  - Picking Girders
  - Setting and Releasing Girders
- Bridge Demolition and/or Re-decking
- Conclusions/Suggestions

Spillway Bridge, Marion County, KS

Presentation Overview

- Contractors and the 3-C's
- Constructibility of Superstructures
- Steel Girder Erection
- Precast Concrete Girder Erection
- Bridge Demolition and/or Re-decking
  - Stability of girders with equipment removing concrete decks
  - Most Demos/Re-decking for Bridges Designed with ASD
  - How will LRFD designed bridges hold up?
- Conclusions/Suggestions

Comm. Ave Bridge, Boston, MA

I-75 Deck Replacement, Detroit, MI

Presentation Overview

- Contractors and the 3-C's
- Constructibility of Superstructures
- Steel Girder Erection
- Precast Concrete Girder Erection
- Bridge Demolition and/or Re-decking
- Conclusions/Suggestions

Owners
Designer Engineers

Construction Engineers
Contractors

Presentation Overview

- Contractors and the 3-C's
- Constructibility of Superstructures
- Steel Girder Erection
- Precast Concrete Girder Erection
- Bridge Demolition and/or Re-decking
- Conclusions/Suggestions

Owners
Designer Engineers

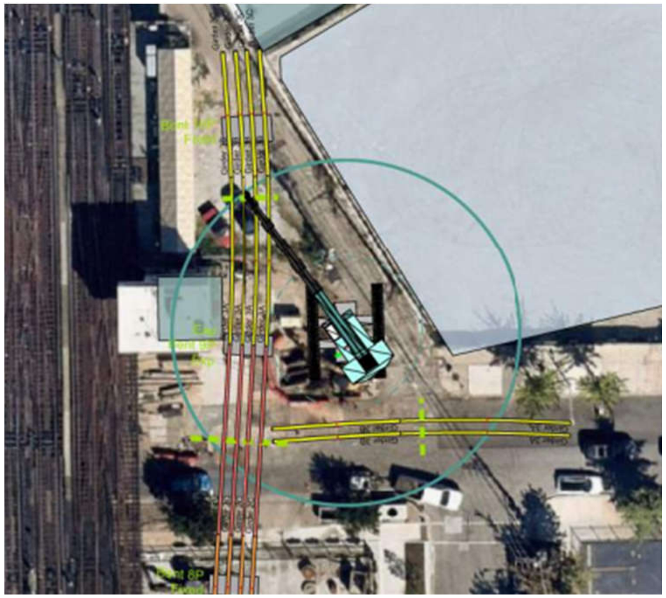
Construction Engineers
Contractors

Contractors & the 3-C's

Constructibility / Costs / Competition

Contractors & The 3-C's

- Constructibility
  - Assessing site to determine direction and sequence of construction
    - Work from fixed pier preferred but not always possible
    - Working from one abutment to the other preferred but not always possible
    - Crane locations may be limited so girder erection must be planned ahead
    - Access may not be available so it has to be created
    - Access may not be available so it dictates the construction method
    - Worker access must also be considered
  - Crane Sizing and Access
  - Girder Delivery



nearmap.com

Contractors & The 3-C's

- Constructibility
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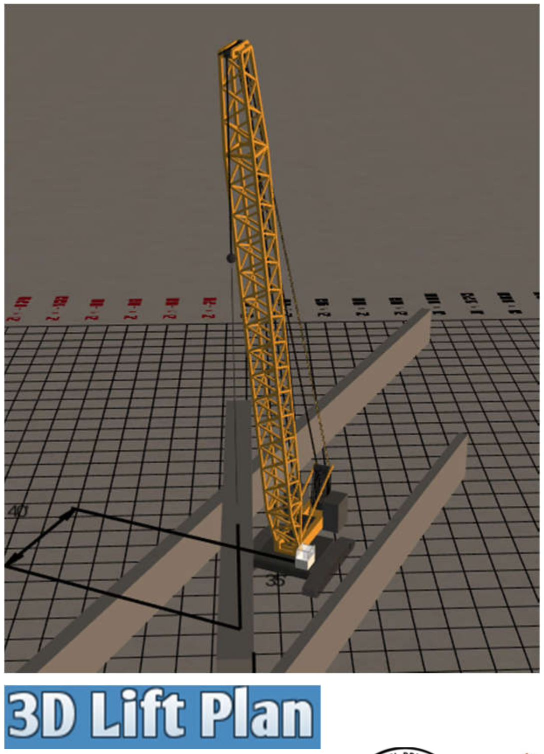

Contractors & The 3-C's

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Whittier Memorial Bridge, Newburyport and Amesbury, MA

Contractors & The 3-C's

- Constructibility
  - Assessing site to determine direction and sequence of construction
    - Work from fixed pier preferred but not always possible
    - Working from one abutment to the other preferred but not always possible
    - Crane locations may be limited so girder erection must be planned ahead
    - Access may not be available so it has to be created
    - Access may not be limited therefore dictating the construction method
    - Worker access must also be considered
  - Crane Sizing and Access
  - Girder Delivery

US 20 – Iowa River Bridge

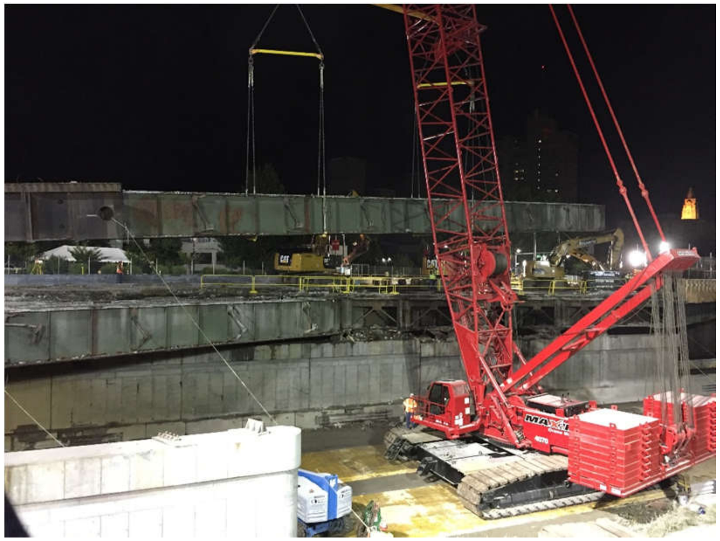
Contractors & The 3-C's

- Constructibility
  - Assessing site to determine direction and sequence of construction
    - Work from fixed pier preferred but not always possible
    - Working from one abutment to the other preferred but not always possible
    - Crane locations may be limited so girder erection must be planned ahead
    - Access may not be available so it has to be created
    - Access may not be available so it dictates the construction method
    - Worker access must also be considered
  - Crane Sizing and Access
  - Girder Delivery

Crum Creek Viaduct, Swarthmore, PA

Contractors & The 3-C's

- Constructibility
  - Assessing site to determine direction and sequence of construction
  - Crane Sizing and Access
    - What are the maximum picks?
    - What is the maximum pick radius?
    - Does the crane have clearance to make the pick?
    - Does a traditional crane even make sense?
    - How high are the girders from the base of the crane and what is the length of the required reach?
    - Land vs. water (same cranes have different capacities)?
    - Sometimes it takes an assist crane to set up the main crane
    - At the end of the day, safety is #1 priority
  - Girder Delivery



Comm. Ave Bridge, Boston, MA

Contractors & The 3-C's

- Constructibility
  - Assessing site to determine direction and sequence of construction
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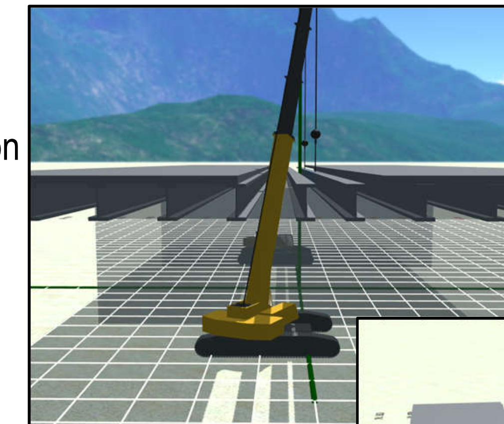

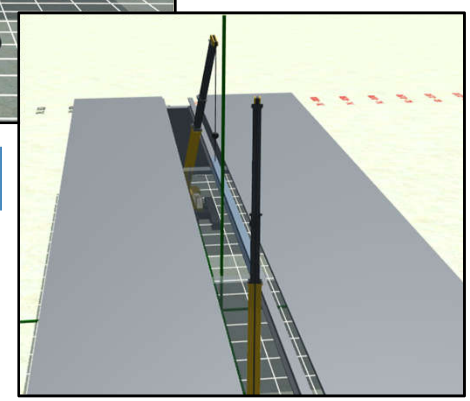

3D Lift Plan

Contractors & The 3-C's

- Constructibility
  - Assessing site to determine direction and sequence of construction
  - Crane Sizing and Access
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Whittier Memorial Bridge, Newburyport and Amesbury, MA

Contractors & The 3-C's

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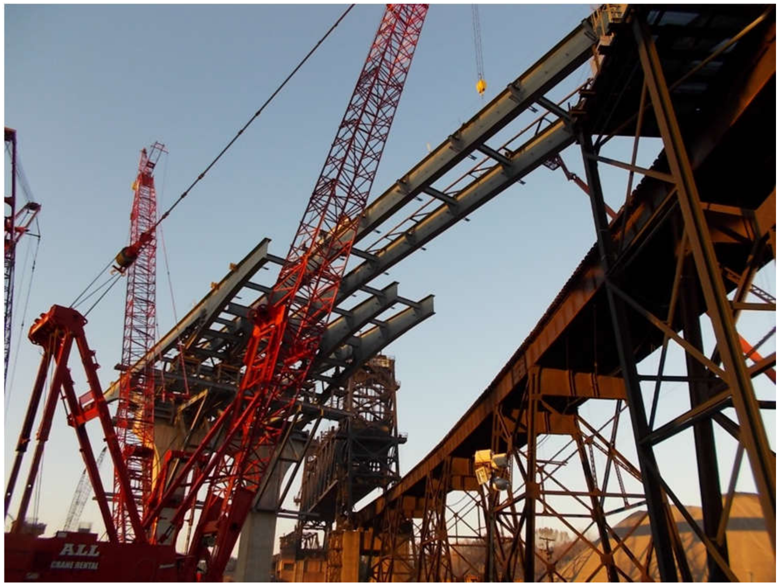

Cleveland Innerbelt, Cleveland, OH

Contractors & The 3-C's

- Constructibility
  - Assessing site to determine direction and sequence of construction
  - Crane Sizing and Access
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Jensen Construction Ringer, Omaha, NE

Contractors & The 3-C's

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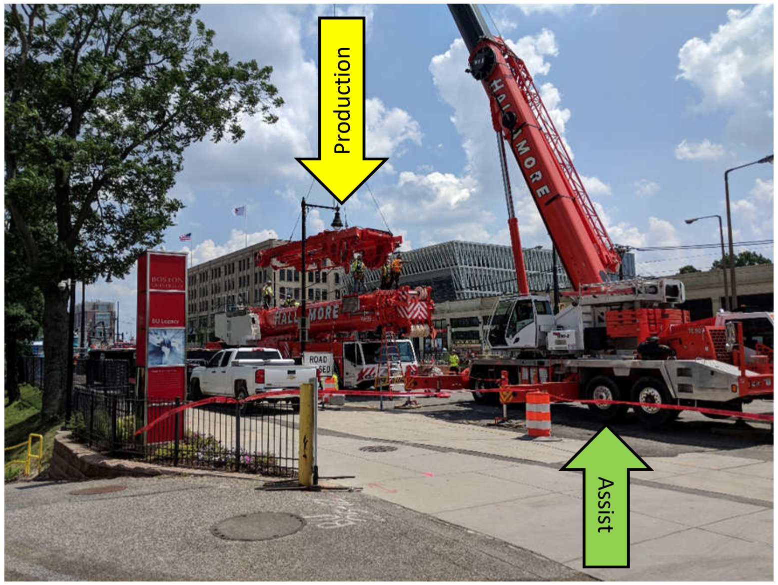

Comm. Ave Bridge, Boston, MA

Contractors & The 3-C's

- Constructibility
  - Assessing site to determine direction and sequence of construction
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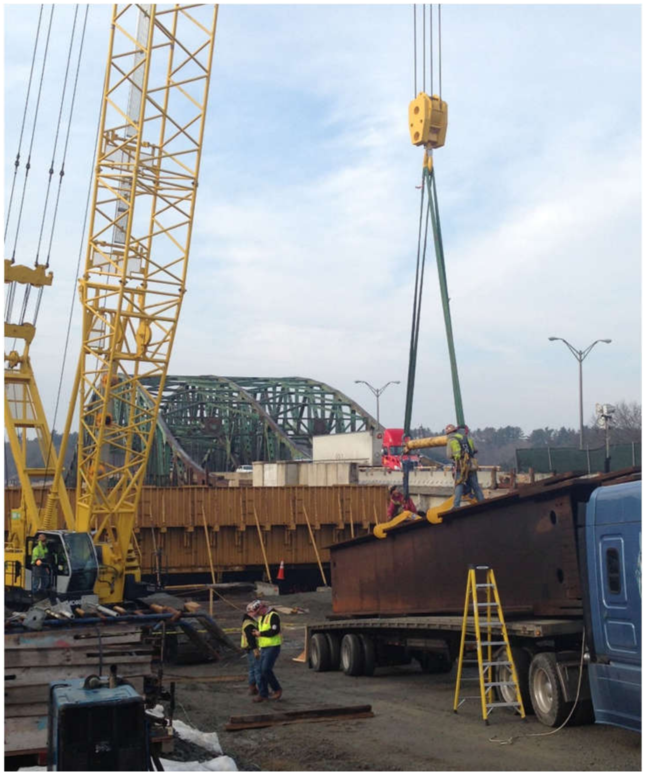
Contractors & The 3-C’s

- Constructibility
  - Assessing site to determine direction and sequence of construction
  - Crane Sizing and Access
  - Girder Delivery
    - Trucks deliver directly within reach of the crane
    - Cranes may have to receive load and then walk with a load
      Crawler – Yes
      Hydraulic on Outriggers – No
    - How are girders delivered to the site?
    - Girder length, weight or delivery position may require two cranes
    - Sometimes the girders are too tall so they are delivered horizontally and require to be unloaded, set down and the tripped to vertical (two extra crane moves)



Whittier Memorial Bridge, Newburyport and Amesbury, MA

Contractors & The 3-C's

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Comm. Ave Bridge, Boston, MA

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Crum Creek Viaduct, Swarthmore, PA

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Comm. Ave Bridge, Boston, MA

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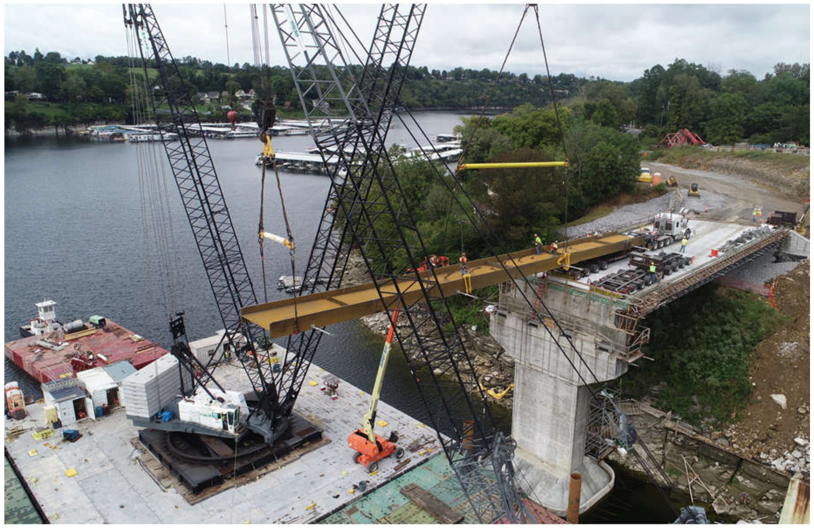

KY 152 over Herrington Lake, Mercer and Garrard Counties, KY

Contractors & The 3-C's

- Constructibility
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  - Crane Sizing and Access
  - Girder Delivery
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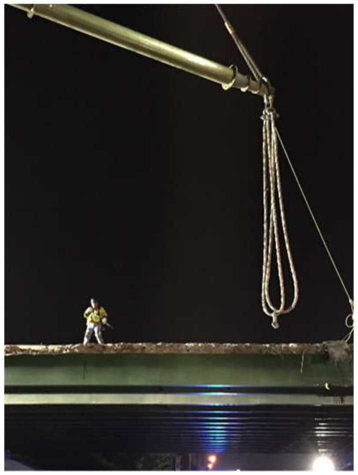
Cleveland Innerbelt, Cleveland, OH

Contractors & The 3-C's

- Constructibility (Cont.)
  - Rigging and Segment Stability
    - Picking girders (flange grabs, underslung slings, bolted/welded picking eyes)
    - Picking girders (spreader beams and picking trees)
    - Single Girder Picks vs. Paired Girder Picks
    - Temporary Top Flange Lateral Bracing (Stability Truss) to Erect
    - Temporary Lateral Bracing to Stabilize before Decking
  - Temporary Towers
  - Environmental Conditions



I40 Fast Fix 8, Nashville, TN

Contractors & The 3-C's

- Constructibility (Cont.)
  - Rigging and Segment Stability
    - Picking girders (flange grabs, underslung slings, bolted/welded picking eyes)
    - Picking girders (spreader beams and picking trees)
    - Single Girder Picks vs. Paired Girder Picks
    - Temporary Top Flange Lateral Bracing (Stability Truss) to Erect
    - Temporary Lateral Bracing to Stabilize before Decking
  - Temporary Towers
  - Environmental Conditions

Cleveland Innerbelt, Cleveland, OH

Contractors & The 3-C's

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Comm. Ave Bridge, Boston, MA

Contractors & The 3-C's

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Cleveland Innerbelt, Cleveland, OH

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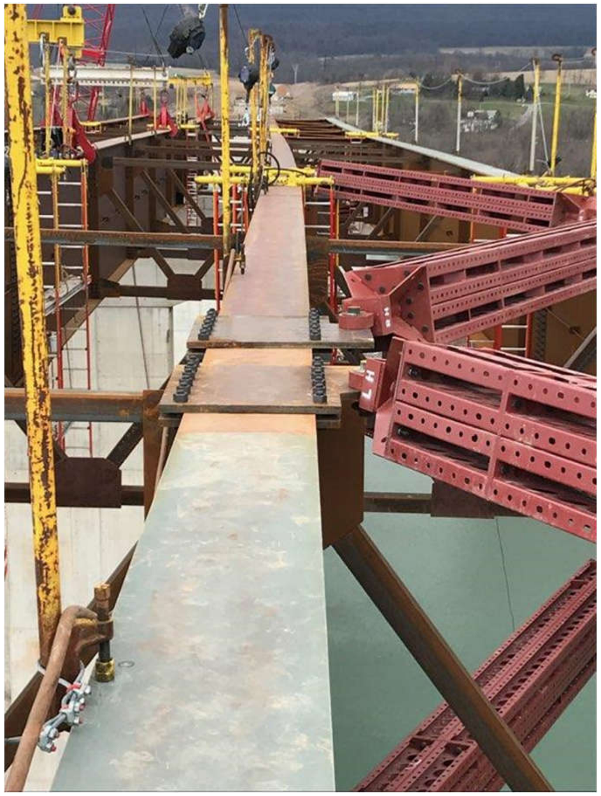

CSVT Project, Pennsylvania

Contractors & The 3-C's

- Constructibility (Cont.)
  - Rigging and Segment Stability
  - Temporary Towers
    - Length of spans, number of girder segments in a span, the curvature of the girder, crane size, crane and delivery access all factor into the need
    - Pre-Manufactured
    - Built to fit the Need
    - Some are so unique there is no possible re-use
  - Environmental Conditions

I-94 & I-69 Interchange, Port Huron, MI

Contractors & The 3-C's

- Constructibility (Cont.)
  - Rigging and Segment Stability
  - Temporary Towers
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Whittier Memorial Bridge, Newburyport and Amesbury, MA

Contractors & The 3-C's

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  - Rigging and Segment Stability
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Cleveland Innerbelt, Cleveland, OH

Contractors & The 3-C's

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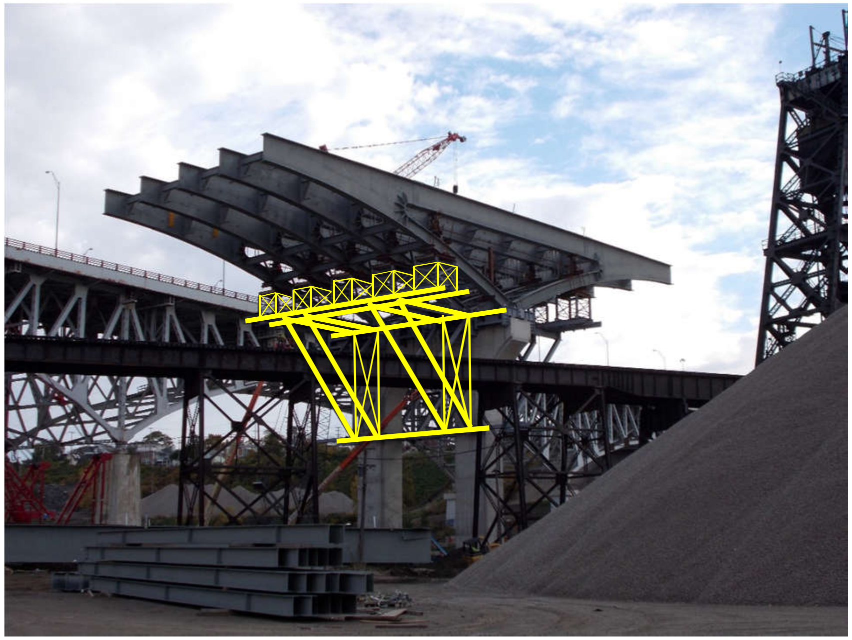

Cleveland Innerbelt, Cleveland, OH

Contractors & The 3-C's

- Constructibility (Cont.)
  - Rigging and Segment Stability
  - Temporary Towers
  - Environmental Conditions
    - Temperature can affect the erected structure (especially orientation of the girders and time of day)
    - Wind impacts on erected girders (initial release, fully erected during deck forming)
    - Some DOT's have strict wind criteria for permanent structures as well as during erection (PennDOT)

Contractors & The 3-C's

- Constructibility (Cont.)
  - Rigging and Segment Stability
  - Temporary Towers
  - Environmental Conditions
    - Temperature can affect the erected structure (especially orientation of the girders and time of day)
    - Wind impacts on erected girders (initial release, fully erected during deck forming)
    - Some DOT's have strict wind criteria for permanent structures as well as during erection (PennDOT)

Blennerhasset Island Bridge, Parkersburg, WV

Contractors & The 3-C's

- Constructibility (Cont.)
  - Rigging and Segment Stability
  - Temporary Towers
  - Environmental Conditions
    - Temperature can affect the erected structure (especially orientation of the girders and time of day)
    - Wind impacts on erected girders (initial release, fully erected during deck forming)
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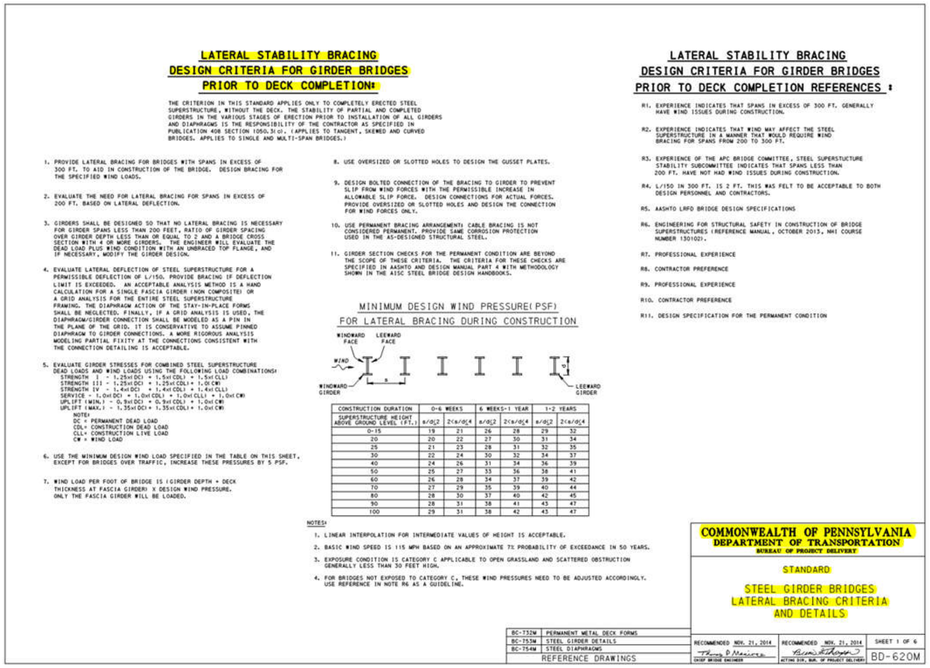


Contractors & The 3-C's

- Costs
  - Crane Rental/Mobilization
    - Size of crane
    - Duration of time on site
    - Shared needs vs. multiple crane sizes
  - Material
  - Labor Forces
  - Temporary Structures
  - Crane Work Platforms
  - Finishes/Coatings
  - Schedule

Contractors & The 3-C's

- Costs
  - Crane Rental/Mobilization
  - Material
    - Costs can fluctuate with demand
    - Expediting delivery schedules will generally increase costs
    - When contractors are asked to hold prices for extended periods cost can increase
  - Labor Forces
  - Temporary Structures
  - Crane Work Platforms
  - Finishes/Coatings
  - Schedule

Contractors & The 3-C's

- Costs
  - Crane Rental/Mobilization
  - Material
  - Labor Forces
    - Union vs. Non-Union Locations
    - Laborers, Operators, Project Managers, Project Engineers
  - Temporary Structures
  - Crane Work Platforms
  - Finishes/Coatings
  - Schedule

Contractors & The 3-C's

- Costs
  - Crane Rental/Mobilization
  - Material
  - Labor Forces
  - Temporary Structures
    - Foundations, Erect, Remove, Temporary Lane Closures
    - Top Flange Bracing (stability trusses)
    - Bottom Flange Lagging – DOT requirements
  - Crane Work Platforms
  - Finishes/Coatings
  - Schedule

Contractors & The 3-C's

- Costs
  - Crane Rental/Mobilization
  - Material
  - Labor Forces
  - Temporary Structures
  - Crane Work Platforms
    - Crane Mats
    - Grading to Level Zones/Temporary Access Roads
    - Barges/Bulkheads for water operations
  - Finishes/Coatings
  - Schedule

Contractors & The 3-C's

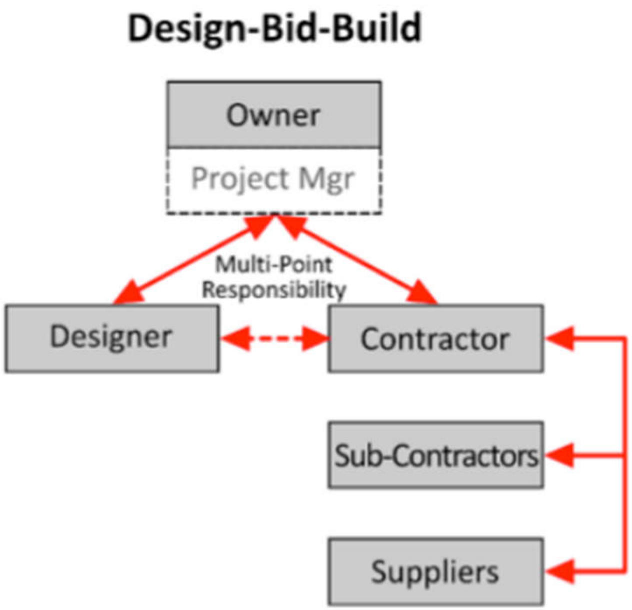
- Costs
  - Crane Rental/Mobilization
  - Material
  - Labor Forces
  - Temporary Structures
  - Crane Work Platforms
  - Finishes/Coatings
    - Steel – Weathering, Primed & Painted, Metalized, Primed, Painted over Metalized (extreme cases)
    - Precast - Some DOT's paint precast for aesthetics
  - Schedule

Contractors & The 3-C's

- Costs
  - Crane Rental/Mobilization
  - Material
  - Labor Forces
  - Temporary Structures
  - Crane Work Platforms
  - Finishes/Coatings
  - Schedule
    - Time is money >>> the more temporary works, the longer the erection schedule
    - Time is money >>> the more special care required in the field, the longer the erection schedule
    - Time is money >>> repairs to steel finishes or precast concrete corners can be expensive and extend the project schedule

Contractors & The 3-C's

- Competition
  - Traditional Design-Bid-Build Project Delivery
    - What are my competitors doing?
    - What special equipment do my competitors own that I have to lease/purchase?
    - What location advantages do my competitors have?
  - Design Build Project Delivery
  - Construction Manager General Contractor (CMGC) Project Delivery

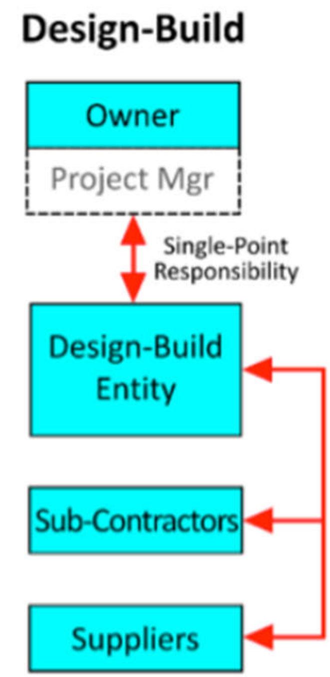


Images Courtesy of:

https://www.engiemep.com/news/advantages-of-design-build-for-mechanical-projects/

Contractors & The 3-C's

- Competition
  - Traditional Design-Bid-Build Project Delivery
  - Design Build Project Delivery
    - Best Idea and Price will win
    - The idea phase is pre-bid and may or may not be fully disclosed to the DOT's (ATC's)
    - Contractors/Designers
    - Sometimes missing is the Construction Engineer that is "bi-lingual"
      - Engineer who can speak the language of the Designer and the Contractor
  - Construction Manager General Contractor (CMGC) Project Delivery

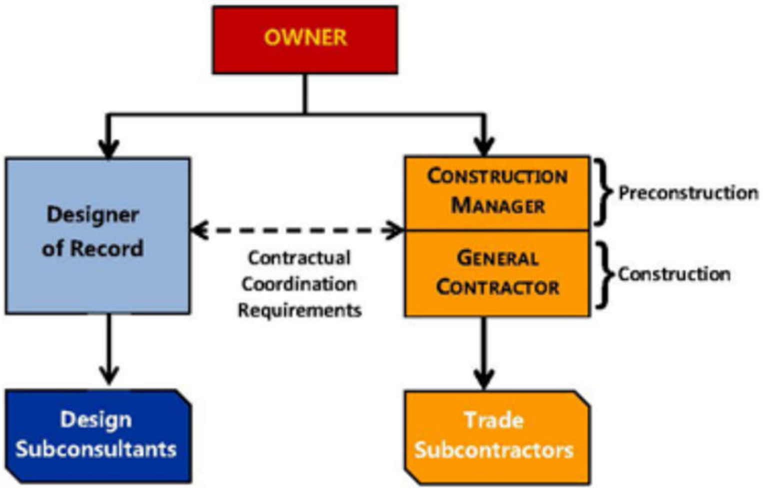


Images Courtesy of:

https://www.engiemep.com/news/advantages-of-design-build-for-mechanical-projects/

Contractors & The 3-C's

- Competition
  - Traditional Design-Bid-Build Project Delivery
  - Design Build Project Delivery
  - Construction Manager General Contractor (CMGC) Project Delivery
    - Best Ideas are Discussed between Contractor/Designer/Owners after team selection
    - The idea phase is pre-final bid but costs and schedule and design are discussed with the owner's full knowledge



Images Courtesy of:

https://www.fhwa.dot.gov/construction/contracts/acm/cmgc.cfm

Constructibility of Superstructures

Who is responsible for what and when?

TYPICAL DESIGN BID BUILD

Owner / DOT

Engineer of Record

Contractor

Who is responsible for what and when?

TYPICAL DESIGN BID BUILD

Owner / DOT → Engineer of Record → Contractor

We need a bridge

Has to be:

- **Affordable**
- **Safe**
- **Durable**

Don't want any issues in construction

Who is responsible for what and when?

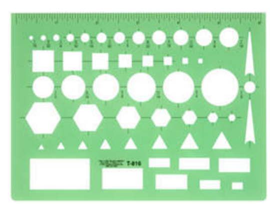
TYPICAL DESIGN BID BUILD

Owner / DOT → Engineer of Record → Contractor

We need a bridge

Best design option

(3) 250-ft steel girders spans. Needs to have an 800-ft Radius



Who is responsible for what and when?

TYPICAL DESIGN BID BUILD

Owner / DOT → Engineer of Record → Contractor

We need a bridge

Best design option

This is how I would build it.
Going to cost you this much

Who is responsible for what and when?

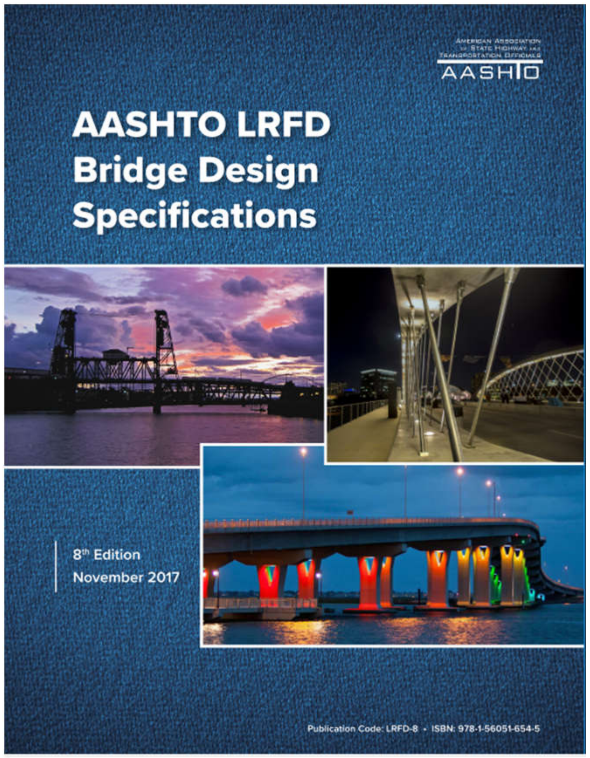
TYPICAL DESIGN BID BUILD

- **Contract Plans = Defines responsibilities of all parties (bidding / fabricating / erecting structure)**

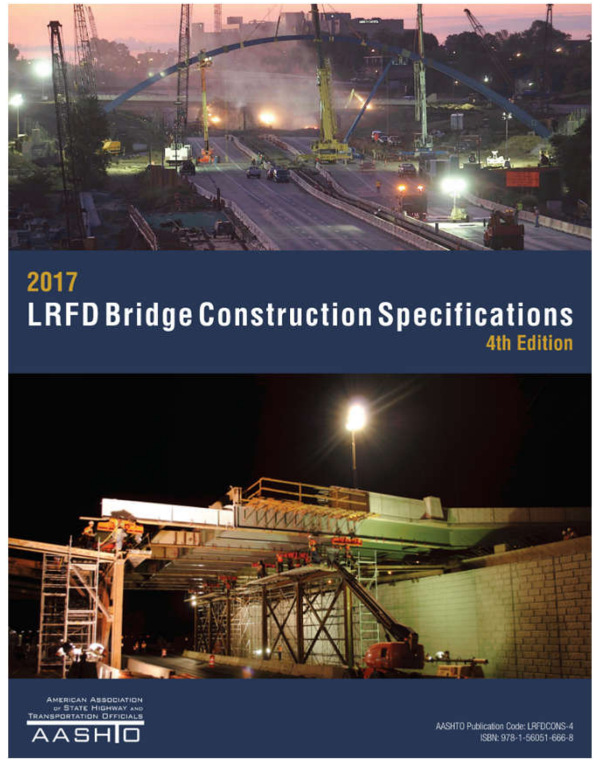
Constructibility of Superstructures

- When is a bridge complex enough so engineering is required to ensure contructibility or stability during erection?
- When should a DOT / Engineer of Record (EOR) make Contractors aware of limitations during construction?
- When does the DOT / EOR owe a Contractor a suggested erection sequence?
- What do the AASHTO Specifications say?

AASHTO Specifications

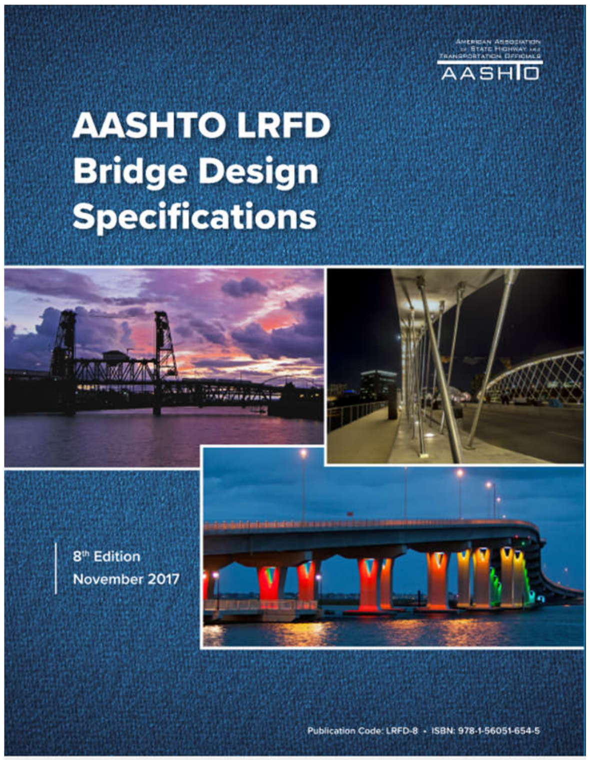


AASHTO Bridge Design Spec.

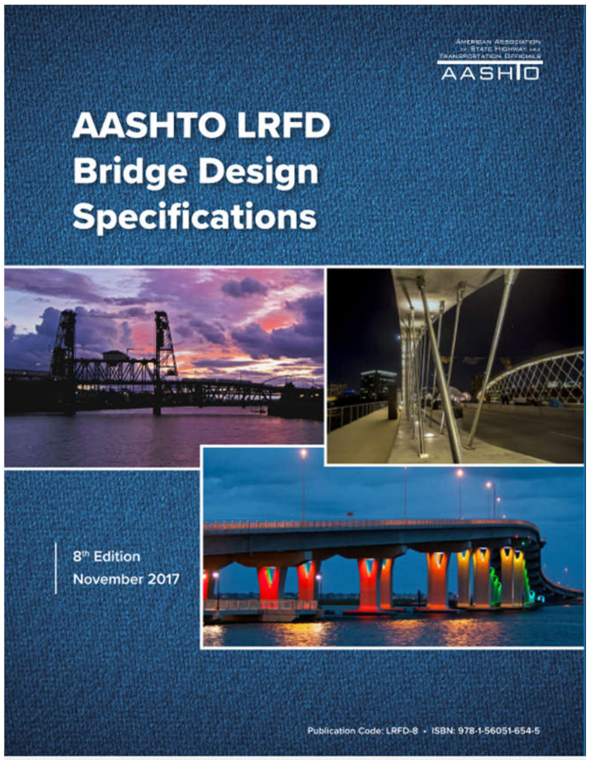


AASHTO Bridge Construction Specs.

AASHTO Bridge Design Specifications



AASHTO Bridge Design Specifications



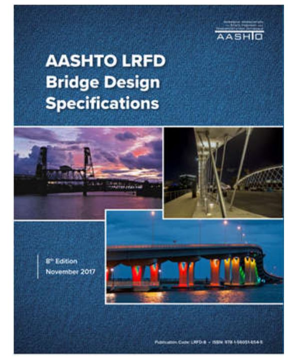
Key Sections:

Chapter 2 General Design and Location Features	• 2.5.3 – Constructibility
Chapter 5 Concrete Structures	• 5.12 – Provisions for Structure Components and Types
Chapter 6 Steel Structures	• 6.10.3 – Steel I-Section Constructibility • 6.11.3 – Box Section

AASHTO – Constructibility

- *2.5.3: This section specifies, "Bridges should be designed in a manner such that fabrication and erection can be performed without undue difficulty or distress and that locked in construction force effects are within tolerable limits."*

- *2.5.3 (Cont.): Where the bridge is of unusual complexity, such as that would be unreasonable to expect an experienced contractor to predict and estimate a suitable method of construction while bidding the project, at least one feasible construction method shall be indicated in the contract documents. If the design requires some strengthening and/or temporary bracing or support during erection by the selected method, indication of the need thereof shall be indicated in the contract documents.*

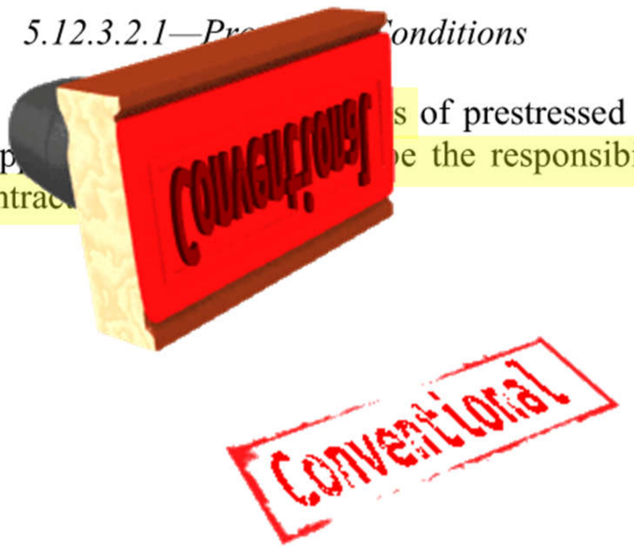


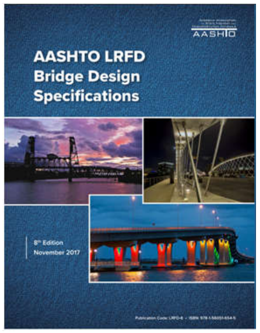
Precast Beams

5.12.3.2—Precast Beams

5.12.3.2.1—Pr… …onditions

…s of prestressed girders for ship… …be the responsibility of the contrac…



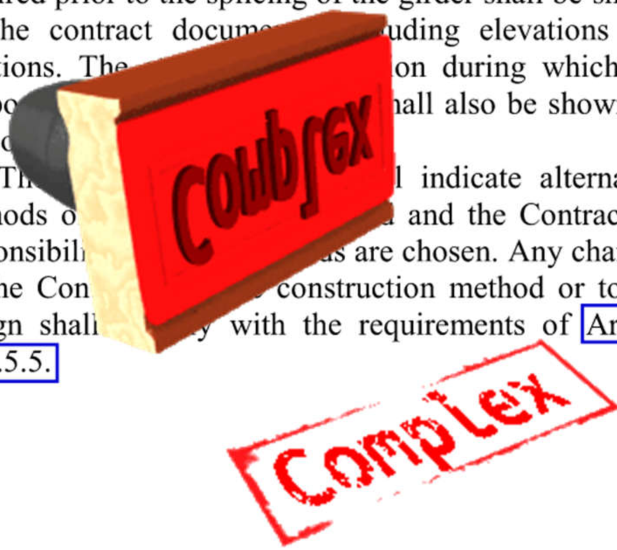


Spliced Precast Girders

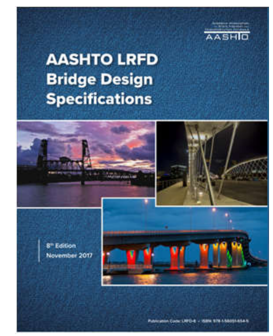
5.12.3.4—Spliced Precast Girders

The method of construction assumed for the design shall be shown in the contract documents. All supports required prior to the splicing of the girder shall be shown on the contract docum[illegible]uding elevations and reactions. The [illegible]on during which the tempo[illegible]hall also be shown on the c[illegible]

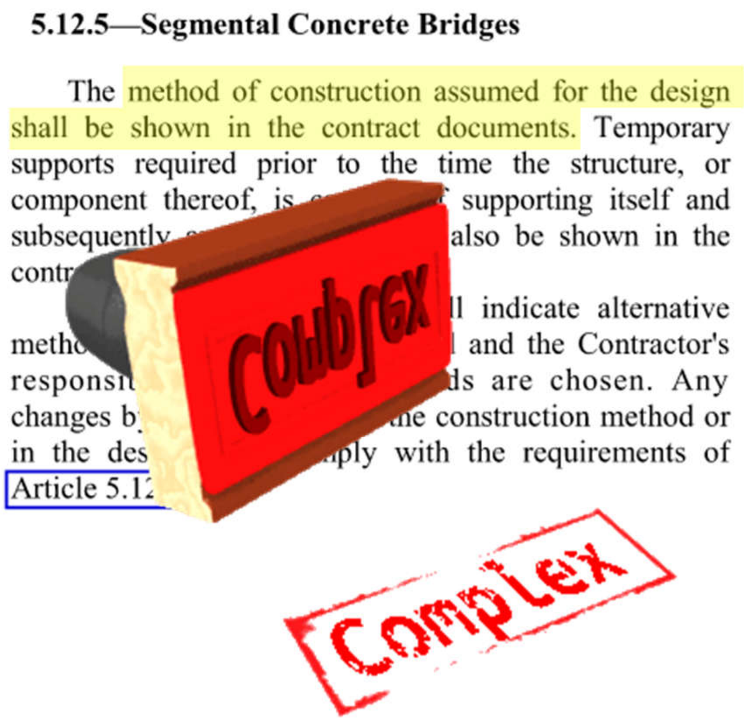
Th[illegible]l indicate alternative methods o[illegible] and the Contractor's responsibil[illegible]s are chosen. Any changes by the Con[illegible] construction method or to the design shall[illegible]y with the requirements of Article 5.12.5.5.



Images Courtesy of: www.post-tensioning.org



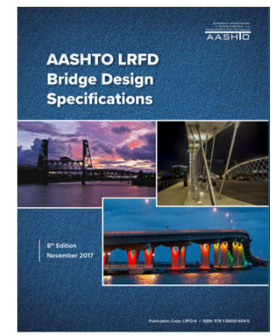
Segmental Concrete Bridges



5.12.5—Segmental Concrete Bridges

The method of construction assumed for the design shall be shown in the contract documents. Temporary supports required prior to the time the structure, or component thereof, is ... supporting itself and subsequently ... also be shown in the contr... ...ll indicate alternative meth... ...l and the Contractor's responsi... ...ds are chosen. Any changes b... ...the construction method or in the des... ...ply with the requirements of Article 5.12...

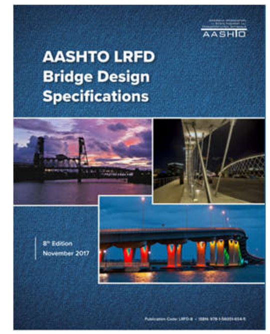
Images Courtesy of: http://www.asbi-assoc.org/



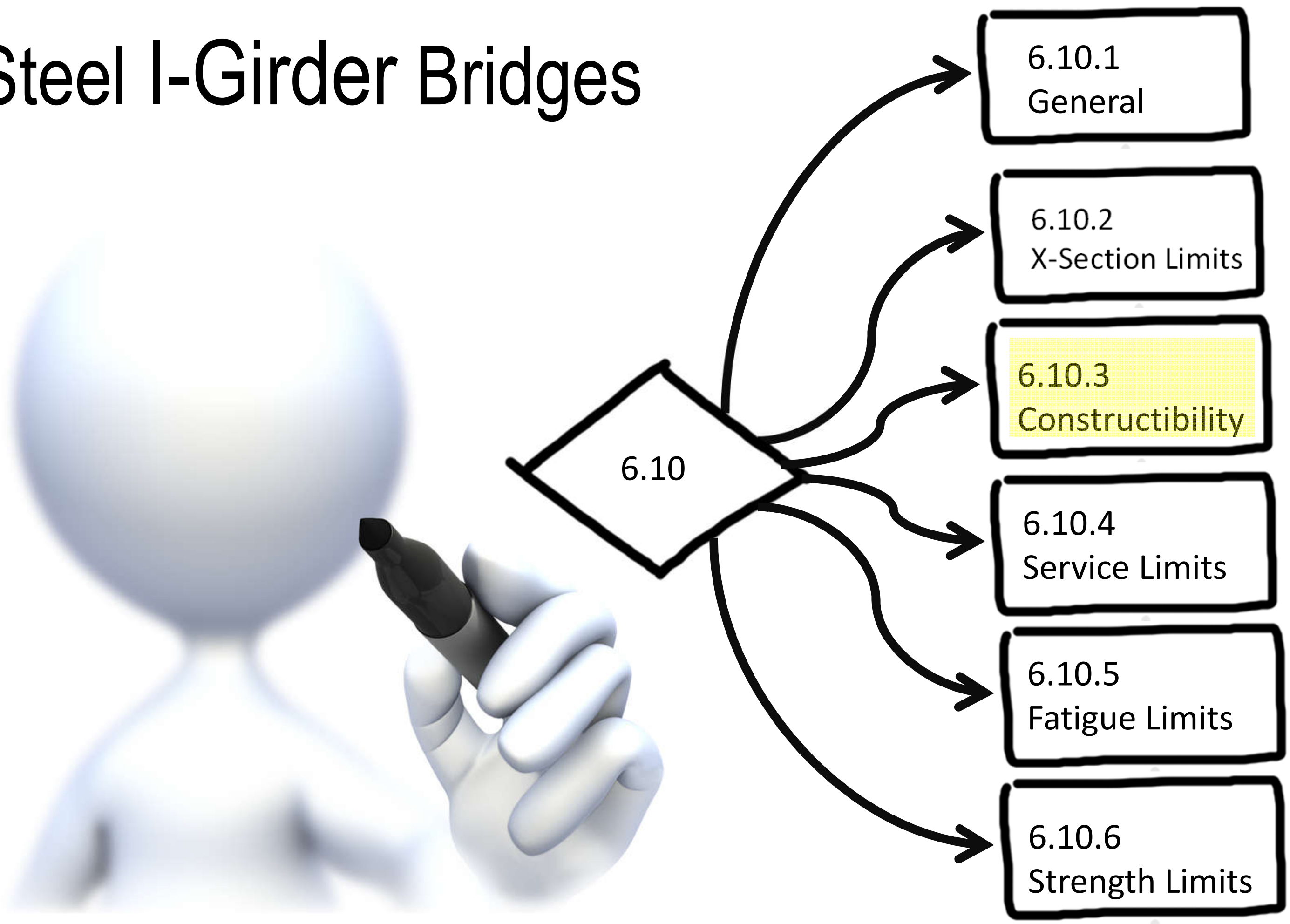
Segmental Concrete Bridges

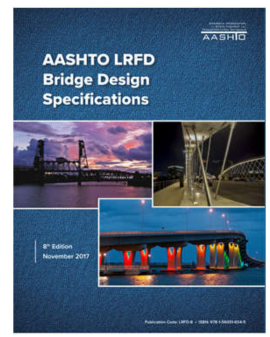
Table 5.12.5.3.3-1—Load Factors and Tensile Stress Limits for Construction Load Combinations

Load Combination	LOAD FACTORS															STRESS LIMITS				
	Dead Load			Live Load			Wind Load			Other Loads					Earth Loads	Flexural Tension		Principal Tension		
	DC *DW*	*DIFF*	*U*	*CEQ* *CLL*	*IE*	*CLE*	*WS*	*WUP*	*WE*	*CR*	*SH*	*TU*	*TG*	A AI *WA*	*EH* *EV* *ES*	Excluding "Other Loads"	Including "Other Loads"	Excluding "Other Loads"	Including "Other Loads"	See Note
a	1.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	γ_{TG}	1.0	1.0	$0.190\sqrt{f'_c}$	$0.220\sqrt{f'_c}$	$0.110\sqrt{f'_c}$	$0.126\sqrt{f'_c}$	—
b	1.0	0.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	γ_{TG}	1.0	1.0	$0.190\sqrt{f'_c}$	$0.220\sqrt{f'_c}$	$0.110\sqrt{f'_c}$	$0.126\sqrt{f'_c}$	—
c	1.0	1.0	0.0	0.0	0.0	0.0	0.7	0.7	0.0	1.0	1.0	1.0	γ_{TG}	1.0	1.0	$0.190\sqrt{f'_c}$	$0.220\sqrt{f'_c}$	$0.110\sqrt{f'_c}$	$0.126\sqrt{f'_c}$	—
d	1.0	1.0	0.0	1.0	0.0	0.0	0.7	1.0	0.7	1.0	1.0	1.0	γ_{TG}	1.0	1.0	$0.190\sqrt{f'_c}$	$0.220\sqrt{f'_c}$	$0.110\sqrt{f'_c}$	$0.126\sqrt{f'_c}$	1
e	1.0	0.0	1.0	1.0	1.0	0.0	0.3	0.0	0.3	1.0	1.0	1.0	γ_{TG}	1.0	1.0	$0.190\sqrt{f'_c}$	$0.220\sqrt{f'_c}$	$0.110\sqrt{f'_c}$	$0.126\sqrt{f'_c}$	2
f	1.0	0.0	0.0	1.0	1.0	1.0	0.3	0.0	0.3	1.0	1.0	1.0	γ_{TG}	1.0	1.0	$0.190\sqrt{f'_c}$	$0.220\sqrt{f'_c}$	$0.110\sqrt{f'_c}$	$0.126\sqrt{f'_c}$	3



Steel I-Girder Bridges





Steel I-Girder Bridges - Constructibility

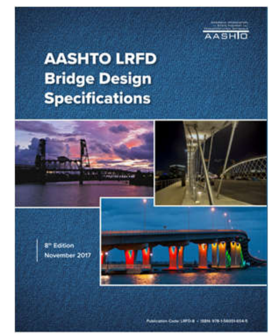
6.10.3—Constructibility

6.10.3.1—General

The provisions of Article 2.5.3 shall apply. In addition to providing adequate strength, nominal yielding or reliance on post-buckling resistance shall not be permitted for main load-carrying members during critical stages of construction, except for yielding of the web in hybrid sections. This shall be accomplished by satisfying the requirements of Articles 6.10.3.2 and 6.10.3.3 at each critical construction stage. For sections in positive flexure that are composite in the final condition, but are noncomposite during construction, the provisions of Article 6.10.3.4 shall apply. For investigating the constructibility of flexural members, all loads shall be factored as specified in Article 3.4.2. For the calculation of deflections, the load factors shall be taken as 1.0.

Potential uplift at bearings shall be investigated at each critical construction stage.

Webs without bearing stiffeners at locations subjected to concentrated loads not transmitted through a deck or deck system shall satisfy the provisions of Article D6.5.



Steel I-Girder Bridges - Constructibility

6.10.3.2.1—Discretely Braced Flanges in Compression

For critical stages of construction, each of the following requirements shall be satisfied. For sections with slender webs, Eq. 6.10.3.2.1-1 shall not be checked when f_ℓ is equal to zero. For sections with compact or noncompact webs, Eq. 6.10.3.2.1-3 shall not be checked.

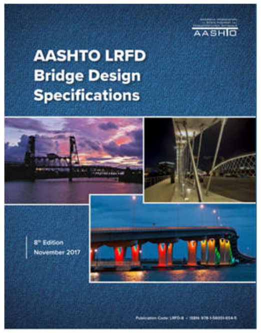
$$f_{bu} + f_\ell \le \phi_f R_h F_{yc}, \qquad (6.10.3.2.1\text{-}1)$$

$$f_{bu} + \frac{1}{3} f_\ell \le \phi_f F_{nc}, \qquad (6.10.3.2.1\text{-}2)$$

and

$$f_{bu} \le \phi_f F_{crw} \qquad (6.10.3.2.1\text{-}3)$$

What are critical stages of construction?



Steel I-Girder Bridges - Constructibility

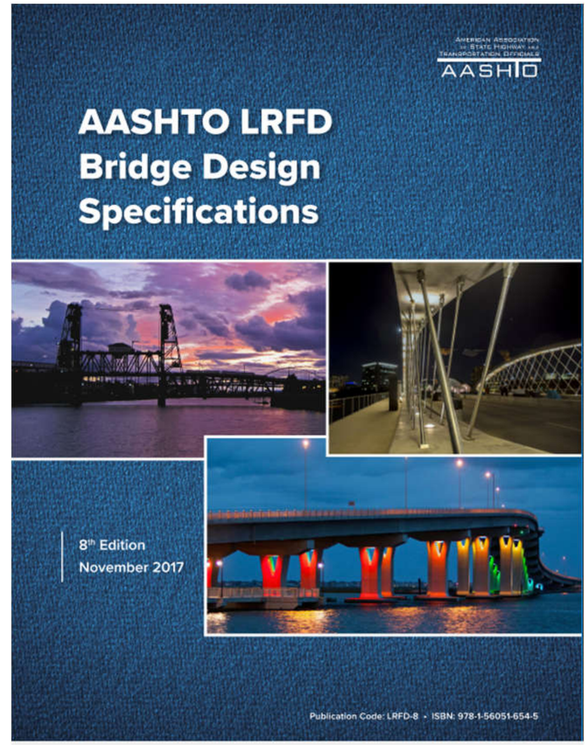
6.10.3.4—Deck Placement

6.10.3.4.1—General

Sections in positive flexure that are composite in the final condition, but are noncomposite during construction, shall be investigated for flexure according to the provisions of Article 6.10.3.2 during the various stages of the deck placement.

Geometric properties, bracing lengths and stresses used in calculating the nominal flexural resistance shall be for the steel section only. Changes in load, stiffness and bracing during the various stages of the deck placement shall be considered.

The effects of forces from deck overhang brackets acting on the fascia girders shall be considered.



Steel I-Girder Bridges - Constructibility

6.10.3.4—Deck Placement

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The effects of forces from deck overhang brackets acting on the fascia girders shall be considered.

Images Courtesy of: www.sellwoodbridge.org

Following pour sequence is important!

Steel I-Girder Bridges - Constructibility

6.10.3.4—Deck Placement

6.10.3.4.1—General

Sections in positive flexure that are composite in the final condition, but are noncomposite during construction, shall be investigated for flexure according to the provisions of Article 6.10.3.2 during the various stages of the deck placement.

Geometric properties, bracing lengths and stresses used in calculating the nominal flexural resistance shall be for the steel section only. Changes in load, stiffness and bracing during the various stages of the deck placement shall be considered.

The effects of forces from deck overhang brackets acting on the fascia girders shall be considered.

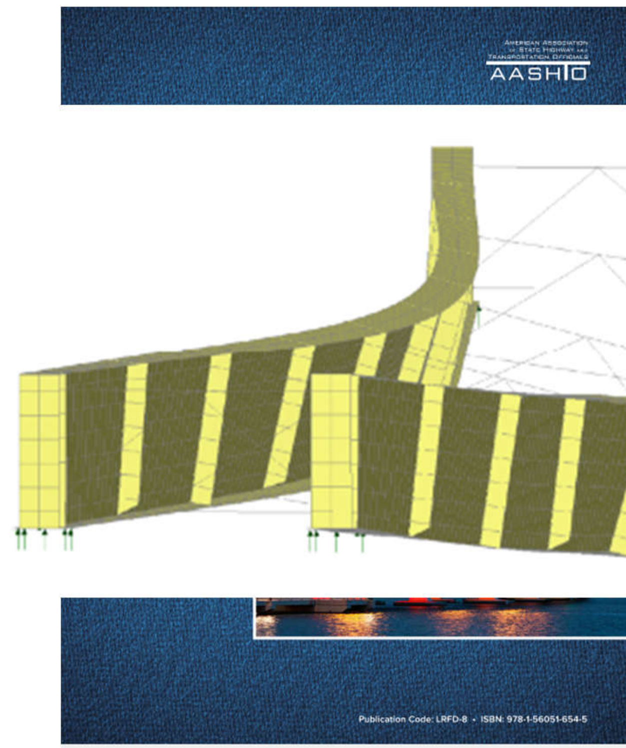
Images Courtesy of: https://www.gamcoform.com/overhang-bracket

Steel I-Girder Bridges– System Stability

6.10.3.4.2—Global Displacement Amplification in Narrow I-Girder Bridge Units

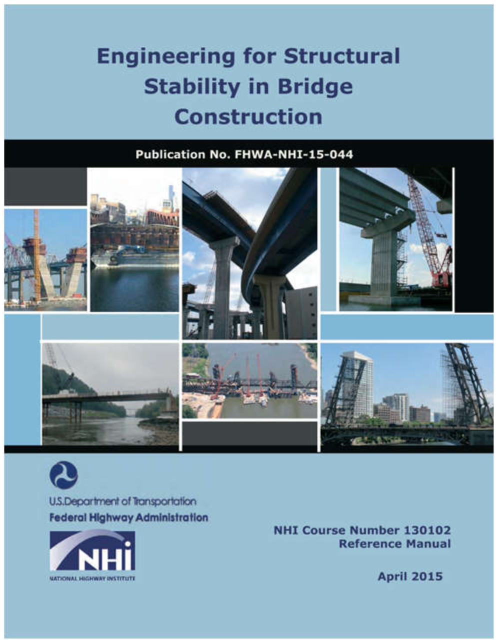
$$M_{gs} = C_{bs} \frac{\pi^2 w_g E}{L^2} \sqrt{I_{eff} I_x} \qquad (6.10.3.4.2\text{-}1)$$

- AASHTO check of narrow 2 or 3 girder system stability during deck pouring
- If Mult > 0.7 Mgs design has following options:
  - Add flange lateral bracing
  - Increase system stiffness
  - Verify with owner that second order displacements are within acceptable tolerances

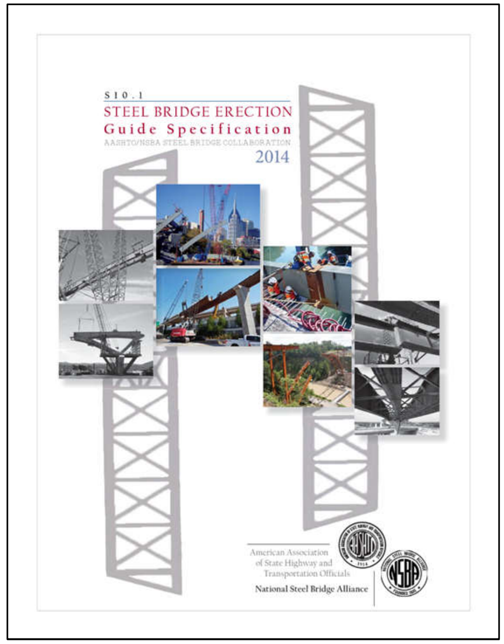


Useful Resources - Erection Analysis

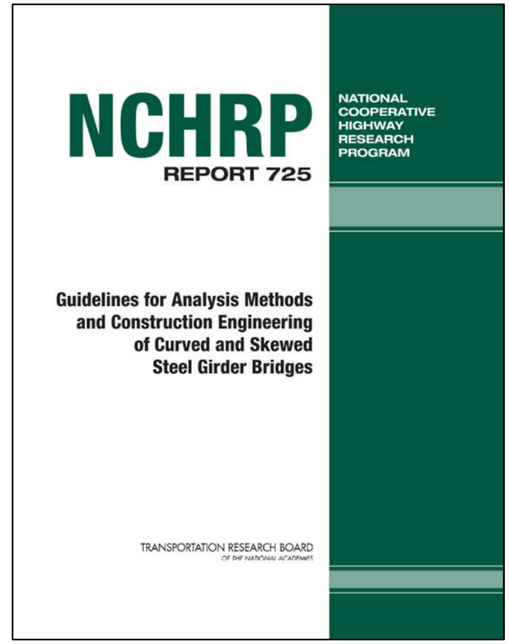
DETOUR



FHWA-NHI-15-044
ALL MATERIAL TYPES



NSBA / AASHTO S10.1



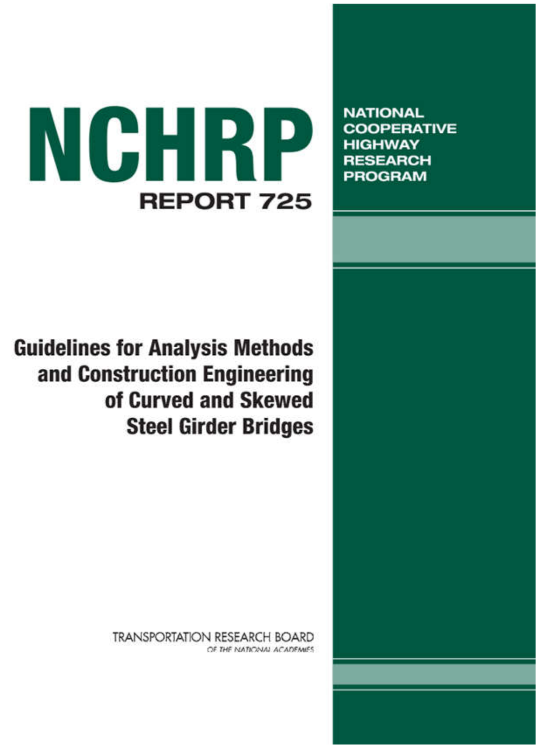
NCHRP Report 725

STEEL BRIDGE SPECIFIC GUIDES

Steel I-Girder Bridges - System Stability

$$M_{crG} = C_b \frac{\pi^2 s E}{L_s^2} \sqrt{I_{ye} I_x} \qquad \text{Eq. 3}$$

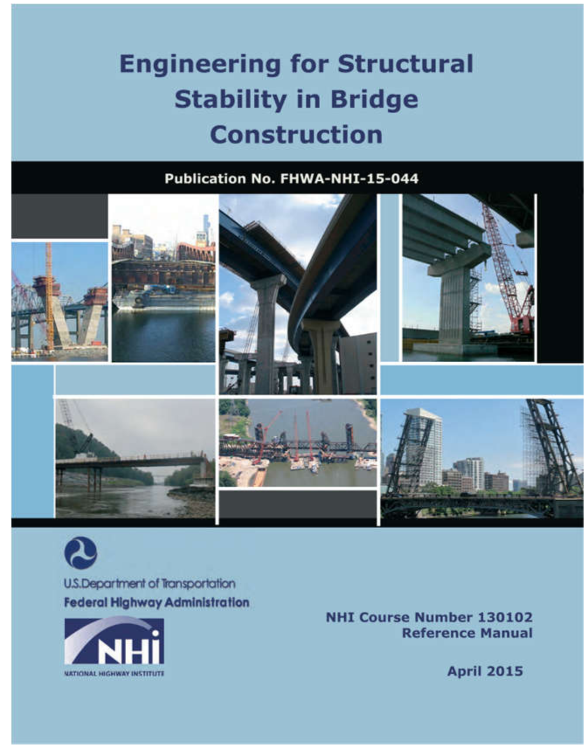
- Simplified check for stages of erection



Steel I-Girder Bridges - System Stability

$$M_{gs} = \frac{\pi^2 S E}{L_g^2}\sqrt{I_y I_x}$$ **Equation 5-12**

- Simplified check for stages of erection



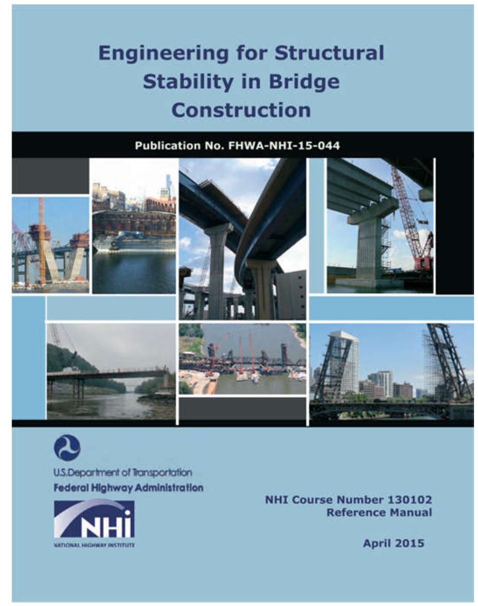
Critical Stages of Construction

7.2.2 Critical Erection Stages

The erection plan and supporting engineering calculations must address both strength and stability at each stage of erection. Deformations associated with each stage should also be evaluated. Critical erection stages for the girder bridge structure during construction normally consist of at least the following:

Contractor / Construction Engineer

- Lifting of girders/members
- Placement of the initial girder and any associated temporary bracing used to hold the girder in place
- First pair of girders set with permanent bracing installed
- All girders and bracing installed prior to the deck placement *[total structure stable in wind]*
- All girders and bracing installed during the deck placement
- Application of the deck overhang bracket loads to the fascia girders during the deck placement



AASHTO dictates these stages shall be considered by Design Engineer

Should be considered by Design Engineer
What design reference should a designer use to evaluate?

Check of Completed Bridge Prior to Deck Pour

- AASHTO design specifications currently do not include section on winds on a completed structure prior to pouring deck
- Designer could refer to "AASHTO Guide Specifications for Wind Loads on Bridges During Construction"

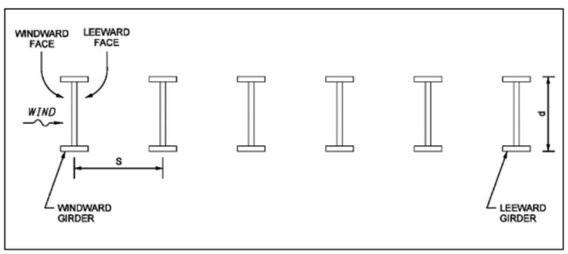
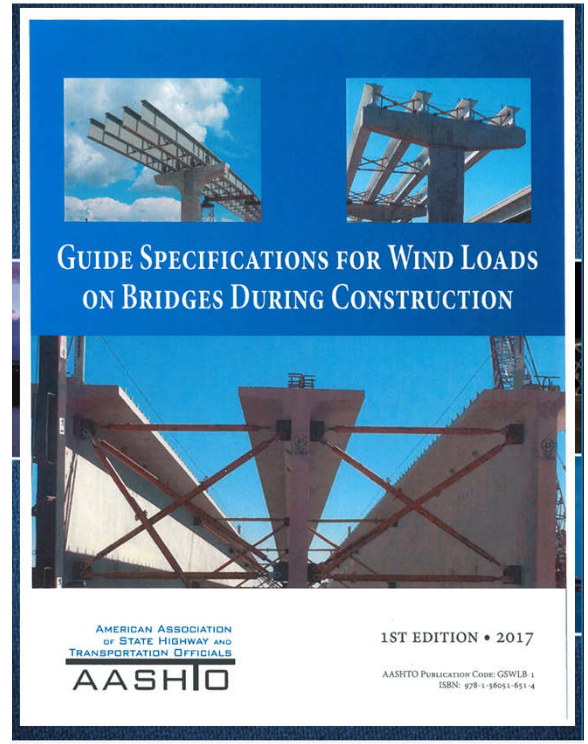
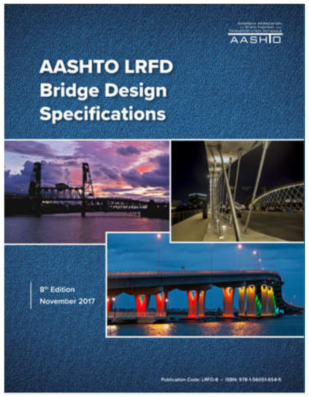


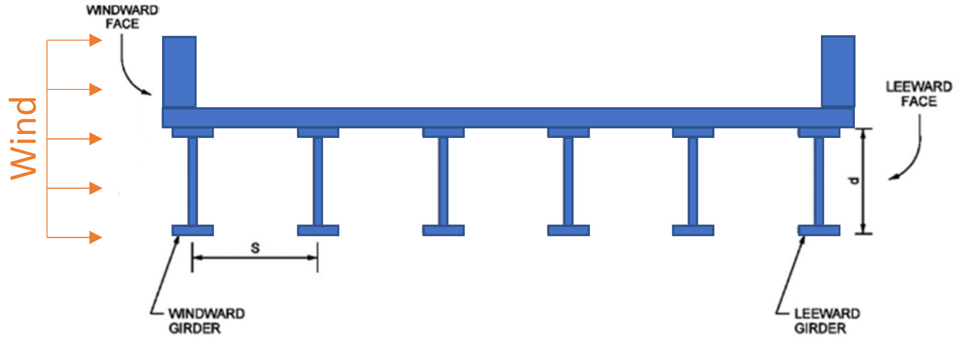
Figure 7-12 Girder Wind Load Terminology

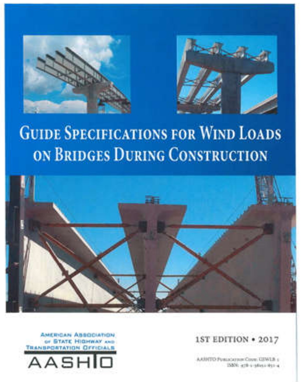
COMPONENT TYPE	CONSTRUCTION CONDITION	FORCE COEFFICIENT (C_f)
I-Shaped Girder Superstructure	Deck forms not in place	2.2 (1)
	Deck forms in place	1.1
U-Shaped and Box-Girder Superstructure	Deck forms not in place	1.5
	Deck forms in place	1.1
Flat Slab or Segmental Box-Girder Superstructure	Any	1.1

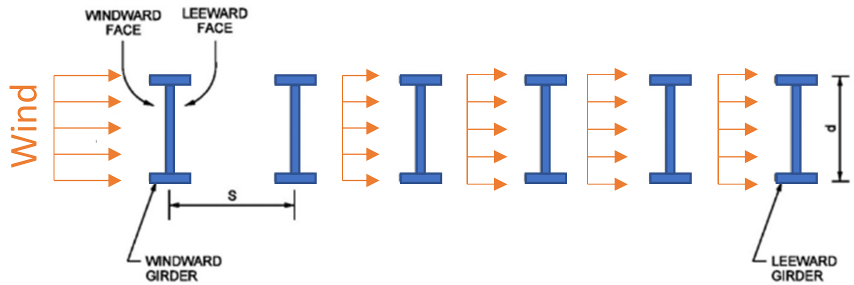


Wind During Erection

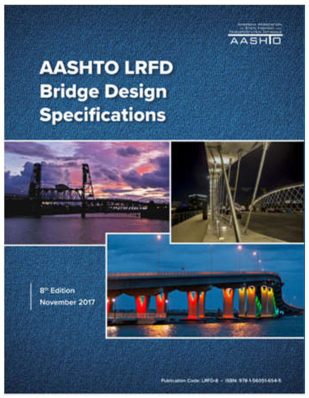






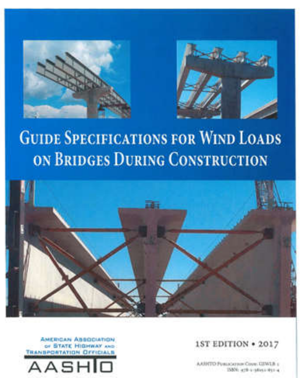


Wind During Erection



$$P_Z = 2.56 \times 10^{-6} V^2 K_z G C_D$$

Component		Drag Coefficient, C_D Windward	Drag Coefficient, C_D Leeward
I-Girder and Box-Girder Bridge Superstructures		1.3	N/A
Trusses, Columns, and Arches	Sharp-Edged Member	2.0	1.0
	Round Member	1.0	0.5
Bridge Substructure		1.6	N/A
Sound Barriers		1.2	N/A

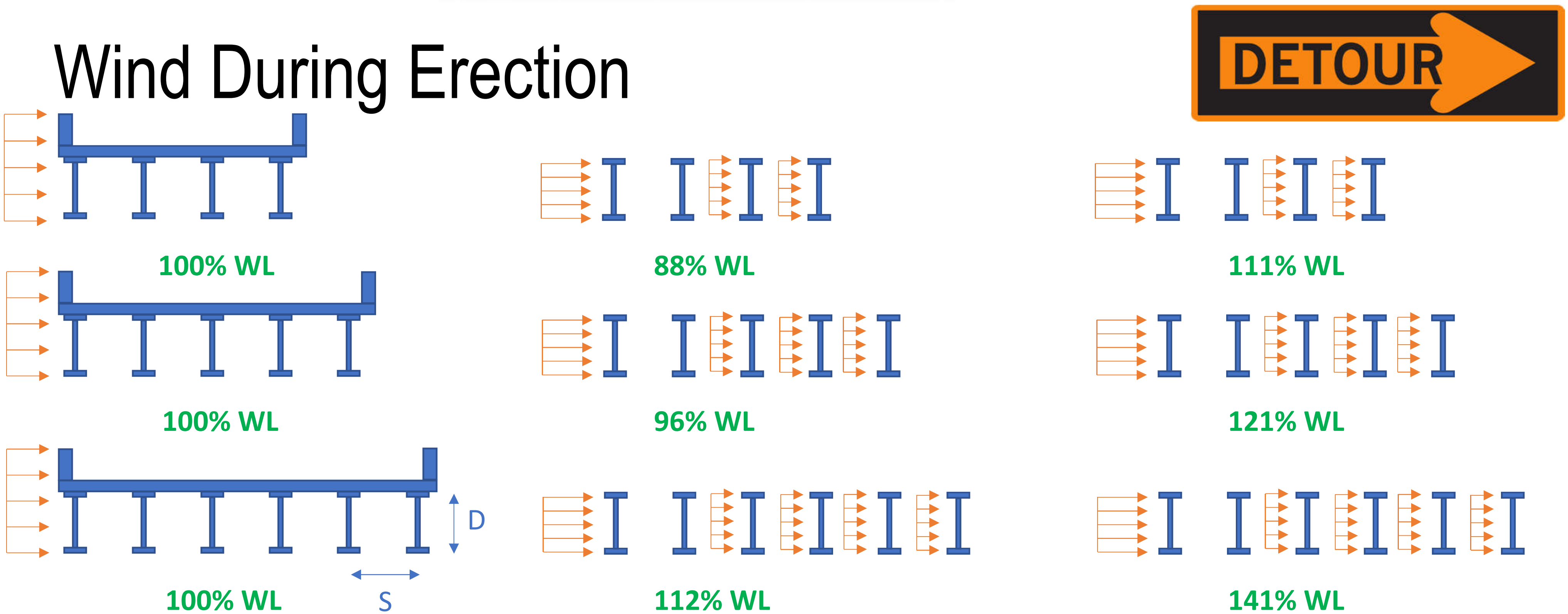


$$P_Z = 2.56 \times 10^{-6} V^2 R^2 K_z G C_D$$

	R
0-6 weeks	0.65
6 weeks to 1 year	0.73
>1-2 years	0.75
>2-3 years	0.77
>3-7years	0.84

Rolled I-Beams	2.2
Concrete I-Beams	2.0
Closed and Open Box-Girders	2.1
Round Members	1.0

Wind During Erection



Final Structure
S/D = 1.0 < 3

Construction (0 to 6 weeks)
R = 0.65

Construction (6 weeks to 1 year)
R = 0.73

PennDOT Requirements

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION
BUREAU OF PROJECT DELIVERY

STANDARD

STEEL GIRDER BRIDGES
LATERAL BRACING CRITERIA
AND DETAILS

LATERAL STABILITY BRACING DESIGN CRITERIA FOR GIRDER BRIDGES PRIOR TO DECK COMPLETION:

THE CRITERION IN THIS STANDARD APPLIES ONLY TO COMPLETELY ERECTED STEEL SUPERSTRUCTURE, WITHOUT THE DECK. THE STABILITY OF PARTIAL AND COMPLETED GIRDERS IN THE VARIOUS STAGES OF ERECTION PRIOR TO INSTALLATION OF ALL GIRDERS AND DIAPHRAGMS IS THE RESPONSIBILITY OF THE CONTRACTOR AS SPECIFIED IN PUBLICATION 408 SECTION 1050.3(c). (APPLIES TO TANGENT, SKEWED AND CURVED BRIDGES. APPLIES TO SINGLE AND MULTI-SPAN BRIDGES.)

PennDOT Requirements

DETOUR

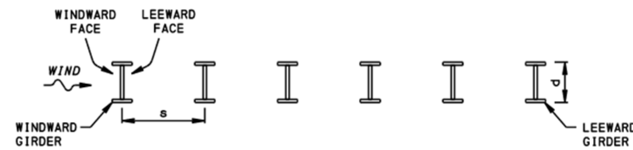
COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION
BUREAU OF PROJECT DELIVERY

STANDARD

STEEL GIRDER BRIDGES
LATERAL BRACING CRITERIA
AND DETAILS

Provides Design Wind Pressures & Load Combinations

MINIMUM DESIGN WIND PRESSURE(PSF)
FOR LATERAL BRACING DURING CONSTRUCTION



CONSTRUCTION DURATION	0-6 WEEKS		6 WEEKS-1 YEAR		1-2 YEARS	
SUPERSTRUCTURE HEIGHT ABOVE GROUND LEVEL (FT.)	$s/d \leq 2$	$2 < s/d \leq 4$	$s/d \leq 2$	$2 < s/d \leq 4$	$s/d \leq 2$	$2 < s/d \leq 4$
0-15	19	21	26	28	29	32
20	20	22	27	30	31	34
25	21	23	28	31	32	35
30	22	24	30	32	34	37
40	24	26	31	34	36	39
50	25	27	33	36	38	41
60	26	28	34	37	39	42
70	27	29	35	39	40	44
80	28	30	37	40	42	45
90	28	31	38	41	43	47
100	29	31	38	42	43	47

PennDOT Requirements

DETOUR

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION
BUREAU OF PROJECT DELIVERY

STANDARD

STEEL GIRDER BRIDGES
LATERAL BRACING CRITERIA
AND DETAILS

<u>Lateral Bracing Requirements Based on Span Length</u>

1. PROVIDE LATERAL BRACING FOR BRIDGES WITH SPANS IN EXCESS OF 300 FT. TO AID IN CONSTRUCTION OF THE BRIDGE. DESIGN BRACING FOR THE SPECIFIED WIND LOADS.

2. EVALUATE THE NEED FOR LATERAL BRACING FOR SPANS IN EXCESS OF 200 FT. BASED ON LATERAL DEFLECTION.

Critical Stages Deflection Criteria

- State Specific (PennDOT)

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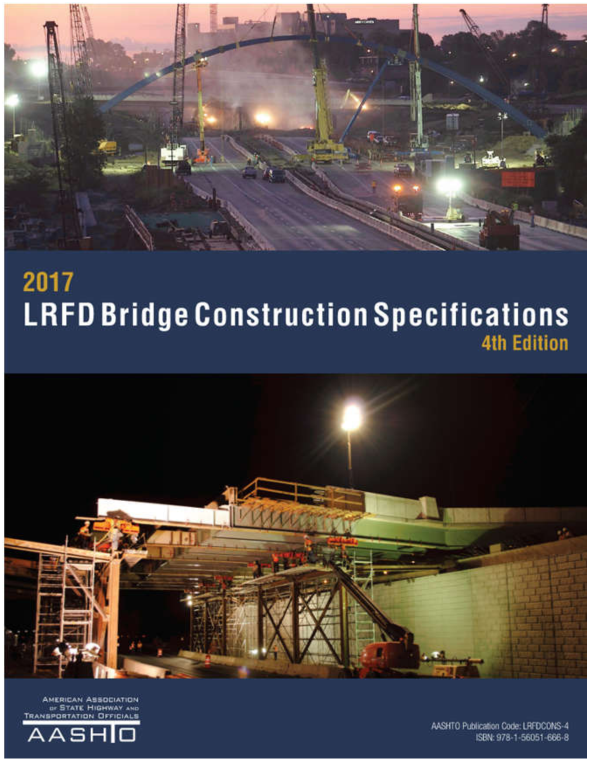
STANDARD

STEEL GIRDER BRIDGES
LATERAL BRACING CRITERIA
AND DETAILS

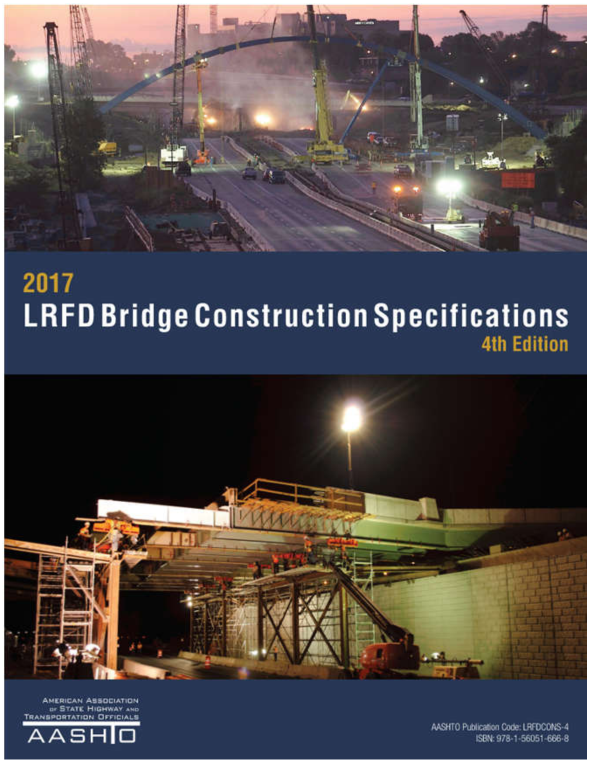
4. EVALUATE LATERAL DEFLECTION OF STEEL SUPERSTRUCTURE FOR A PERMISSIBLE DEFLECTION OF L/150. PROVIDE BRACING IF DEFLECTION LIMIT IS EXCEEDED. AN ACCEPTABLE ANALYSIS METHOD IS A HAND CALCULATION FOR A SINGLE FASCIA GIRDER (NON COMPOSITE) OR A GRID ANALYSIS FOR THE ENTIRE STEEL SUPERSTRUCTURE FRAMING. THE DIAPHRAGM ACTION OF THE STAY-IN-PLACE FORMS SHALL BE NEGLECTED. FINALLY, IF A GRID ANALYSIS IS USED, THE DIAPHRAGM/GIRDER CONNECTION SHALL BE MODELED AS A PIN IN THE PLANE OF THE GRID. IT IS CONSERVATIVE TO ASSUME PINNED DIAPHRAGM TO GIRDER CONNECTIONS. A MORE RIGOROUS ANALYSIS MODELING PARTIAL FIXITY AT THE CONNECTIONS CONSISTENT WITH THE CONNECTION DETAILING IS ACCEPTABLE.

- No AASHTO Criteria

AASHTO Bridge Construction Specifications



AASHTO Bridge Construction Specifications



<u>Key Sections:</u>

Chapter 8
Concrete Structures

- 8.13 – Precast Concrete Members
- 8.16 – Special Provisions for Segmental Bridges

Chapter 11
Steel Structures

- 11.2 – Erection Drawings
- 11.8 – Additional Provisions for Curved Girders

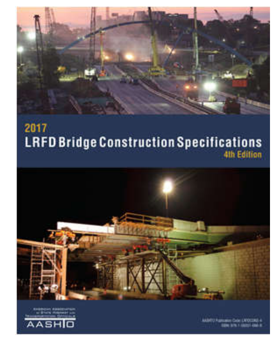
Precast Beams

8.13—PRECAST CONCRETE MEMBERS

8.13.6—Erection

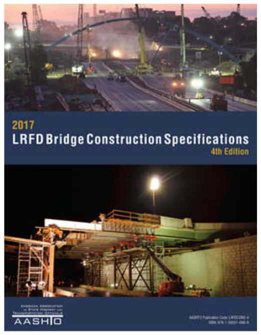
The Contractor shall be responsible for the safety of precast members during all stages of construction. Lifting devices shall be used in a manner that does not cause damaging, bending, or torsional forces. After a member has been erected and until it is secured to the structure, temporary braces shall be provided as necessary to resist wind or other loads.

US50 Over BNSF RR, Lamar, CO



Special Provisions for Segmental

- Contractor's geometry control plan including the effect of time-dependent prestress losses and creep
- Additional requirements for construction procedure design calculations including falsework design



Images Courtesy of: http://www.asbi-assoc.org/

Steel Girder Bridges

11.2.2—Erection Drawings

The Contractor shall submit drawings illustrating fully the proposed method of erection. The drawings shall show details of all falsework bents, bracing, guys, dead-men, lifting devices, and attachments to the bridge members: sequence of erection, location of cranes and barges, crane capacities, location of lifting points on the bridge members, and weights of the members. The drawings shall be complete in detail for all anticipated phases and conditions during erection. Calculations may be required to demonstrate that factored resistances are not exceeded and that member capacities and final geometry will be correct.

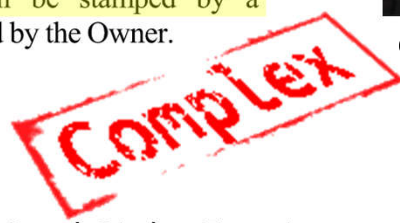
Comm. Ave Bridge, Boston, MA

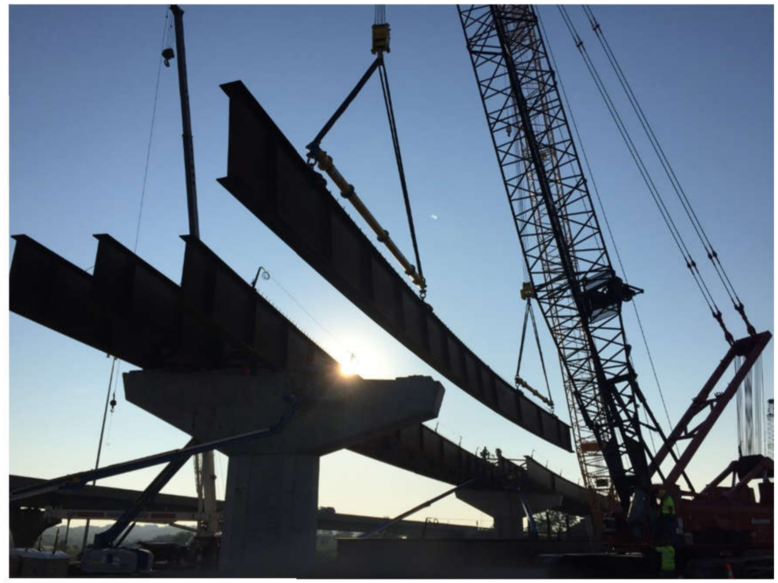
Curved Steel Girder Bridges

11.8—ADDITIONAL PROVISIONS FOR CURVED STEEL GIRDERS

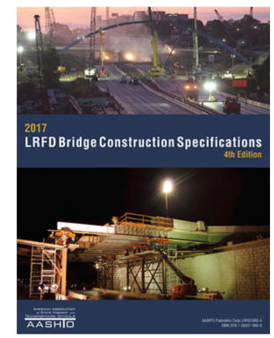
11.8.2—Contractor's Construction Plan for Curved Girder Bridges

The Contractor shall provide a construction plan which details fabrication, procedures for … deck placement, and which shall … as the Contractor's constru… on the plan shown in the co… ded, or may be developed entir… event, it shall demonstrate the gen… ure and individual components du… construction, including while supported … porary jacks. The Contractor's construction … all be stamped by a Professional Engineer and be accepted by the Owner.





Gateway Interchange Flyovers, Johnson County, KS



Constructibility Summary

Structure Classification	Material	Structure Type
Conventional	Concrete	Precast Beams
	Steel	Shorter Straight Spans (< 200-ft)
Complex	Concrete	Spliced Prestressed Beams / Segmental
	Steel	Long Spans (> 200-ft) / Curved / High Skew

Constructibility Summary

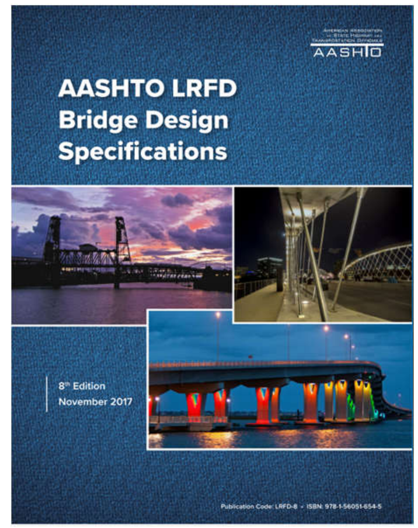
Structure Classification	Material	Structure Type	EOR Responsibility Suggested Construction Plan
Conventional	Concrete	Precast Beams	No
	Steel	Shorter Straight Spans (< 200-ft)	No
Complex	Concrete	Spliced Prestressed Beams / Segmental	Yes
	Steel	Long Spans (> 200-ft) / Curved / High Skew	Sometimes

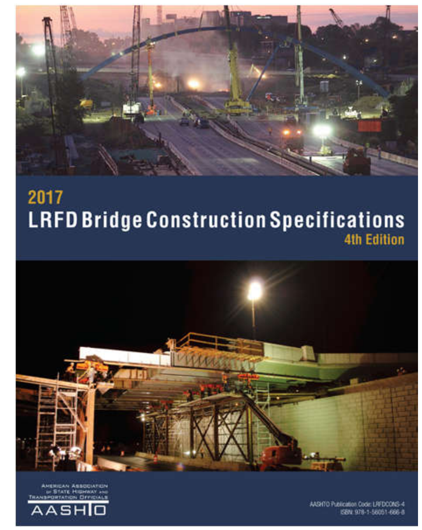
Constructibility Summary

			EOR Responsibility	Contractor Responsibility	
Structure Classification	Material	Structure Type	Suggested Construction Plan	Erection Plan Required?	Erection Engineering Required?
Conventional	Concrete	Precast Beams	No	Yes	DOT Dependent
	Steel	Shorter Straight Spans (< 200-ft)	No	Yes	DOT Dependent
Complex	Concrete	Spliced Prestressed Beams / Segmental	Yes	Yes	Yes
	Steel	Long Spans (> 200-ft) / Curved / High Skew	Sometimes	Yes	Sometimes

Constructibility Summary

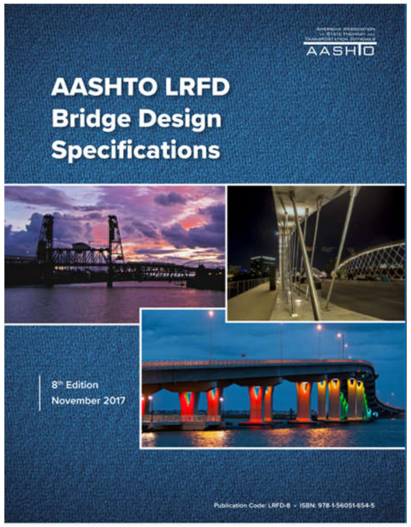
- AASHTO Specifications clearly distinguish between complex and conventional for concrete girder bridges
- AASHTO Specifications are not as clear for steel girder bridges (I-Girder / Box Girder)
- DOT guides have made effort to address

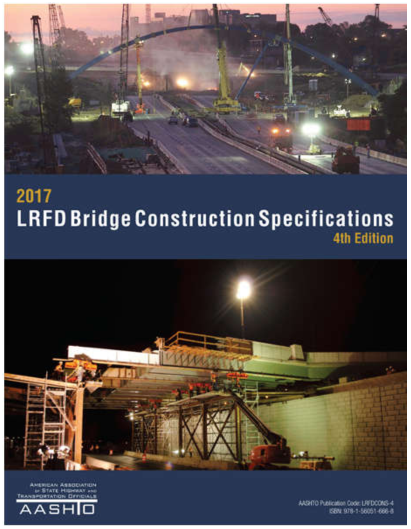




Constructibility Summary

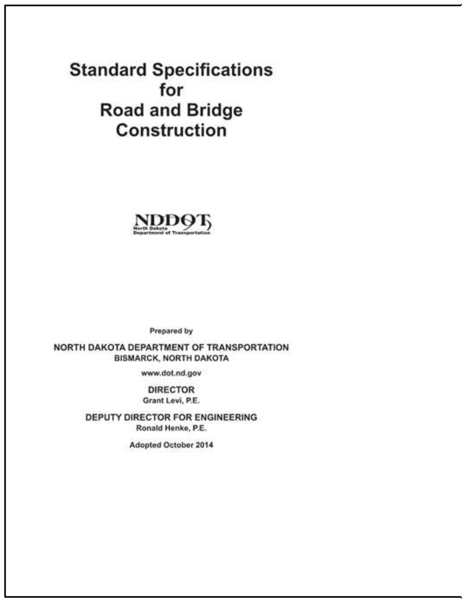
- AASHTO Specifications clearly distinguish between complex and conventional for concrete girder bridges …Mostly out of necessity
- AASHTO Specifications are not as clear for steel girder bridges (I-Girder / Box Girder)
- DOT guides have made effort to address





Steel Girder Erection Classification – SDDOT/ NDDOT

- Standard Specifications indicate working drawings (which include erection plan) must be reviewed by Engineer
- No threshold defined for when an engineered erection plan would be required



Standard Specifications
for
Road and Bridge
Construction

NDDOT
North Dakota
Department of Transportation

Prepared by

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION
BISMARCK, NORTH DAKOTA

www.dot.nd.gov

DIRECTOR
Grant Levi, P.E.

DEPUTY DIRECTOR FOR ENGINEERING
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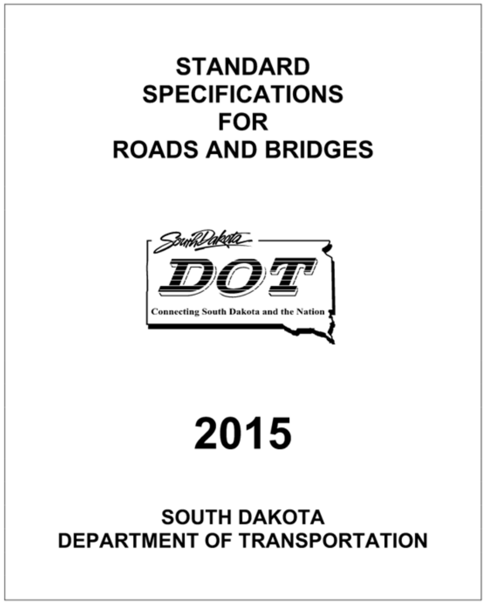
Adopted October 2014



STANDARD
SPECIFICATIONS
FOR
ROADS AND BRIDGES

South Dakota DOT
Connecting South Dakota and the Nation

2015

SOUTH DAKOTA
DEPARTMENT OF TRANSPORTATION

Erection Classification Example - KDOT

- KDOT Section 737 provides erection category system based on complexity
- Accounts for span length, skew and curvature
- Based on category, which designer can indicate on Contract Plans, the level of erection considerations may be required.
- Everyone is on even playing field during bid phase

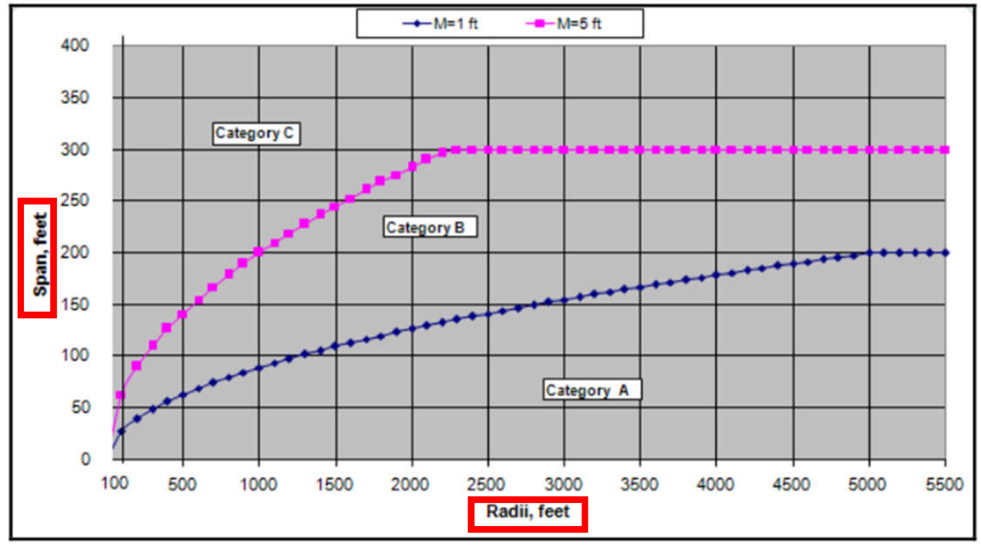


FIGURE 736-1

Special Requirements for Bridge Designers to Designate Erection Plan Categories

The initial Category is based on the chart which considers the length of the longest span, the curvature of the bridge and the skew angle.

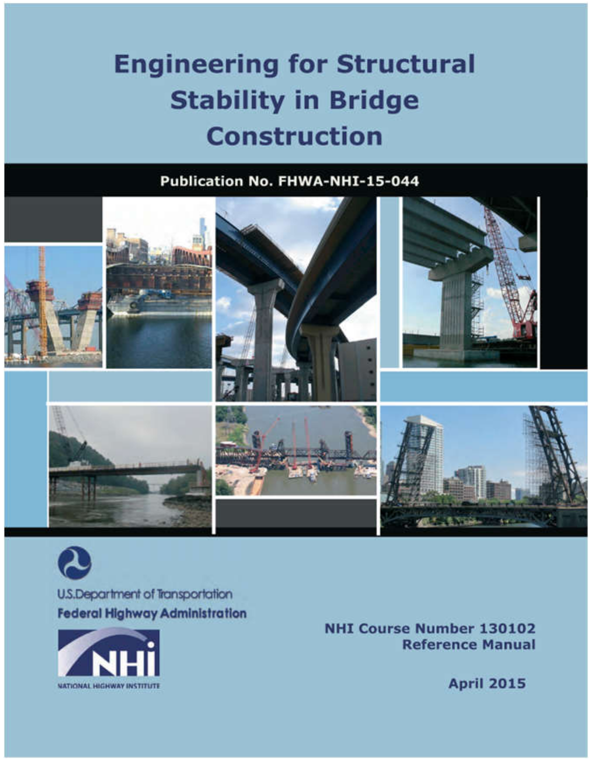
If skew is greater than 30°, move up one Category (A to B or B to C).

If a structure crosses traffic or a railroad, require Category B as a minimum.

If the Contractor uses falsework bents or strong-backs for the field erection, Category C Erection Plans are required.

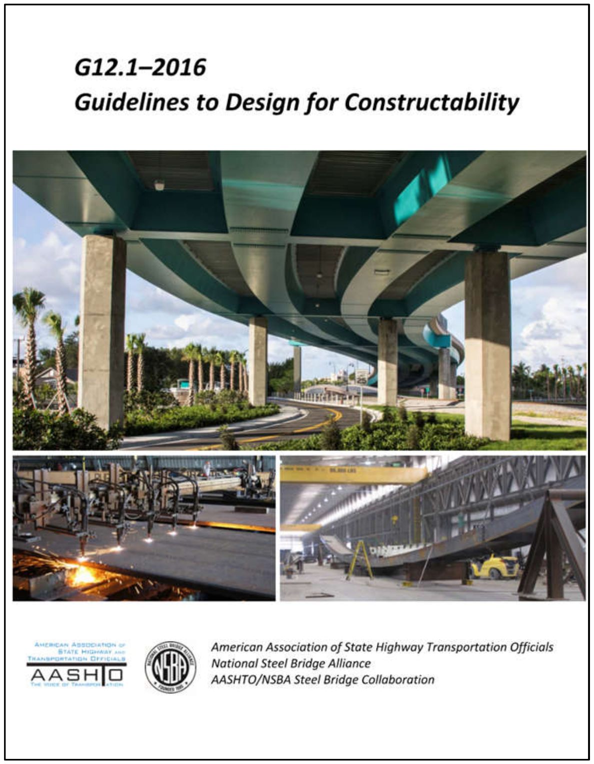
The designer may elevate a structure to the necessary Category based upon engineering judgment and unique circumstances.

Erection Classification - Survey



- Survey of AASHTO member states for engineering requirements for structural safety during erection
- 33 states responded to survey
- Past issues related to girder erection
- Threshold for when submittal of erection plans required for review

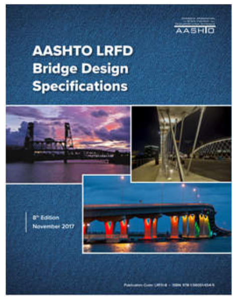
Useful Resources - Constructability

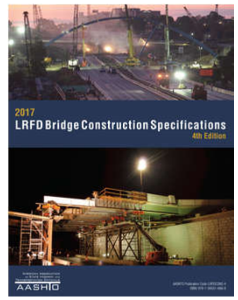


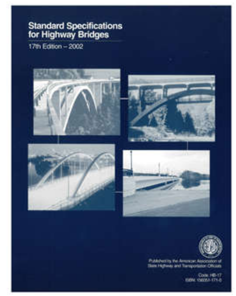
- G12.1-2016 - NSBA / AASHTO Collaboration
- Great resource to ensure a bridge is easy to fabricate and connections are constructible
- Does not cover erection analysis

Construction Engineer's Literature Review

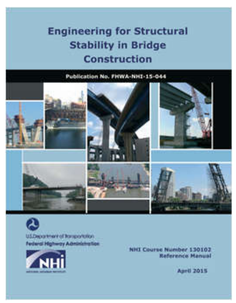
Design Specifications

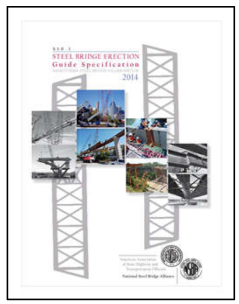


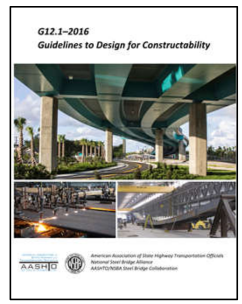


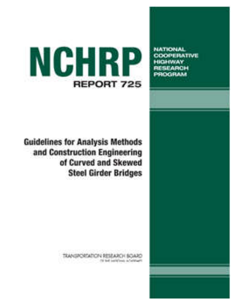


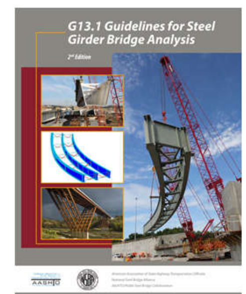
Erection Guides/Specifications



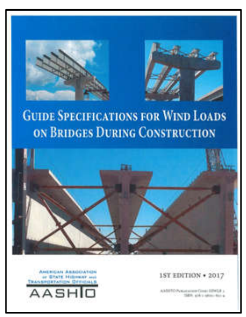


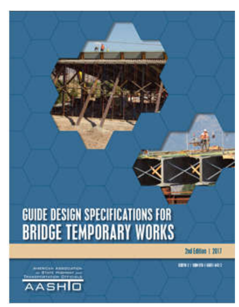


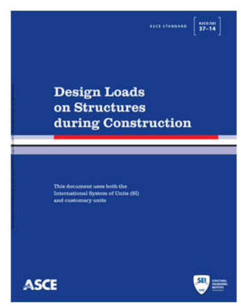


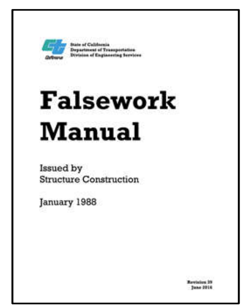


Design Loads



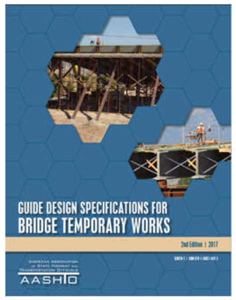


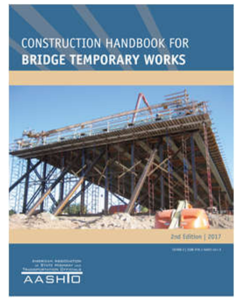


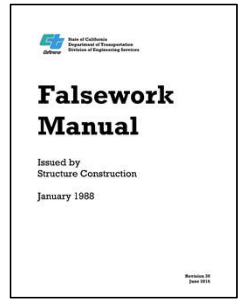


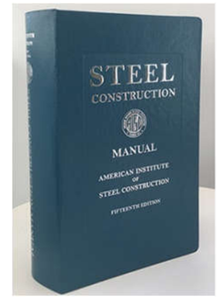
Construction Engineer’s Literature Review

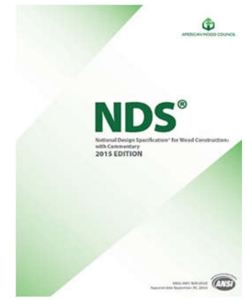
Temporary Works

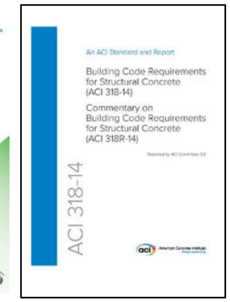




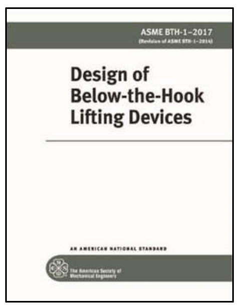


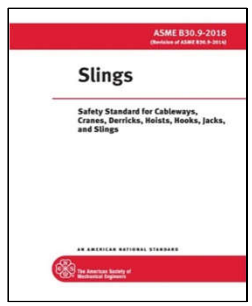




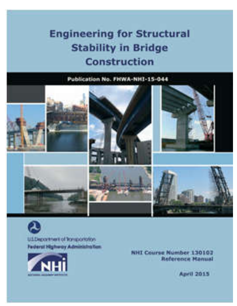


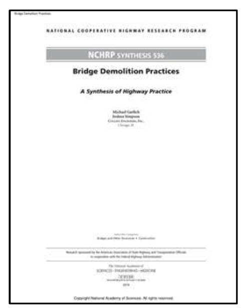
Rigging Hardware

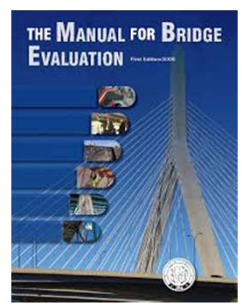




Demolition Guides

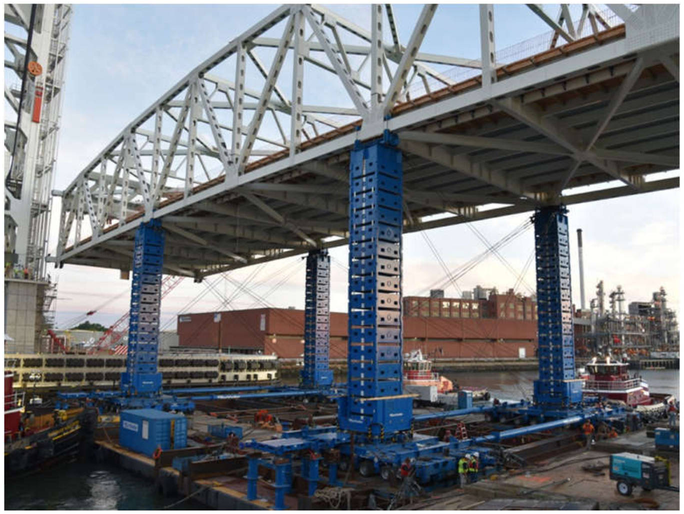






Construction Engineer's Literature Review

Equipment Specifications



Fore River Lift Bridge Replacement, Quincy, MA

Hole in the Wall RR Bridge, Fort Worth, TX

Age old question…

Constructibility

6.10.3—Constructibility

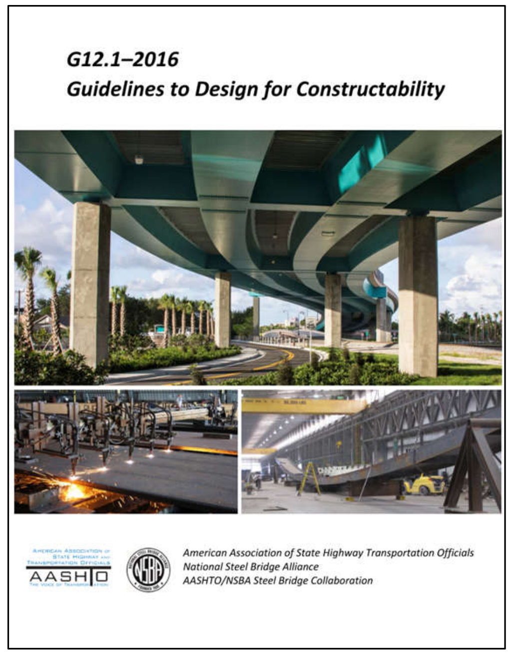
6.10.3.1—General

The provisions of Article 2.5.3 shall apply. In addition to providing adequate strength, nominal yielding or reliance on post-buckling resistance shall not be permitted for main load-carrying members during critical stages of construction, except for yielding of the web in hybrid sections. This shall be accomplished by satisfying the requirements of Articles 6.10.3.2 and 6.10.3.3 at each critical construction stage. For sections in positive flexure that are composite in the final condition, but are noncomposite during construction, the provisions of Article 6.10.3.4 shall apply. For investigating the constructibility of flexural members, all loads shall be factored as specified in Article 3.4.2. For the calculation of deflections, the load factors shall be taken as 1.0.

Potential uplift at bearings shall be investigated at each critical construction stage.

Webs without bearing stiffeners at locations subjected to concentrated loads not transmitted through a deck or deck system shall satisfy the provisions of Article D6.5.

Constructability



Steel Girder Erection

Through the Eyes of a Construction Engineer

Steel Girder Erection

- Compression Flange Slenderness Requirements
- Picking Girders
- Staged Construction Evaluation
- Temporary Works

Compression Flange Requirements

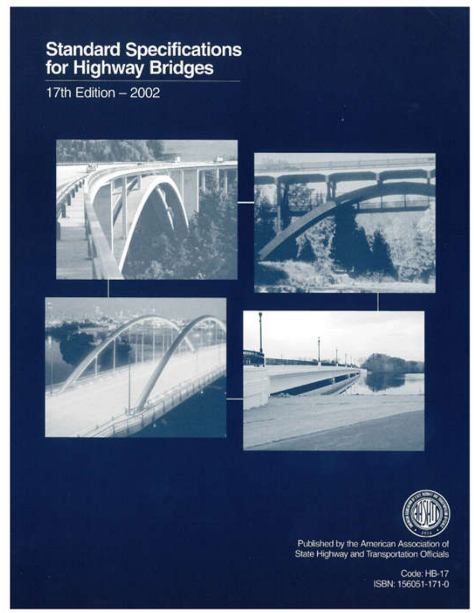
b/t RATIO

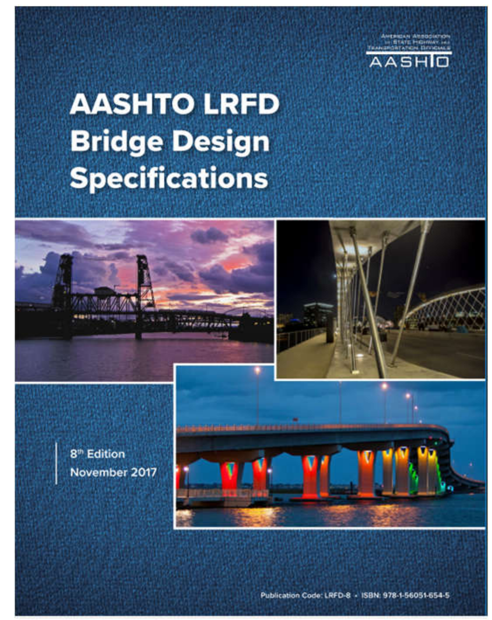
- Compression flange slenderness (b/t) has a major impact on plate girder constructability.
  - Stability of Girders while Hoisting
  - Stability of Partially Constructed Girder Systems
- Prior to deck pour, the flanges provide the only means of stiffness between cross-frames.
- Changes to AASHTO requirements have allowed compression flanges to be more “optimized”

AASHTO History

b/t RATIO

- ASD (Allowable Stress Design)
- LFD (Load Factor Design)
- LRFD (Load Resistance Factor Design)





ASD (Allowable Stress Design)

σ.allowable ≥ σ.demand

1930's

LFD (Load Factor Design)

$$R_n \geq effects\ of \sum \gamma_i Q_i$$

1970's

LRFD (Load Resistance Factor Design)

$$\phi R_n \geq effects\ of \sum \gamma_i Q_i$$

1994

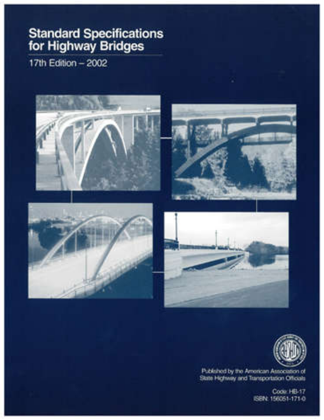
Images Courtesy of:

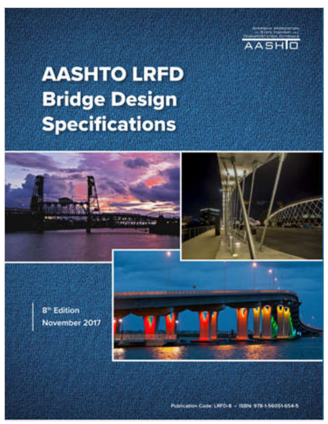
https://imgur.com/gallery/Yg6XWqB
https://www.biography.com/news/saturday-night-fever-40th-anniversary
https://csengineermag.com/article/john-kulicki-setting-new-standards/

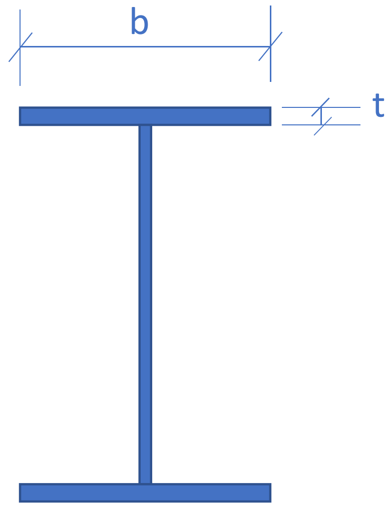
Compression Flange Requirements

b/t RATIO

- ASD
- LFD
- LRFD







Golden Rule

Flange Proportion Limit

$b/t \leq 24$

ASD - Compression Flange Requirements

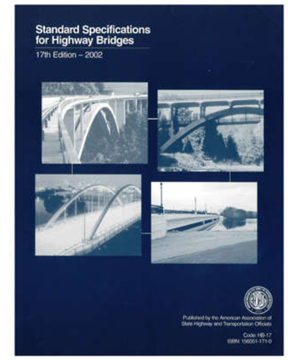
b/t RATIO

10.34.2.1.3 The ratio of compression flange plate width to thickness shall not exceed the value determined by the formula

$$\frac{b}{t} = \frac{3,250}{\sqrt{f_b}} \quad \text{but in no case shall b/t exceed 24} \qquad (10\text{-}19)$$

10.34.2.1.4 Where the calculated compressive bending stress equals .55 F_y the (b/t) ratios for the various grades of steel shall not exceed the following:

36,000 psi, Y.P. Min. b/t = 23
50,000 psi, Y.P. Min. b/t = 20
70,000 psi, Y.P. Min. b/t = 17
90,000 psi, Y.P. Min. b/t = 15
100,000 psi, Y.P. Min. b/t = 14



- b/t limit is function of applied stress (f_b)
- Defines maximum flange width to thickness limits when fb = 0.55fy

LFD - Compression Flange Requirements

b/t RATIO

10.48.1.1 Compact sections shall meet the following requirements: (For certain frequently used steels these requirements are listed in Table 10.48.1.2A.)

(a) Compression flange

$$\frac{b}{t} \leq \frac{4{,}110}{\sqrt{F_y}} \qquad (10\text{-}93)$$

TABLE 10.48.1.2A Limitations for Compact Sections

F_y (psi)	36,000	50,000	70,000
b/t	21.7	18.4	15.5
D/t_w	101	86	72
L_b/r_y ($M_1/M_u = 0$*)	100	72	51
L_b/r_y ($M_1/M_u = 1$*)	39	28	20

* For values of M_1/M_u other than 0 and 1, use Equation (10-96).

TABLE 10.48.2.1A Limitations for Braced Noncompact Sections

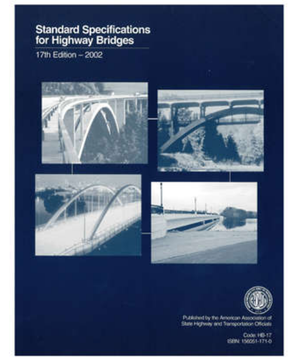
F_y (psi)	36,000	50,000	70,000	90,000	100,000
b/t *	23.2	19.7	16.6	14.7	13.9
$\frac{L_b d}{A_f}$	556	400	286	222	200
D/t_w	Refer to Articles 10.48.5.1, 10.48.6.1, 10.49.2, or 10.49.3, as applicable. For unstiffened webs, the limit is 150.				

* Limits shown are for $F_{cr} = F_y$. Refer also to Articles 10.48.2 and 10.48.2.1(a).

10.48.2.1 The above equations are applicable to sections meeting the following requirements:

(a) Compression flange

$$\frac{b}{t} \leq 24 \qquad (10\text{-}100)$$



LRFD - Compression Flange Requirements

b/t RATIO

6.10.2.2—Flange Proportions

Compression and tension flanges shall be proportioned such that:

$$\frac{b_f}{2t_f} \leq 12.0, \qquad (6.10.2.2\text{-}1)$$

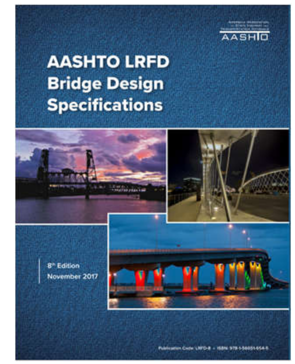
→ bf / tf < 24

$$b_f \geq D/6, \qquad (6.10.2.2\text{-}2)$$

$$t_f \geq 1.1t_w, \qquad (6.10.2.2\text{-}3)$$

and:

$$0.1 \leq \frac{I_{yc}}{I_{yt}} \leq 10 \qquad (6.10.2.2\text{-}4)$$



LRFD - Compression Flange Requirements

b/t RATIO

6.10.8.2.2—Local Buckling Resistance

The local buckling resistance of the compression flange shall be taken as:

- If $\lambda_f \le \lambda_{pf}$, then:

$$F_{nc} = R_b R_h F_{yc} \qquad (6.10.8.2.2\text{-}1)$$

- Otherwise:

$$F_{nc} = \left[1 - \left(1 - \frac{F_{yr}}{R_h F_{yc}}\right)\left(\frac{\lambda_f - \lambda_{pf}}{\lambda_{rf} - \lambda_{pf}}\right)\right] R_b R_h F_{yc} \qquad (6.10.8.2.2\text{-}2)$$

in which:

λ_f = slenderness ratio for the compression flange

$$= \frac{b_{fc}}{2t_{fc}} \qquad (6.10.8.2.2\text{-}3)$$

λ_{pf} = limiting slenderness ratio for a compact flange

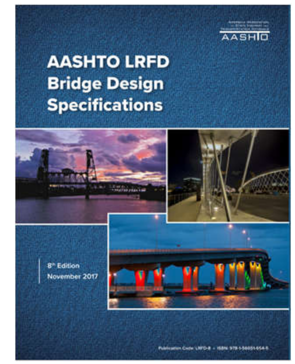
$$= 0.38\sqrt{\frac{E}{F_{yc}}} \qquad (6.10.8.2.2\text{-}4)$$

λ_{rf} = limiting slenderness ratio for a noncompact flange

$$= 0.56\sqrt{\frac{E}{F_{yr}}} \qquad (6.10.8.2.2\text{-}5)$$

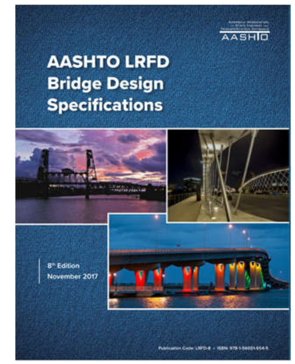
$bf / 2tf < \lambda pf$

$bf / tf < 2\lambda pf$



Compression Flange Requirements

b/t RATIO



- ASD or LFD Non-Compact

  $\frac{b}{t} = \frac{3,250}{\sqrt{f_b}}$ let fb = 0.55fy

- LFD Compact

  $\frac{b}{t} \leq \frac{4,110}{\sqrt{F_y}}$

- LRFD

  $2 \times 0.38\sqrt{\frac{E}{F_{yc}}}$

- ASD / LFD / LRFD

  $\frac{b}{t} \leq 24$

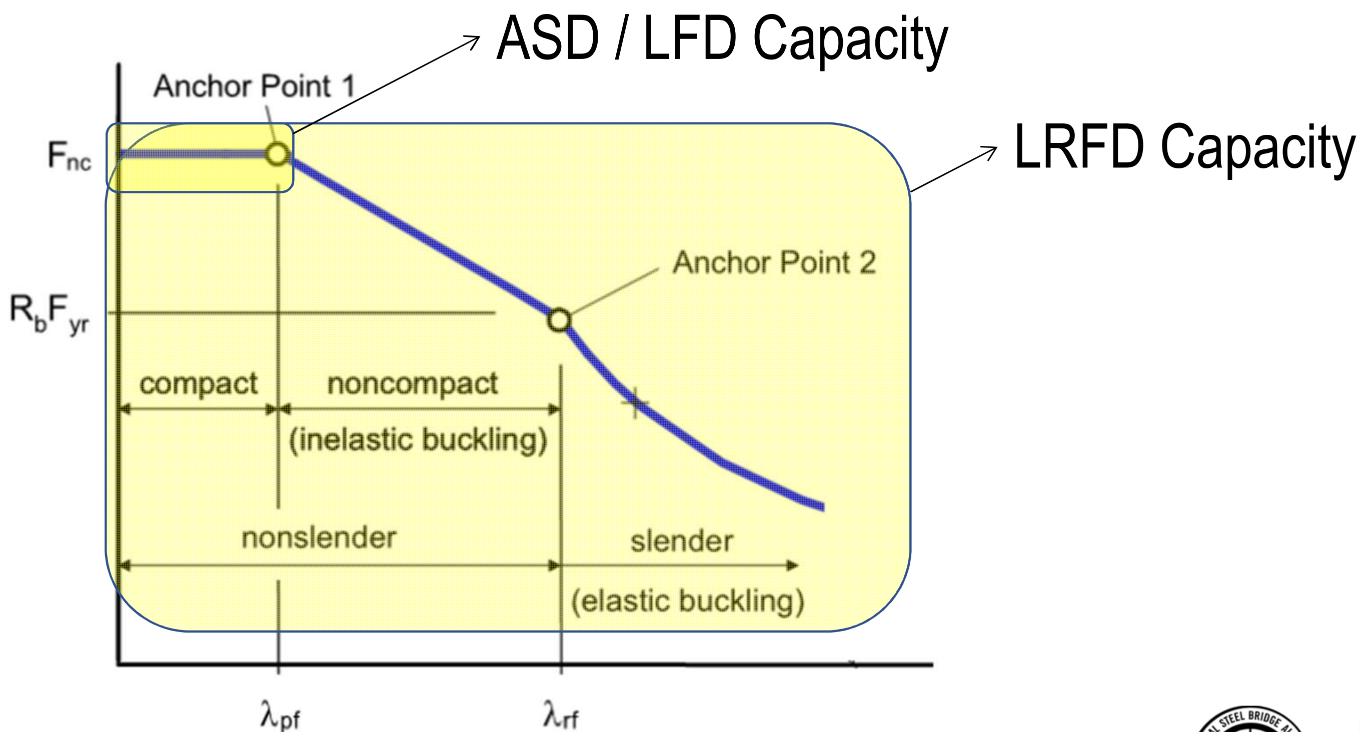
fy (ksi)	ASD or LFD Non-Compact	LFD Compact	LRFD
36	23.1	21.7	21.6
50	19.6	18.4	18.3
70	16.6	15.5	15.5
90	14.6	13.7	13.6
100	13.9	13.0	12.9

ASD & LFD Hard Limit

LRFD Limit for when LB must be considered

Compression Flange Requirements

b/t RATIO



Compression Flange Requirements

b/t RATIO

- Governing codes have become more refined (& complicated) in the calculation of both member capacity and load demands.
- Computer power allows for more refined analysis.
- This has in turn allowed for more "efficient" structures.
- Results in potentially larger compression flange b/t ratios.
  - Final bridge condition may be adequate
  - More difficult to erect.
- More "efficient" structures do NOT always result in project cost savings.

Steel Girder Erection

PICKING

- Compression Flange Slenderness Requirements
- Picking Girders
  - Single Girder vs Paired Girder
  - Curved Girder
  - Rigging Options
- Staged Construction Evaluation
- Temporary Works

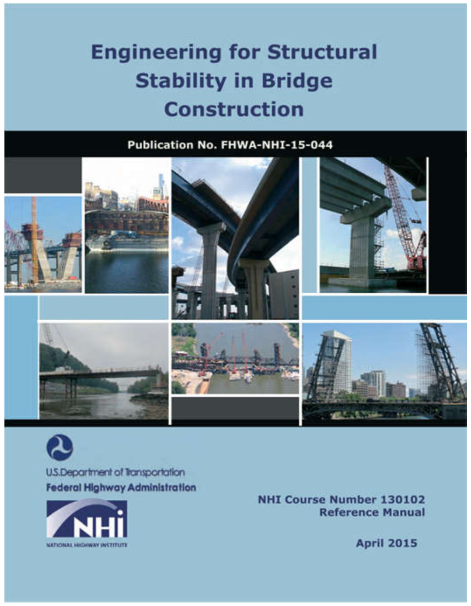
Critical Stages of Construction

PICKING

7.2.2 Critical Erection Stages

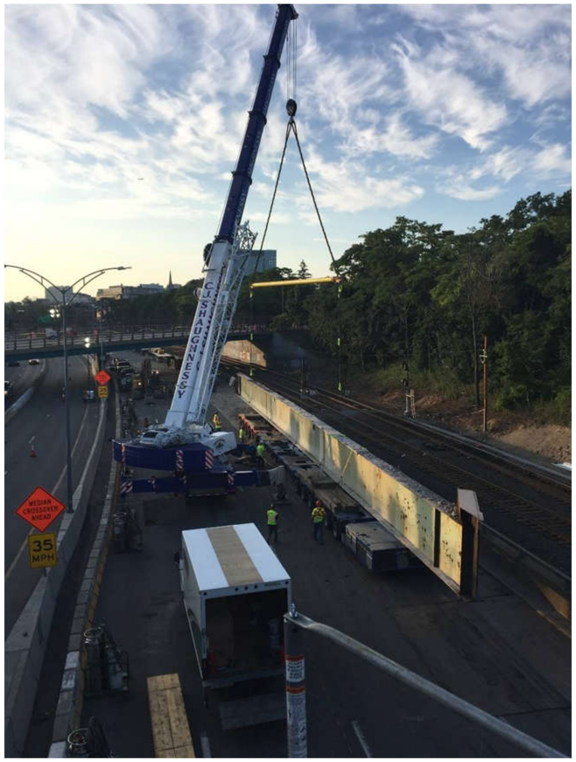
The erection plan and supporting engineering calculations must address both strength and stability at each stage of erection. Deformations associated with each stage should also be evaluated. Critical erection stages for the girder bridge structure during construction normally consist of at least the following:

- Lifting of girders/members
- Placement of the initial girder and any associated temporary bracing used to hold the girder in place
- First pair of girders set with permanent bracing installed
- All girders and bracing installed prior to the deck placement
- All girders and bracing installed during the deck placement
- Application of the deck overhang bracket loads to the fascia girders during the deck placement



Single vs. Paired Girder Pick

PICKING



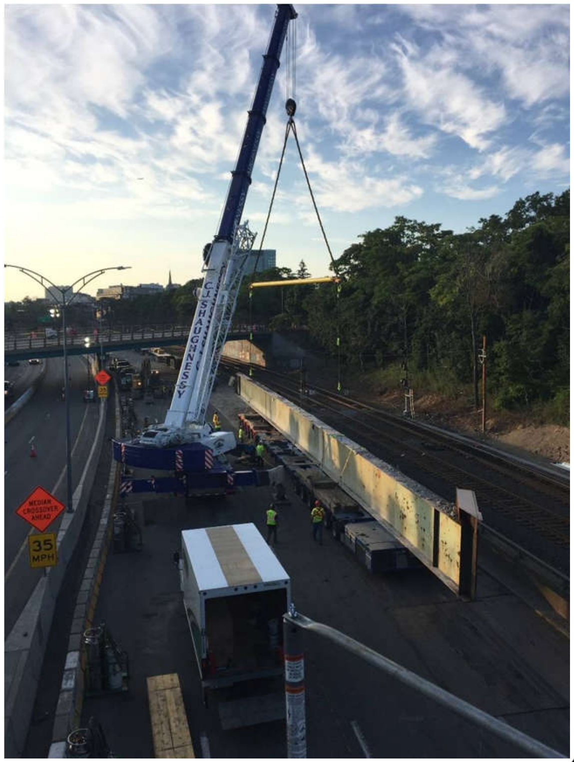
Comm. Ave Bridge, Boston, MA

Comm. Ave Bridge, Boston, MA

Single Girder Pick Advantages

PICKING

- Smaller Crane
  - Lighter pick load
- Larger Radius
  - Site constraints may dictate
- Simpler Rigging
  - No transverse spreaders
- Expedited Installation
  - One field splice connection



Comm. Ave Bridge, Boston, MA

Paired Girder Pick Advantages

PICKING

- More Ground Assembly
  - Cross frame connections
- More Stable while Hoisted
  - Reduced lateral torsional buckling concerns

KY 152 over Herrington Lake, Mercer and Garrard Counties, KY

Curved Girder Pick

PICKING

Fulbright Expressway, Fayetteville, AR

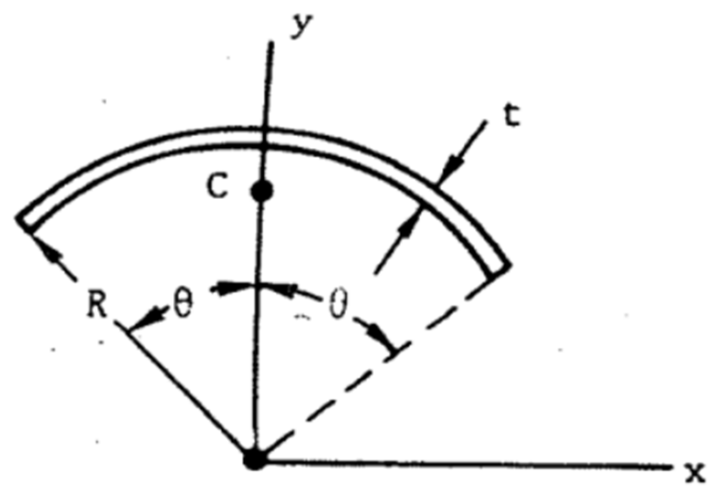
Gateway Interchange Flyovers, Johnson County, KS

Curved Girder Pick

PICKING

Girder Center of Gravity

28. Sector of Thin Annulus



$$x_C = 0$$

$$y_C = R\frac{\sin\theta}{\theta}$$

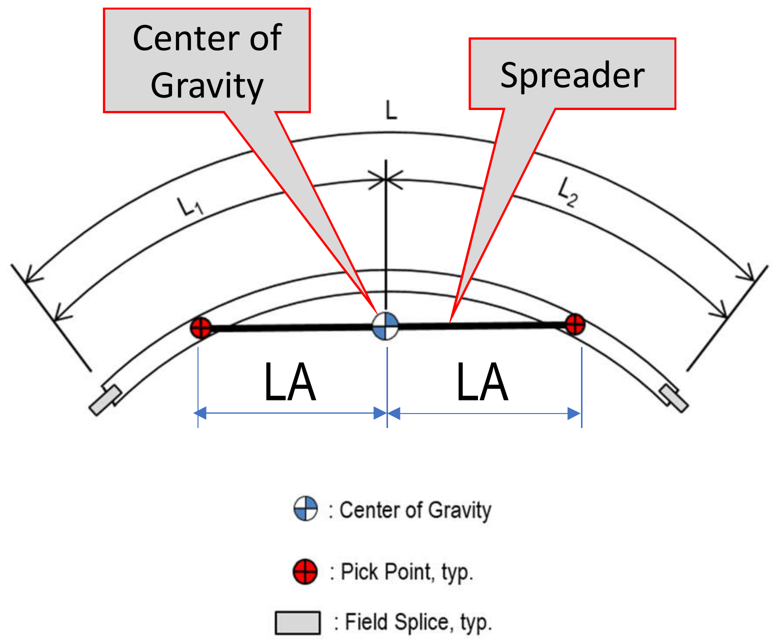
Curved Girder Pick

PICKING

Girder Center of Gravity

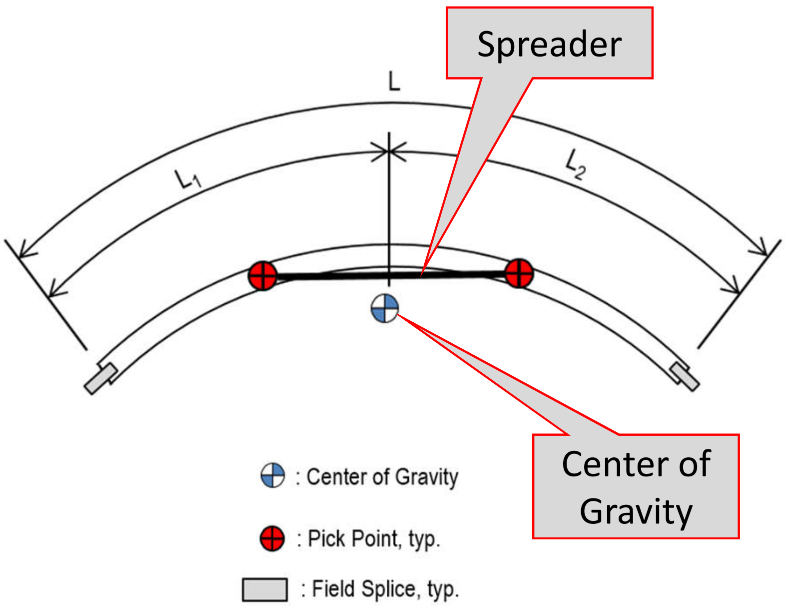
- Span Lengths
- Changing Girder Cross Section
  - Shop Splices
- Field Splices
- Cross Frames

Ideal Spreader Length



Curved Girder Pick

Spreader Shorter Than Ideal Length



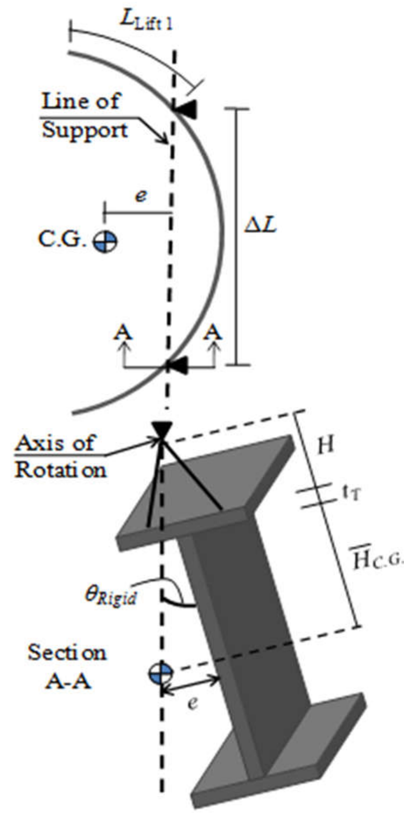


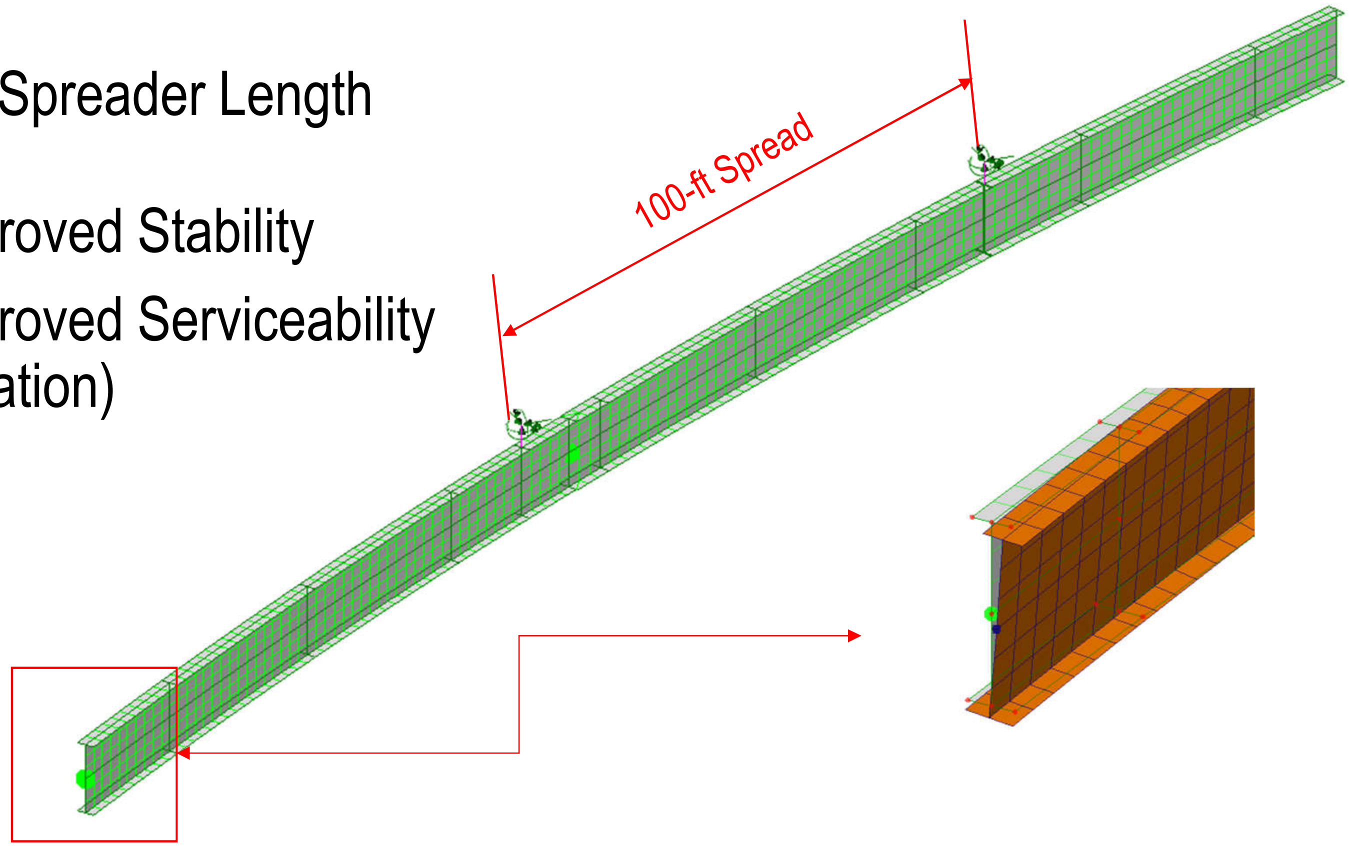
Image Courtesy of: UTLift

Curved Girder Pick

PICKING

Ideal Spreader Length

- Improved Stability
- Improved Serviceability (rotation)

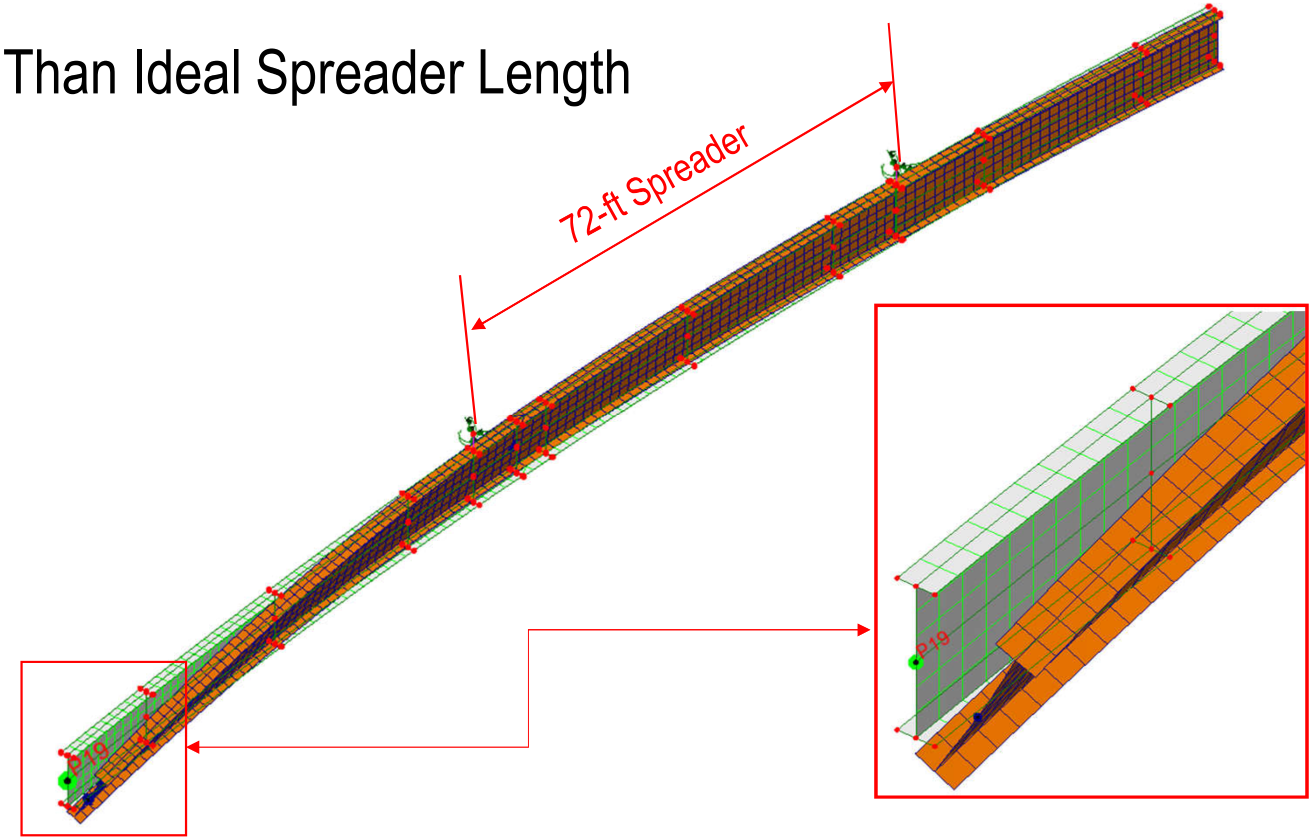


9" Lateral Displacement

Curved Girder Pick

PICKING

Shorter Than Ideal Spreader Length

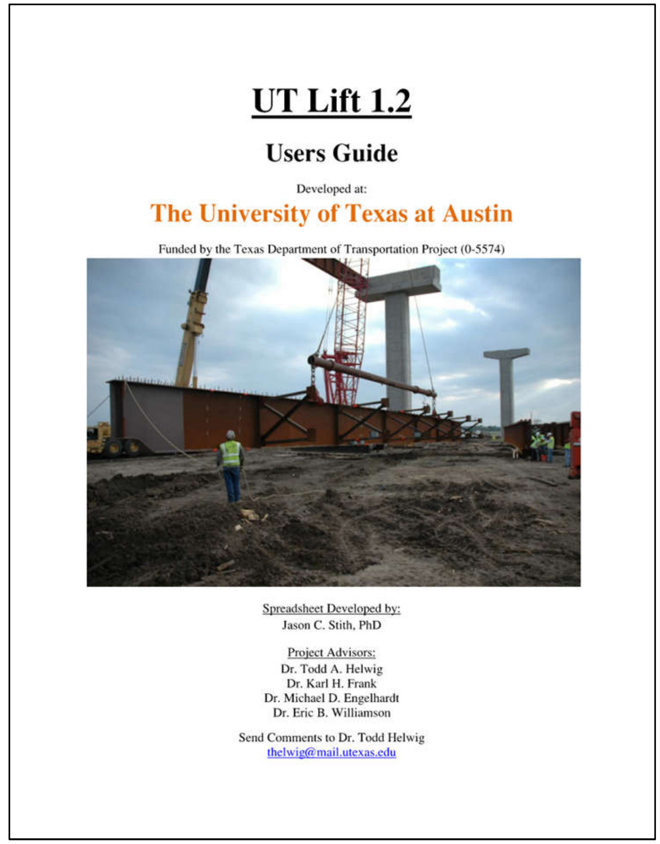


20” Lateral Displacement

Curved Girder Pick – UT Lift

PICKING

- UT Lift Software used for curved girder hoisting analysis



UT Lift 1.2

Users Guide

Developed at:

The University of Texas at Austin

Funded by the Texas Department of Transportation Project (0-5574)

Spreadsheet Developed by:
Jason C. Stith, PhD

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Dr. Michael D. Engelhardt
Dr. Eric B. Williamson

Send Comments to Dr. Todd Helwig
thelwig@mail.utexas.edu

Curved Girder Pick – UT Lift

PICKING

- Input:
  - Girder section properties
  - Curve radius
  - Cross-frame information, if applicable
- Output:
  - Pick weight and C.G.
  - Ideal spread between pick points
  - Max girder picking stresses
  - Girder twist
  - Girder Demand/Capacity (D/C) Ratio

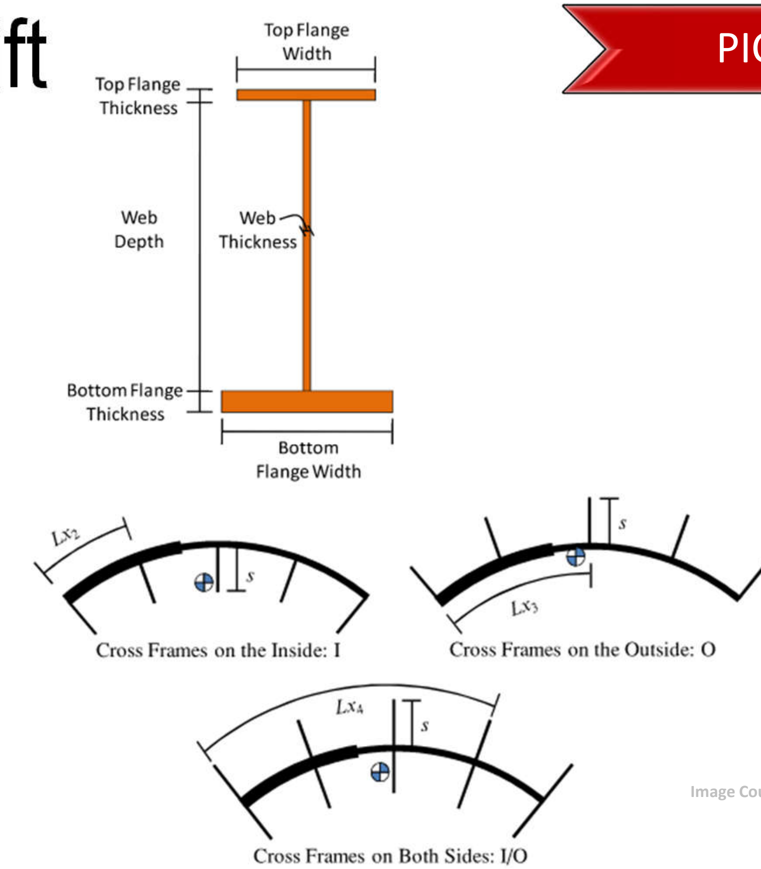
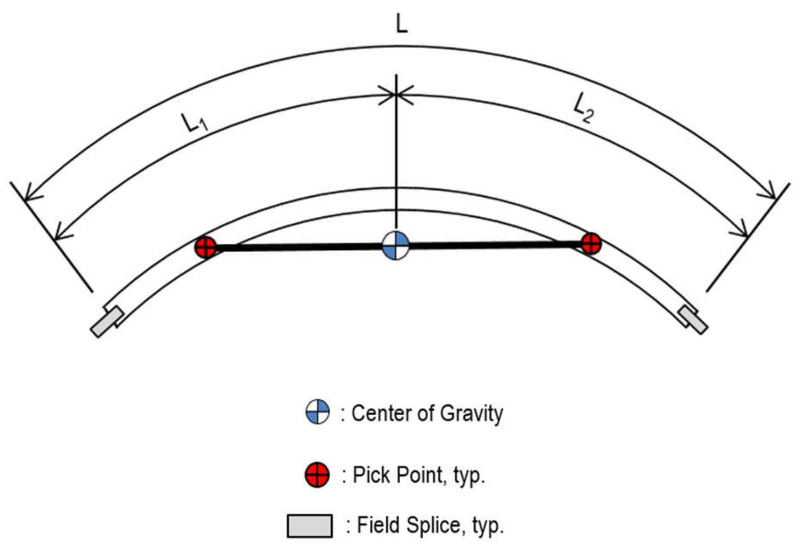


Image Courtesy of: UTLift

Curved Girder Pick – UT Lift

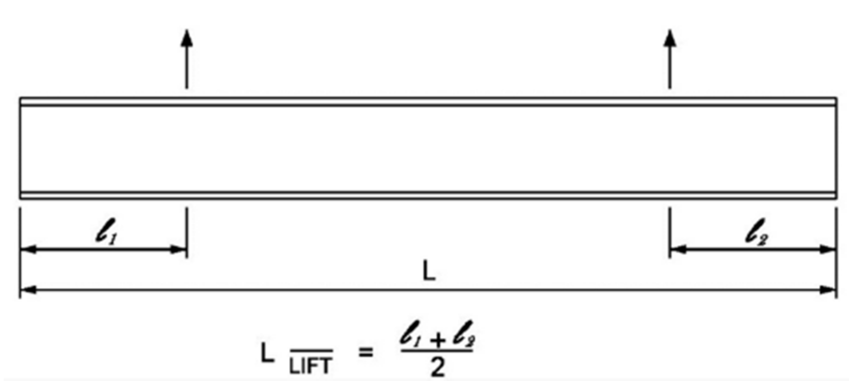
PICKING

- Input:
  - Girder section properties
  - Curve radius
  - Cross-frame information, if applicable
- Output:
  - Pick weight and C.G.
  - Ideal spread between pick points
  - Max girder picking stresses
  - Girder twist
  - Girder Demand/Capacity (D/C) Ratio



Curved Girder Pick – UT Lift

PICKING



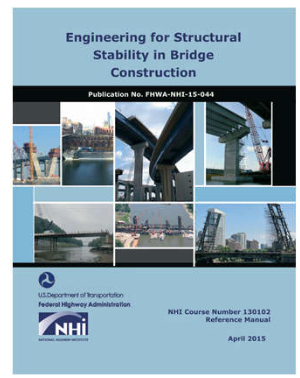
$$M_u < \phi_b M_{cr} = \phi_b C_{bL} \frac{\pi}{L_b} \sqrt{EI_y GJ + E^2 I_y C_w \left(\frac{\pi^2}{L_b^2} \right)}$$ **Equation 7-7**

L_b = Unbraced length = L (total length of girder segment)

$$C_{bL} = 2.0 \; for \; \frac{L_{Lift}}{L} \leq 0.225$$ **Equation 7-8**

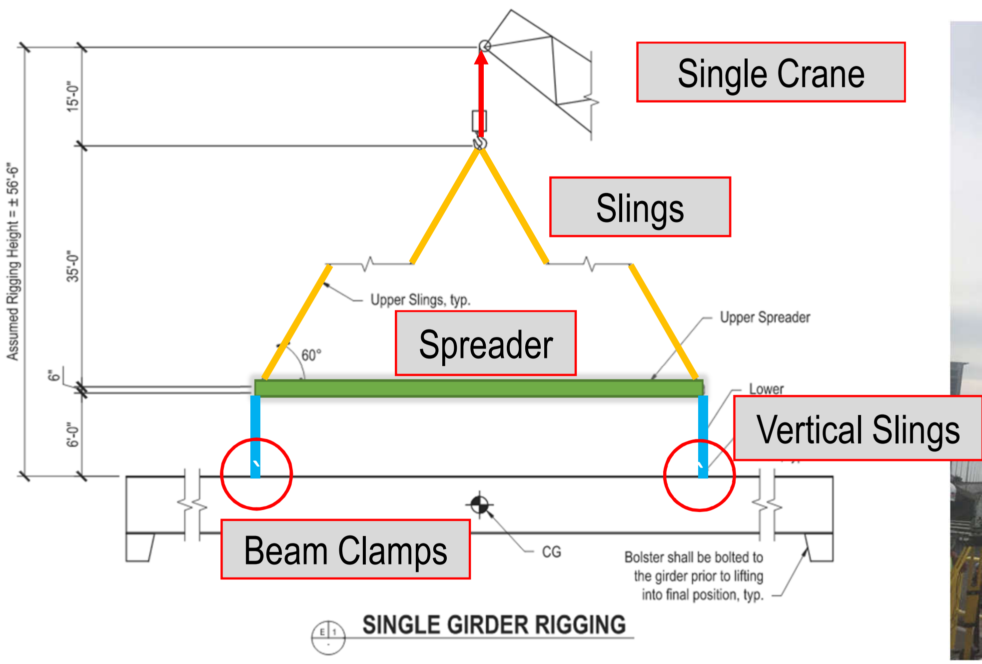
$$C_{bL} = 6.0 \; for \; 0.225 < \frac{L_{Lift}}{L} < 0.3$$ **Equation 7-9**

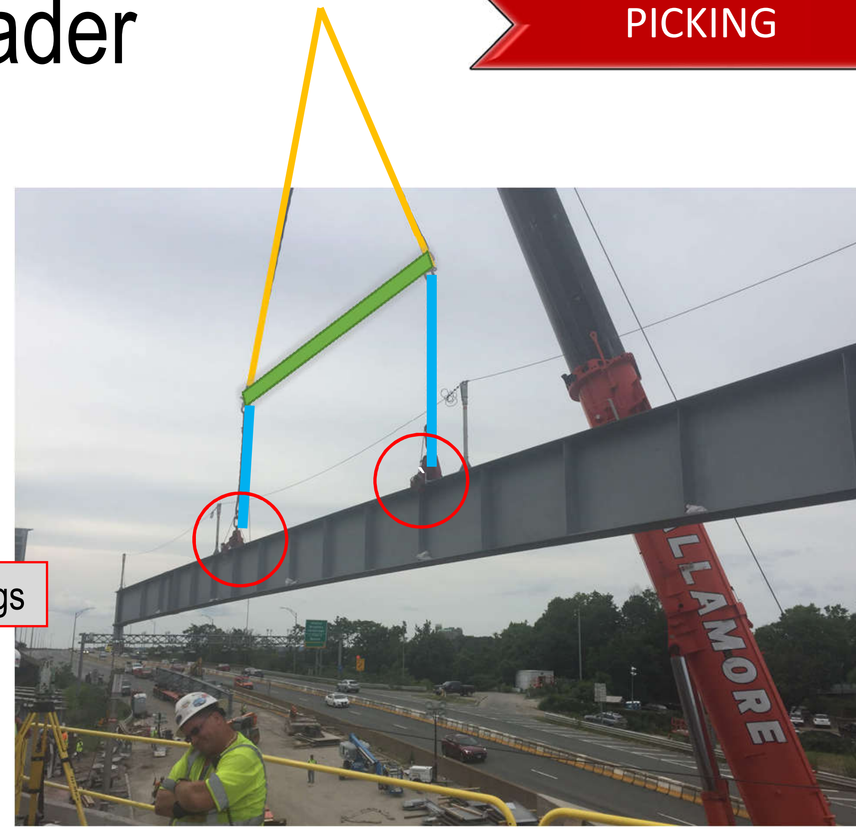
$$C_{bL} = 4.0 \; for \; \frac{L_{Lift}}{L} \geq 0.3$$ **Equation 7-10**



Rigging – Single Girder Spreader

PICKING

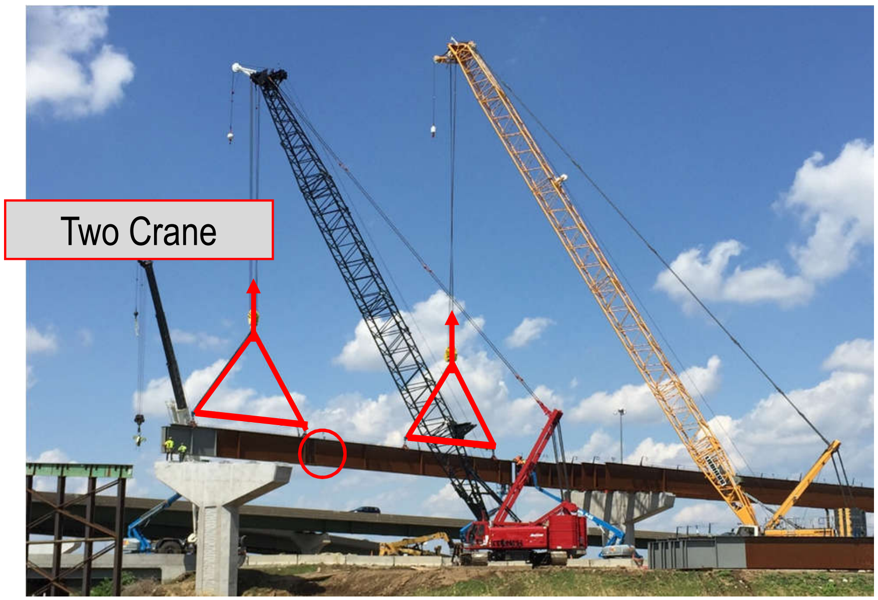




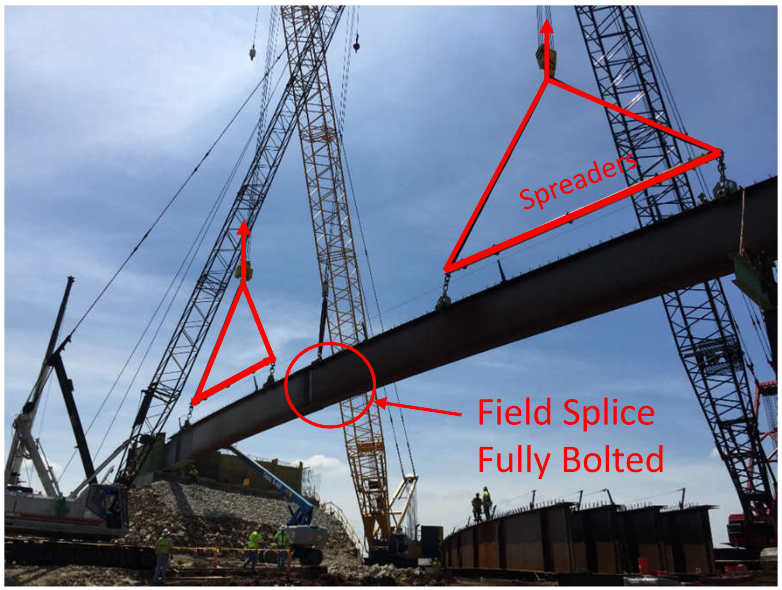
Comm. Ave Bridge, Boston, MA

Rigging – Single Girder Spreader

PICKING



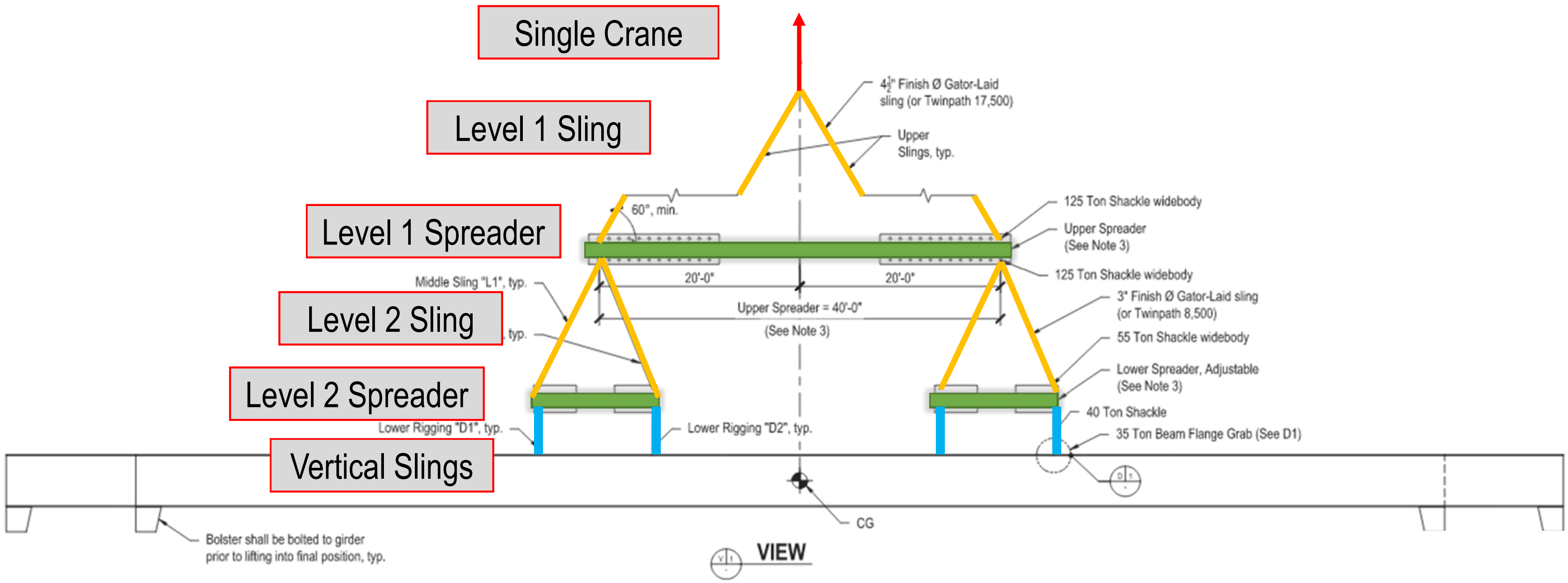
Gateway Interchange Flyovers, Johnson County, KS



Gateway Interchange Flyovers, Johnson County, KS

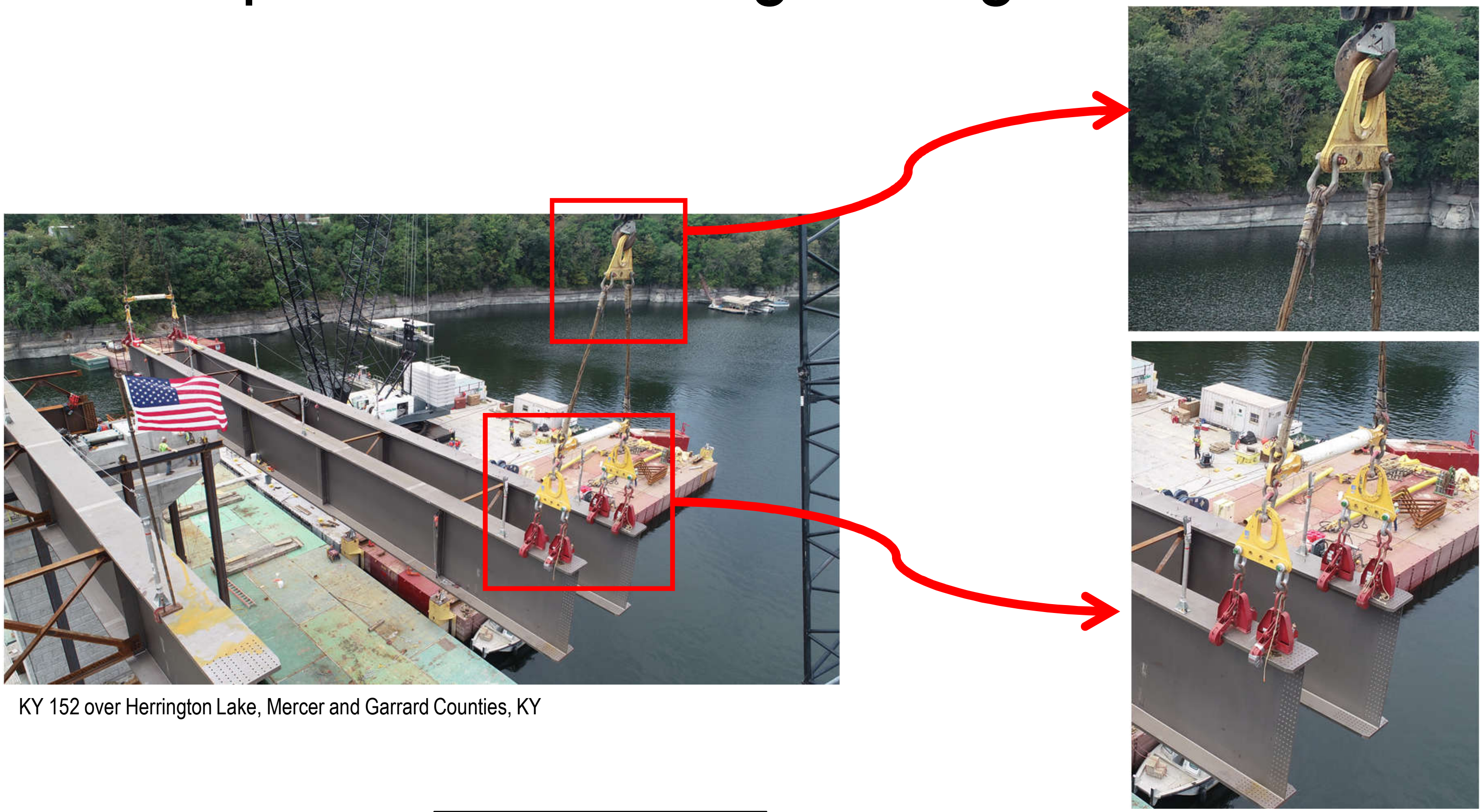
Rigging – Multi-Level Spreaders

PICKING



Load Equalizers – Lifting Triangles

PICKING



KY 152 over Herrington Lake, Mercer and Garrard Counties, KY

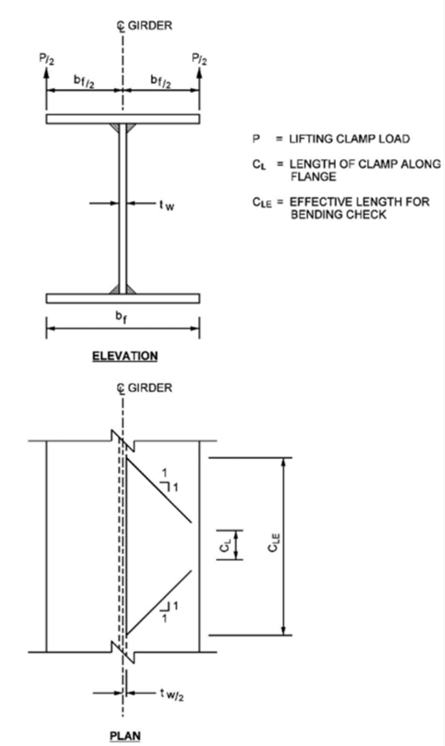
Beam Clamps

PICKING

Fulbright Expressway, Fayetteville, AR

Beam Clamps

PICKING

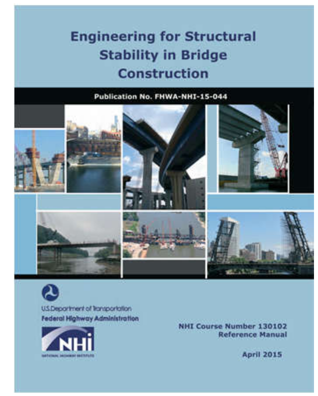


$$f_{lb} = \frac{R_c k}{(b_f + C_L)(t_f)^2 / 6}$$

Equation 7-23

$$f_{lb} \le 0.75\, F_{yf}$$

Equation 7-24

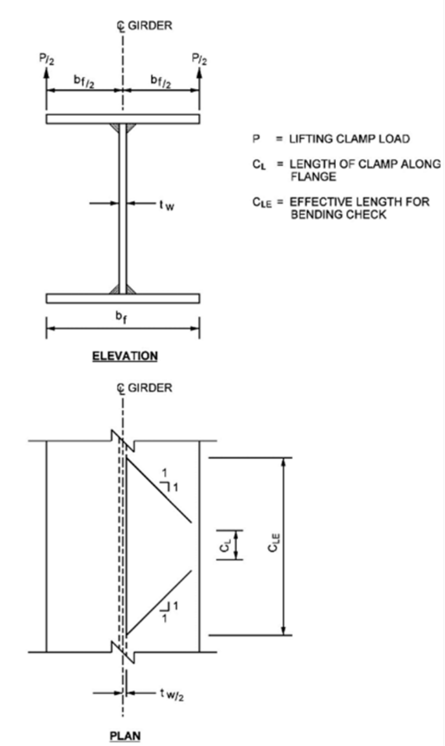


Where:

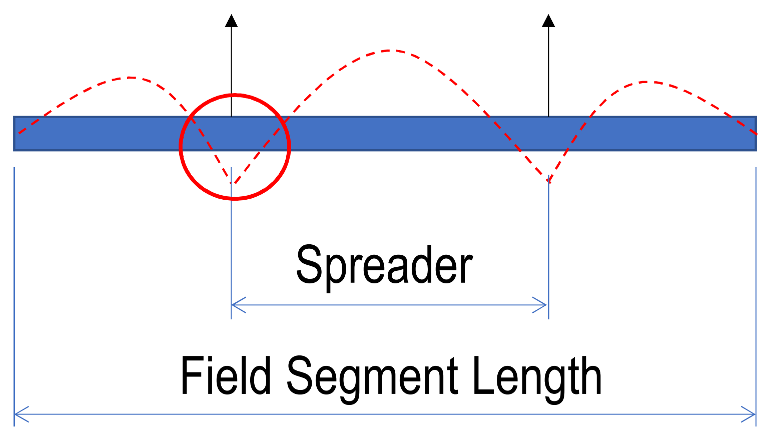
- R_c = service level concentrated force at each flange edge (kip)
- F_{yf} = specified minimum flange yield stress (ksi)
- b_f = flange width (in)
- t_f = flange thickness (in)
- C_L = length of clamp along flange (in)
- k = distance from outer face of flange to web toe of fillet (in)

Beam Clamps

PICKING



Global Strong Axis Bending Moment



Steel Girder Erection

- Compression Flange Slenderness Requirements
- Picking Girders
- Staged Construction Evaluation
  - Check for critical stages of stability concerns
  - Check stage specific demands with stage specific capacity
  - Perform detailed finite element model buckling analysis
- Temporary Works

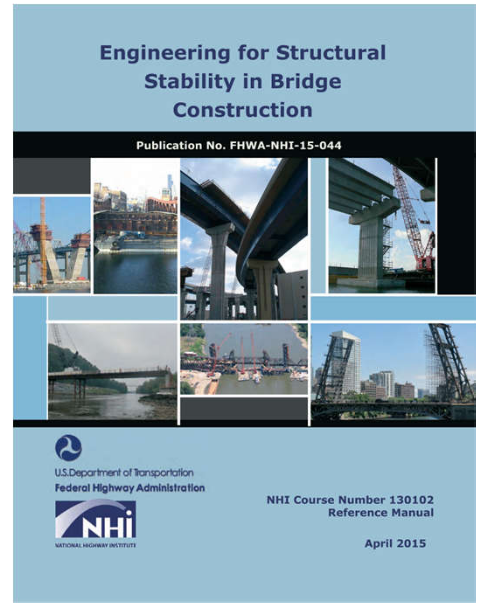
Critical Stages of Construction

STAGED CONST.

7.2.2 Critical Erection Stages

The erection plan and supporting engineering calculations must address both strength and stability at each stage of erection. Deformations associated with each stage should also be evaluated. Critical erection stages for the girder bridge structure during construction normally consist of at least the following:

- Lifting of girders/members
- Placement of the initial girder and any associated temporary bracing used to hold the girder in place
- First pair of girders set with permanent bracing installed
- All girders and bracing installed prior to the deck placement
- All girders and bracing installed during the deck placement
- Application of the deck overhang bracket loads to the fascia girders during the deck placement



Critical Stages of Construction

STAGED CONST.

6.10.3.2.1—Discretely Braced Flanges in Compression

For critical stages of construction, each of the following requirements shall be satisfied. For sections with slender webs, Eq. 6.10.3.2.1-1 shall not be checked when f_ℓ is equal to zero. For sections with compact or noncompact webs, Eq. 6.10.3.2.1-3 shall not be checked.

$$f_{bu} + f_\ell \le \phi_f R_h F_{yc}, \qquad (6.10.3.2.1\text{-}1)$$

$$f_{bu} + \frac{1}{3} f_\ell \le \phi_f F_{nc}, \qquad (6.10.3.2.1\text{-}2)$$

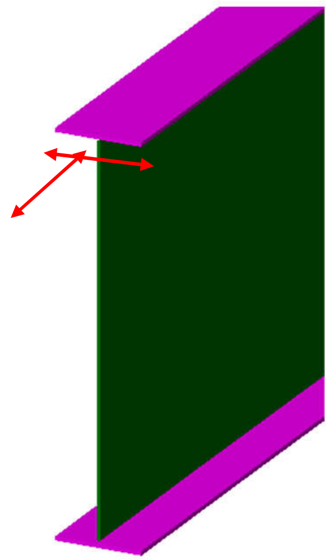
and

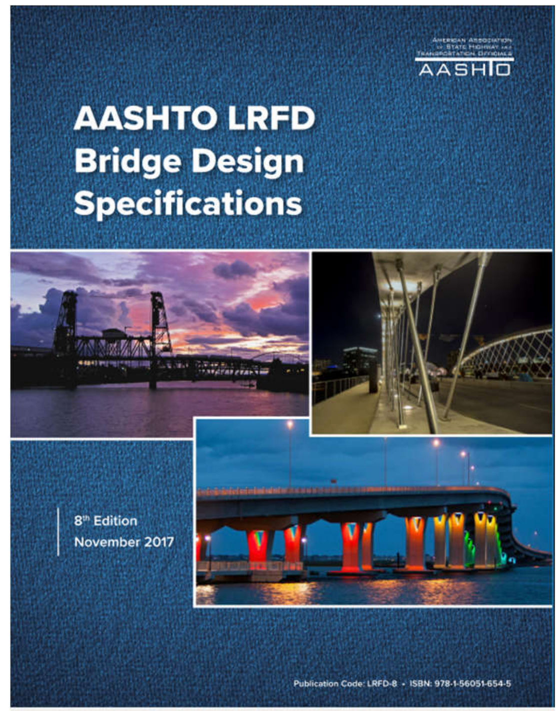
$$f_{bu} \le \phi_f F_{crw} \qquad (6.10.3.2.1\text{-}3)$$

6.10.3.2.2—Discretely Braced Flanges in Tension

For critical stages of construction, the following requirement shall be satisfied:

$$f_{bu} + f_\ell \le \phi_f R_h F_{yt} \qquad (6.10.3.2.2\text{-}1)$$





Critical Stages of Construction

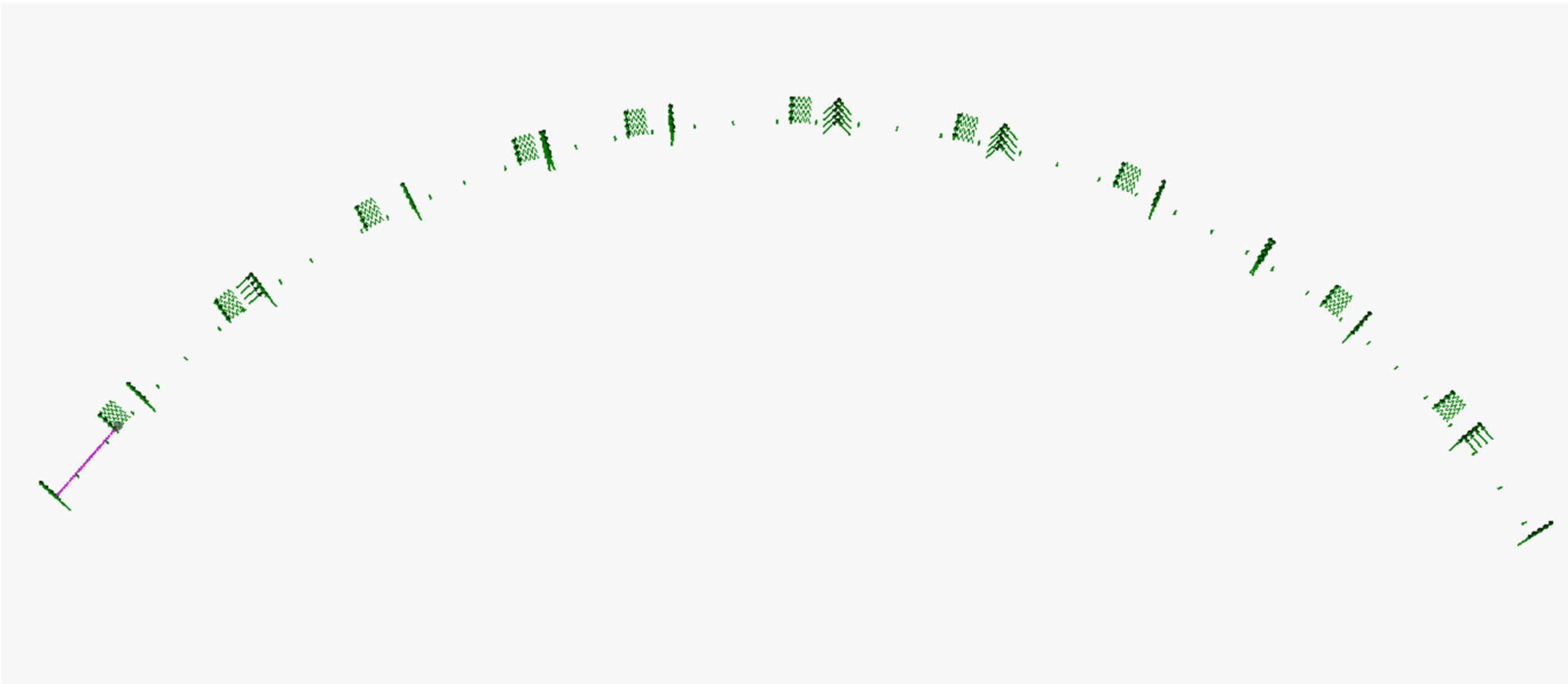
STAGED CONST.

KY 152 over Herrington Lake, Mercer and Garrard Counties, KY

Gateway Interchange Flyovers, Johnson County, KS

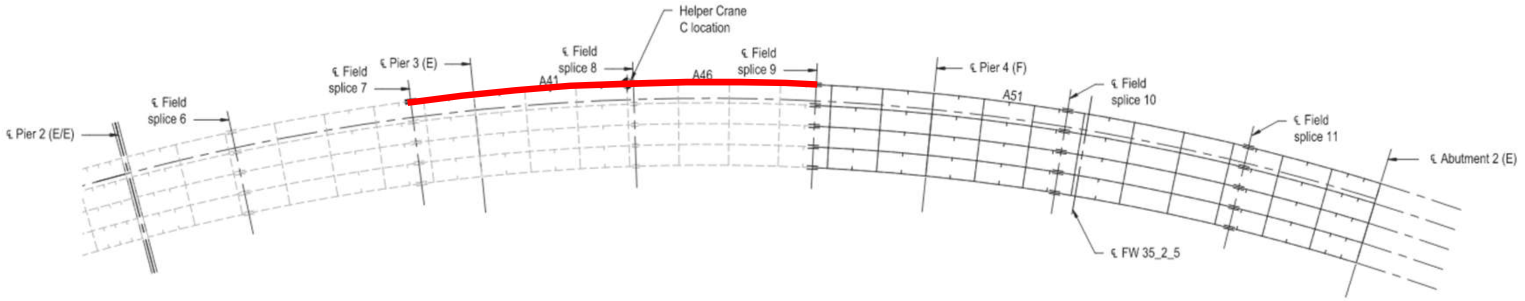
Staged Construction Evaluation

STAGED CONST.



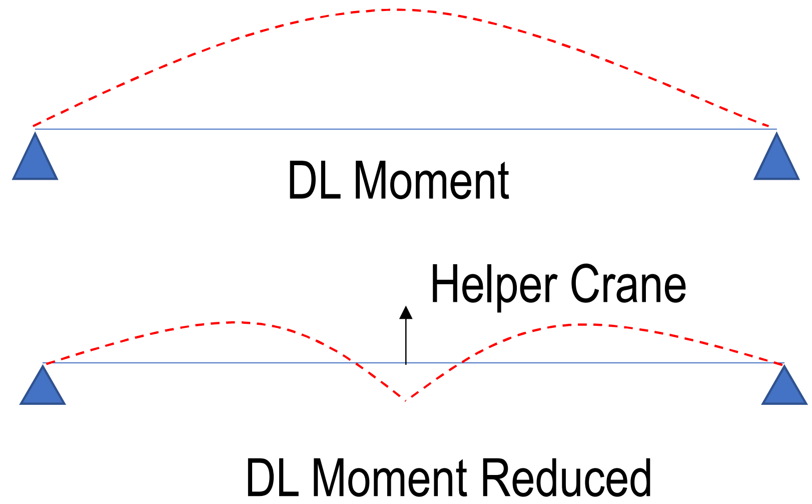
Single Girder Stability

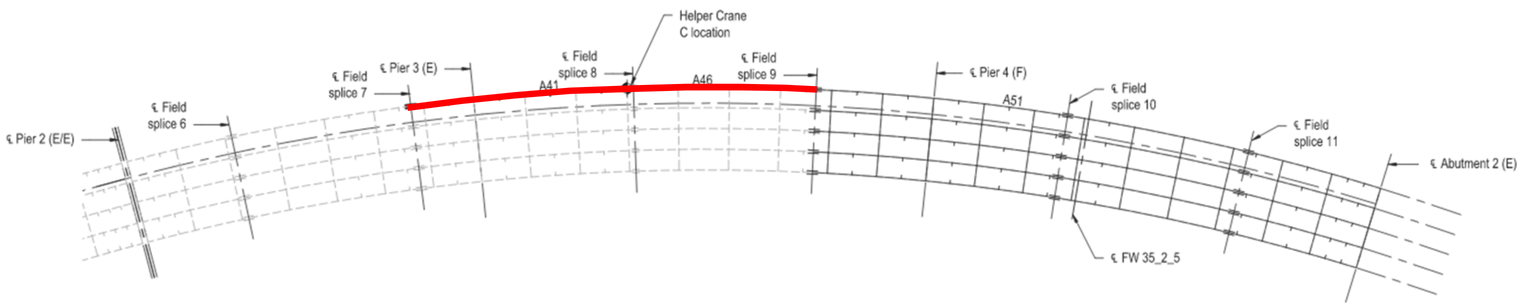
STAGED CONST.



Single Girder Stability

STAGED CONST.

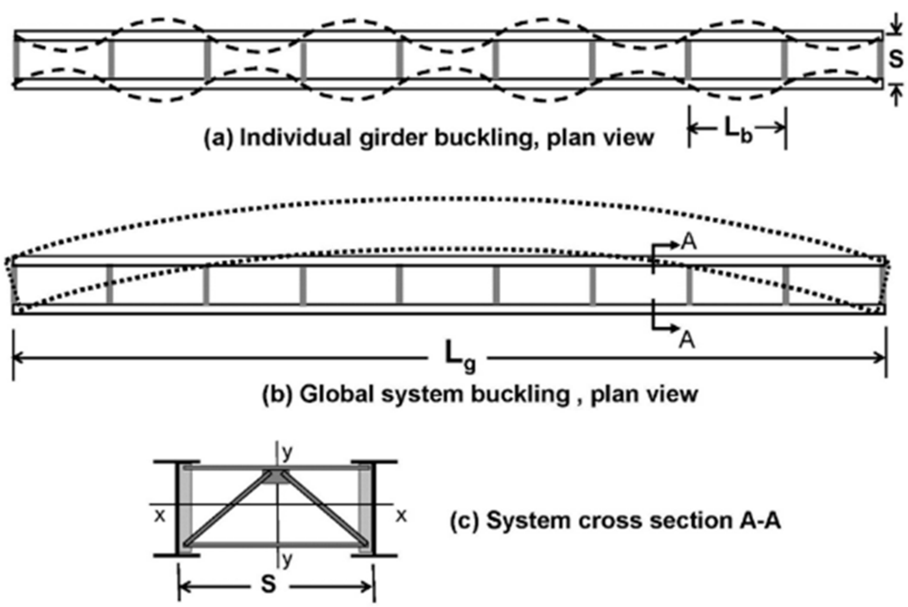


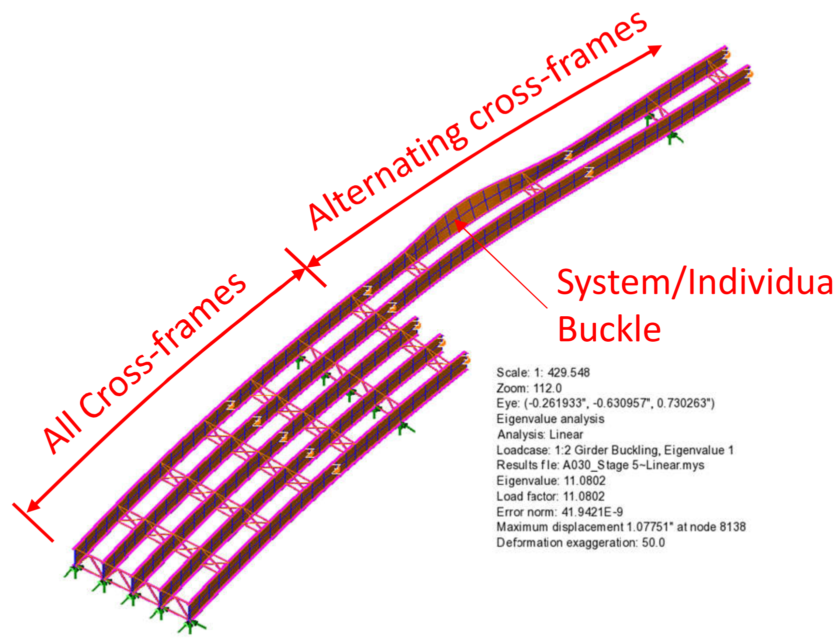


Girder System Stability

STAGED CONST.

LUSAS





Images Courtesy of: Engineering for Structural Stability in Bridge Construction

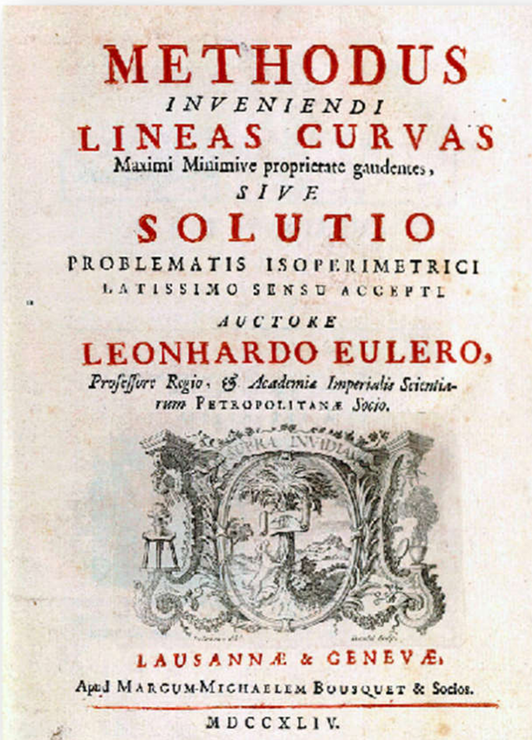
Girder System Stability

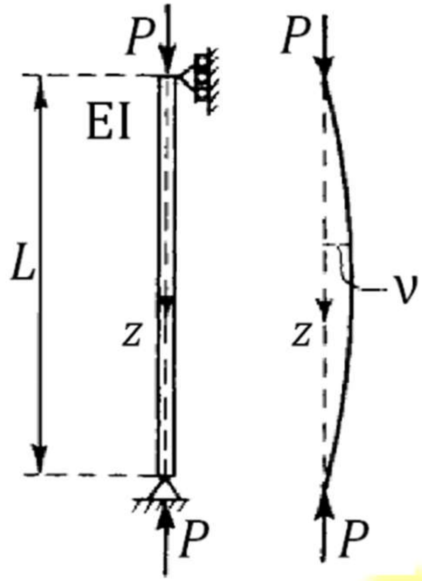
STAGED CONST.

Images Courtesy of: edmontonsun.com

Eigenvalue & 2nd Order Nonlinear Analysis

STAGED CONST.


METHODUS
INVENIENDI
LINEAS CURVAS
Maximi Minimive proprietate gaudentes,
SIVE
SOLUTIO
PROBLEMATIS ISOPERIMETRICI
LATISSIMO SENSU ACCEPTI
AUCTORE
LEONHARDO EULERO,
Professore Regio, & Academiæ Imperialis Scientiarum Petropolitanæ Socio.
LAUSANNÆ & GENEVÆ,
Apud Marcum-Michaelem Bousquet & Socios.
MDCCXLIV.

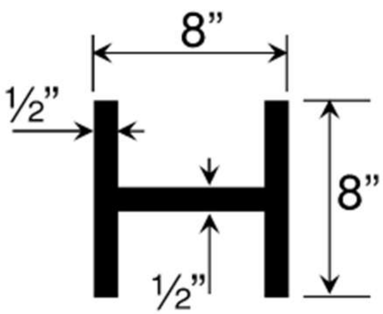


$$P_e = \frac{\pi^2 EI}{L^2}$$

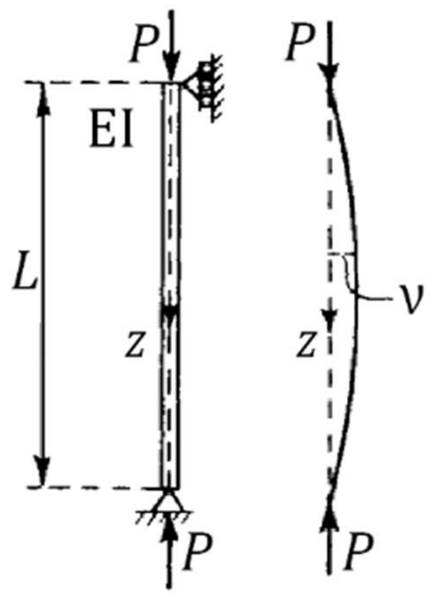
Reference:

Eigenvalue Analysis

STAGED CONST.



$A_g = 11.5\ in^2$
$I_{zz} = 42.74\ in^4$
$L = 18'$
$E = 29{,}000\ ksi$



$$P_e = \frac{\pi^2 \times 29{,}000 \times 42.74}{(18 \times 12)^2} = 262\text{kip}$$

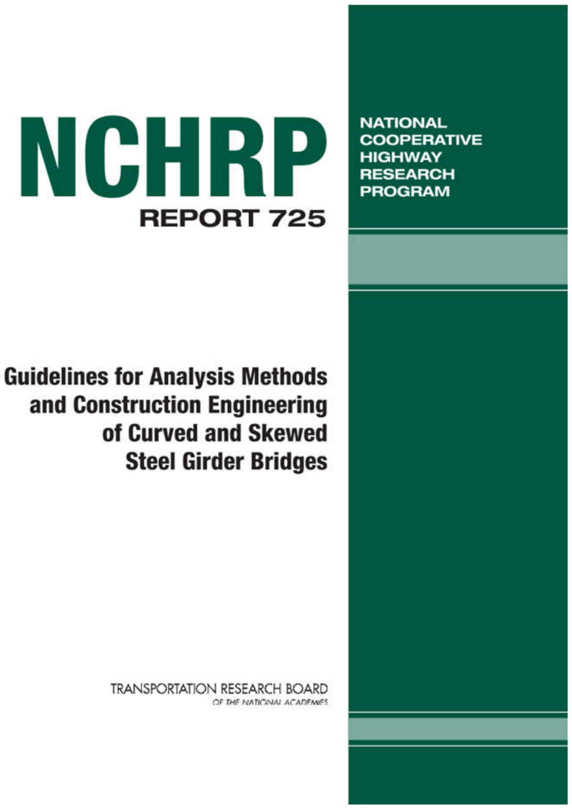
Reference:

P = 1 kip
Eigenvalue = 262
FOS = 262

P = 262 kip
Eigenvalue = 1
FOS = 1

Eigenvalue & 2nd Order Nonlinear Analysis

STAGED CONST.


NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP REPORT 725

Guidelines for Analysis Methods and Construction Engineering of Curved and Skewed Steel Girder Bridges

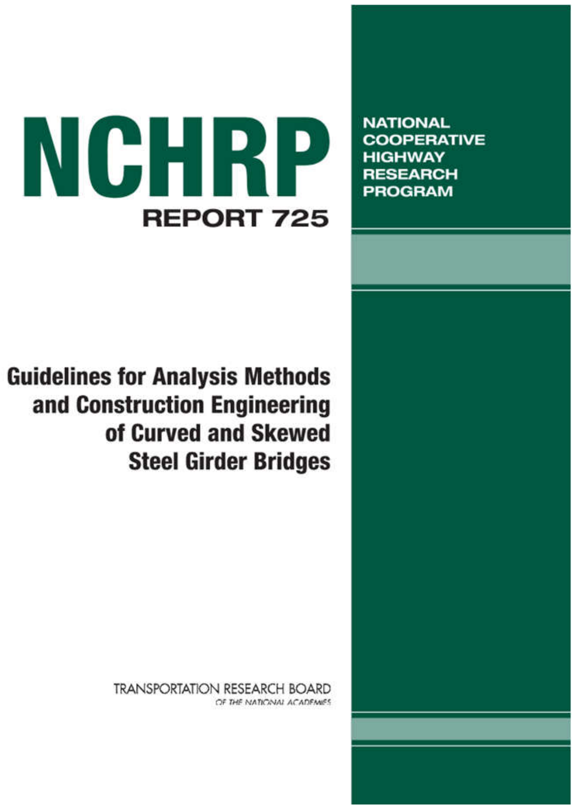
TRANSPORTATION RESEARCH BOARD OF THE NATIONAL ACADEMIES

$$AF_G = \frac{1}{1 - \dfrac{M_{\max G}}{M_{crG}}}$$

- AF_G = Amplification Factor = System Stability Indicator
- M_{maxG} = Maximum Total Moment support by bridge unit
- M_{crG} = Elastic global buckling moment of the bridge
- M_{crG} / M_{maxG} = Eigenvalue

Eigenvalue & 2nd Order Nonlinear Analysis

STAGED CONST.



$$AF_G = \frac{1}{1 - \frac{M_{\max G}}{M_{crG}}}$$

- Second order effects may be neglected
  - $AF_G < 1.10$
  - Eigenvalue > 11
- Second order 3D FEM recommended
  - $AF_G > 1.25$
  - Eigenvalue < 5

Eigenvalue & 2nd Order Nonlinear Analysis

STAGED CONST.

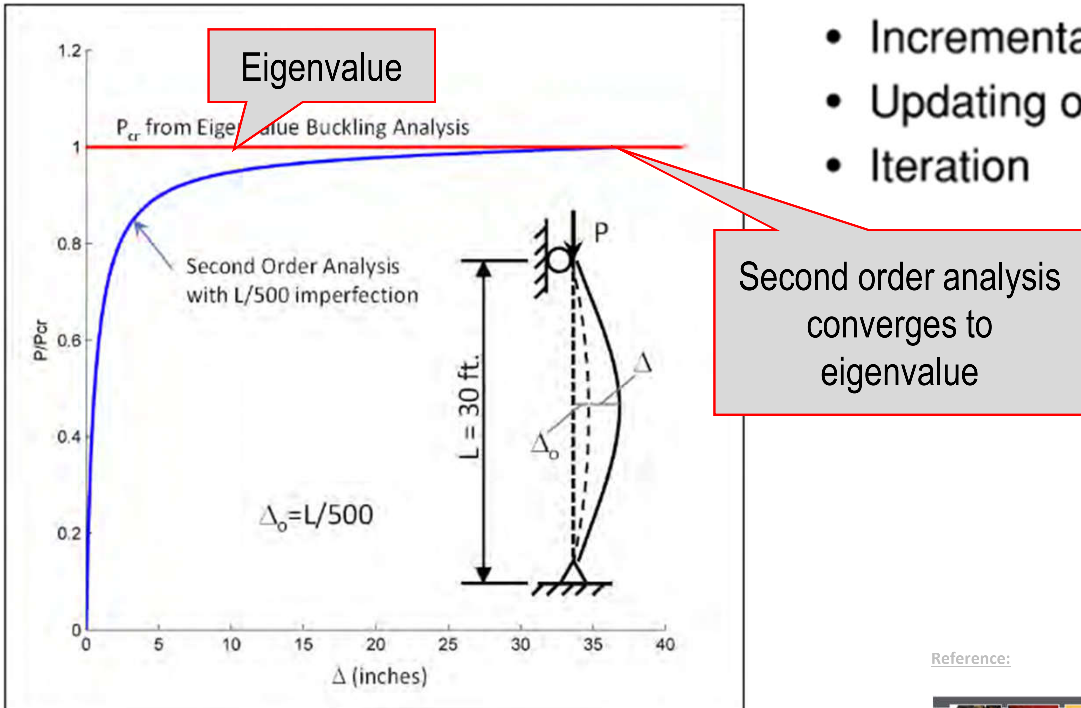
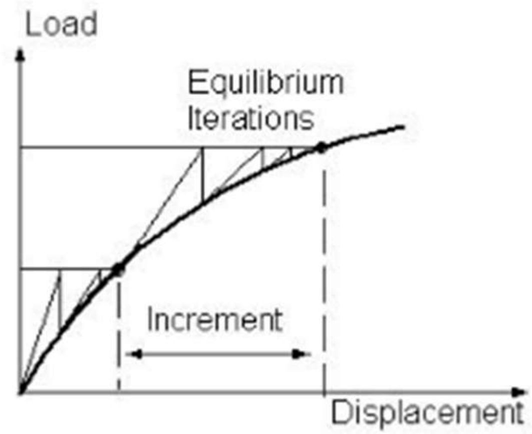


Figure 6-10 Second Order Analysis on Column with Initial Imperfection

Images Courtesy of: Engineering for Structural Stability in Bridge Construction

- Incremental application of load
- Updating of stiffnesses
- Iteration



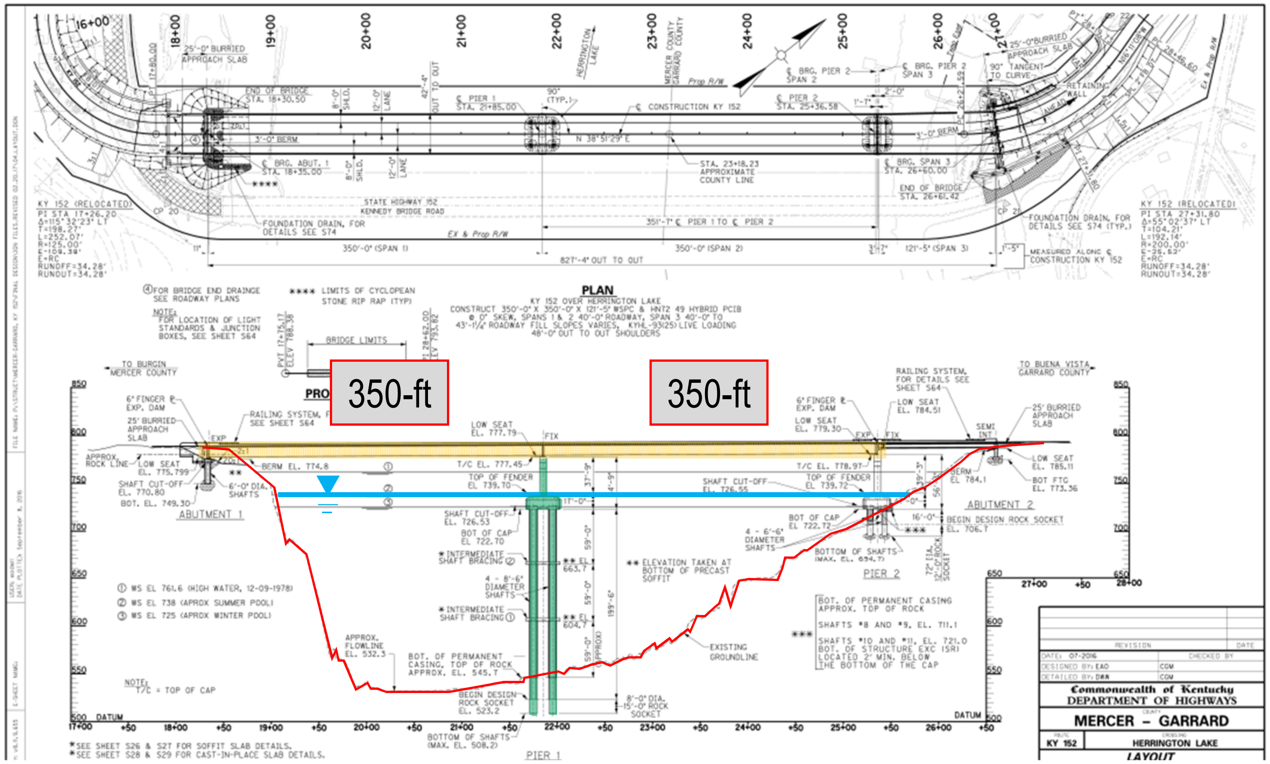
Reference:

LUSAS

System Buckling Case Study

STAGED CONST.

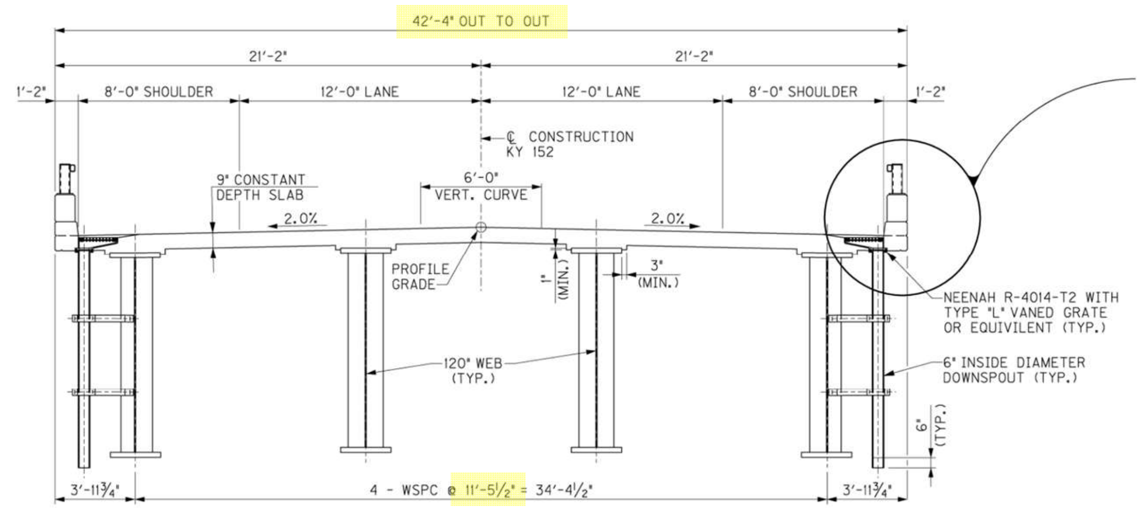
- Two Span Continuous Steel Plate Girder Bridge
- Span Length = 350’



System Buckling Case Study

STAGED CONST.

- Two Span Continuous Steel Plate Girder Bridge
- Span Length = 350’
- Girder Spa = 11’-5 1/2”
- Bridge Width = 42’-4”
- Very Long & Narrow



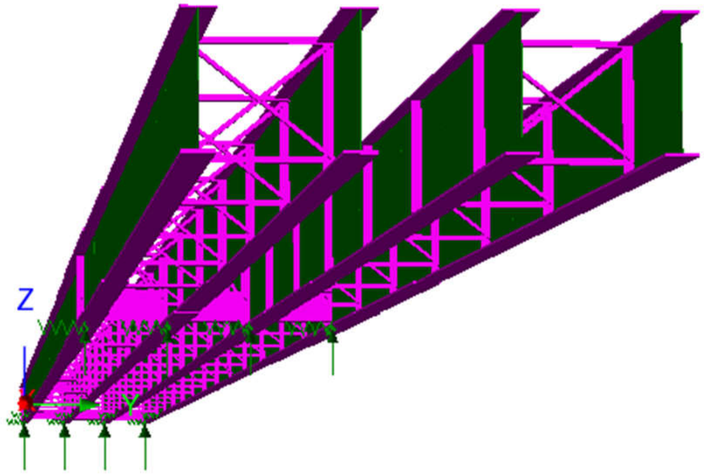
TYPICAL SECTION
(SPANS 1 & 2) LOOKING AHEAD

System Buckling Case Study

STAGED CONST.

LUSAS

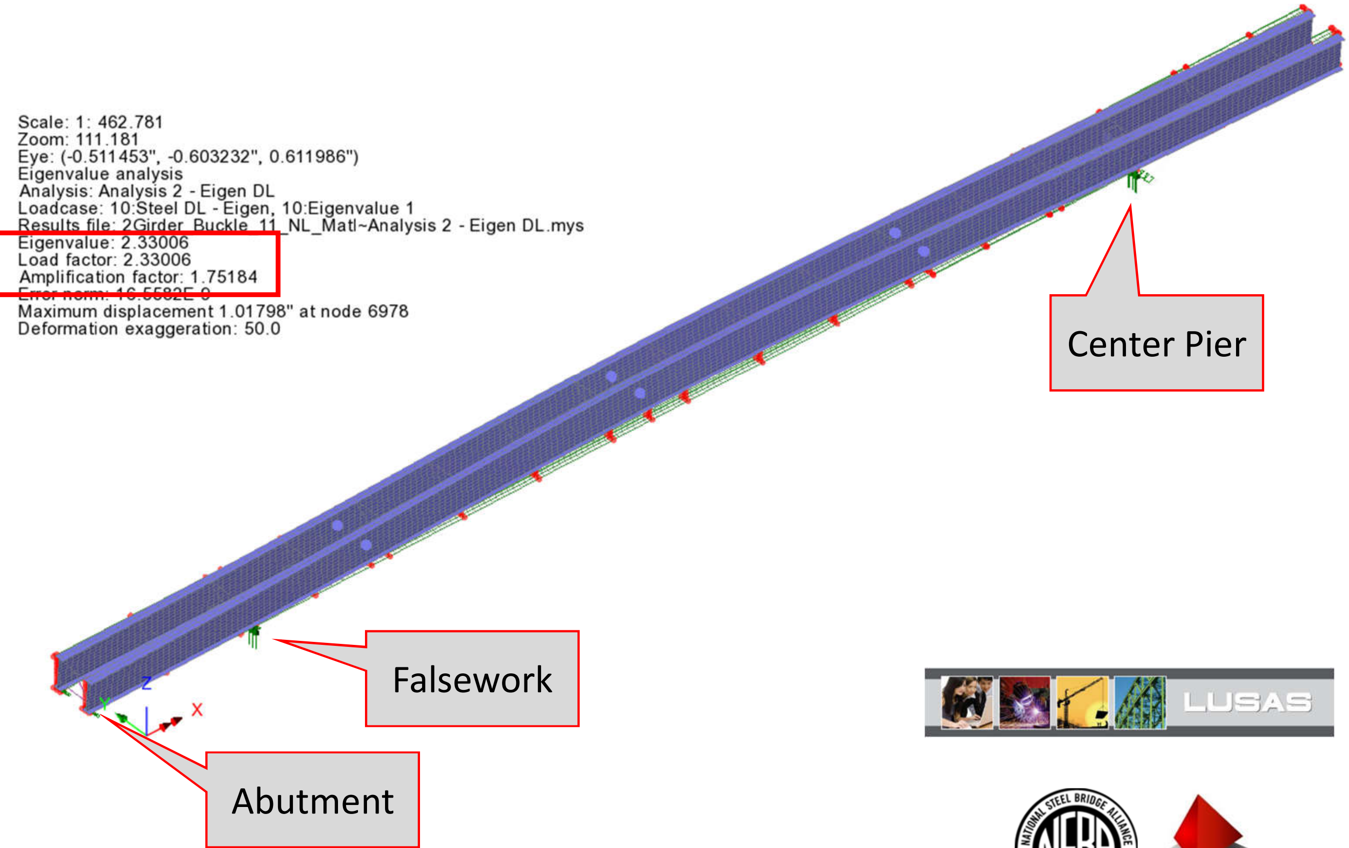
KY 152 over Herrington Lake, Mercer and Garrard Counties, KY



System Buckling Case Study

STAGED CONST.

- Eigenvalue Analysis



Eigenvalue = 2.33

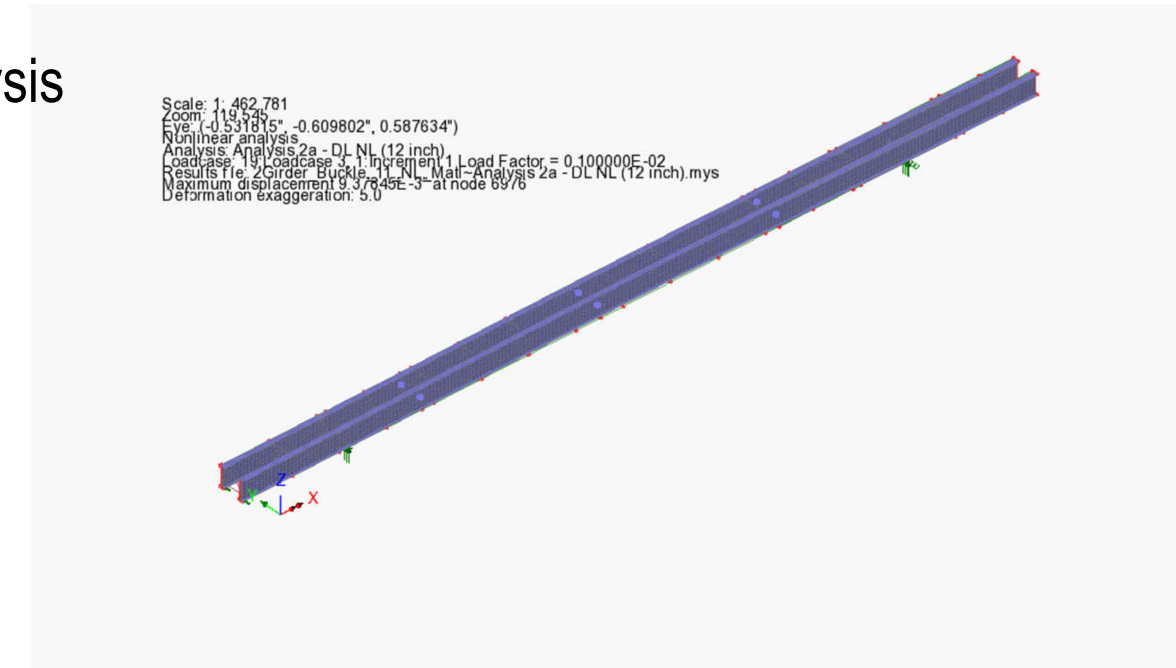
$$AF_G = \frac{1}{1-\frac{1}{2.33}} = 1.75 > 1.25$$

Second Order Analysis Req'd

System Buckling Case Study

STAGED CONST.

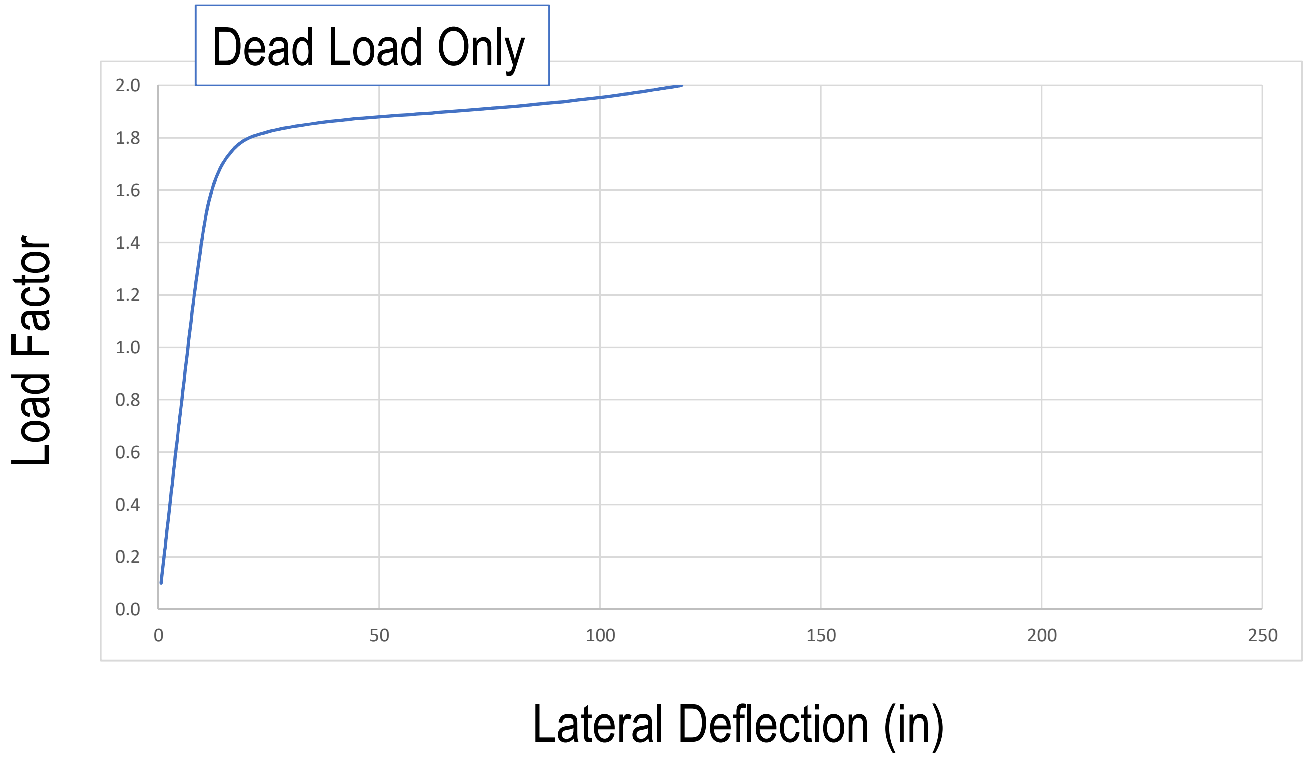
- 2^{nd} Order Nonlinear Analysis
  - Increasing Load Factor
  - Key Point Deflection



LUSAS

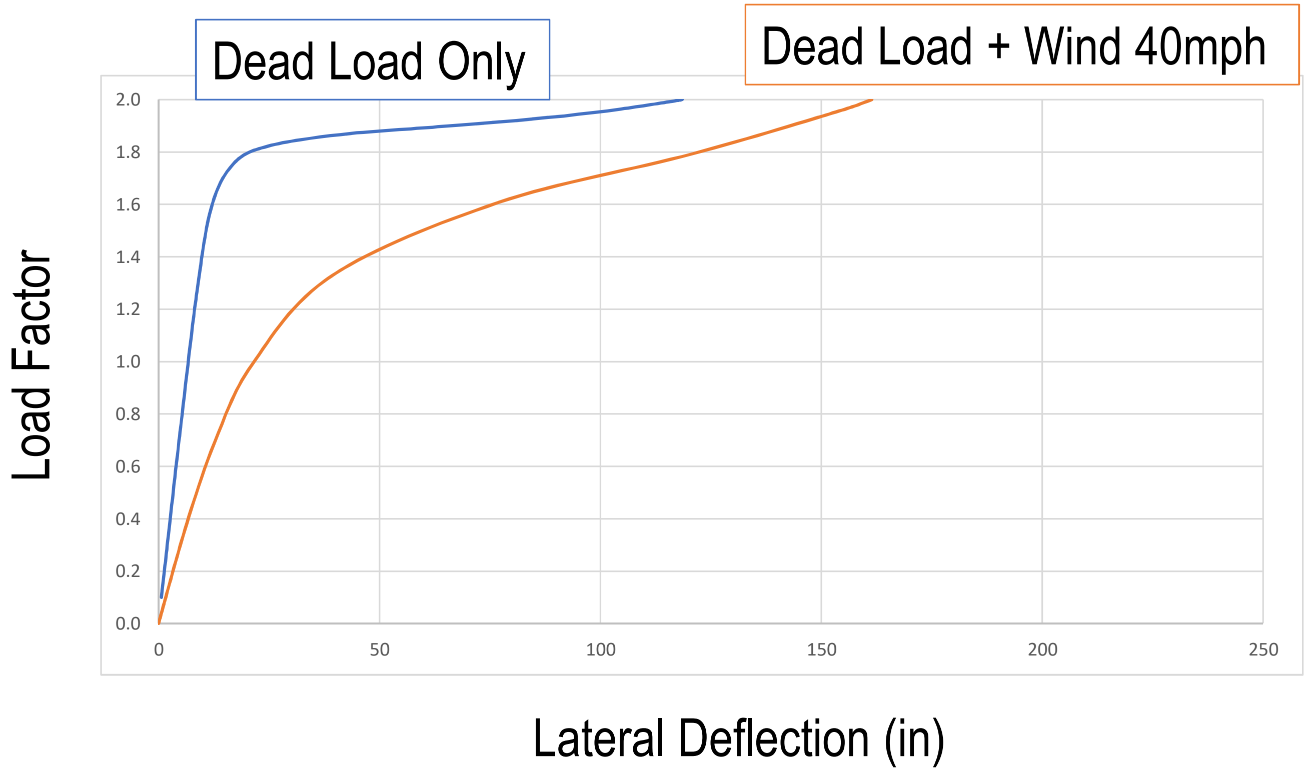
System Buckling Case Study

STAGED CONST.



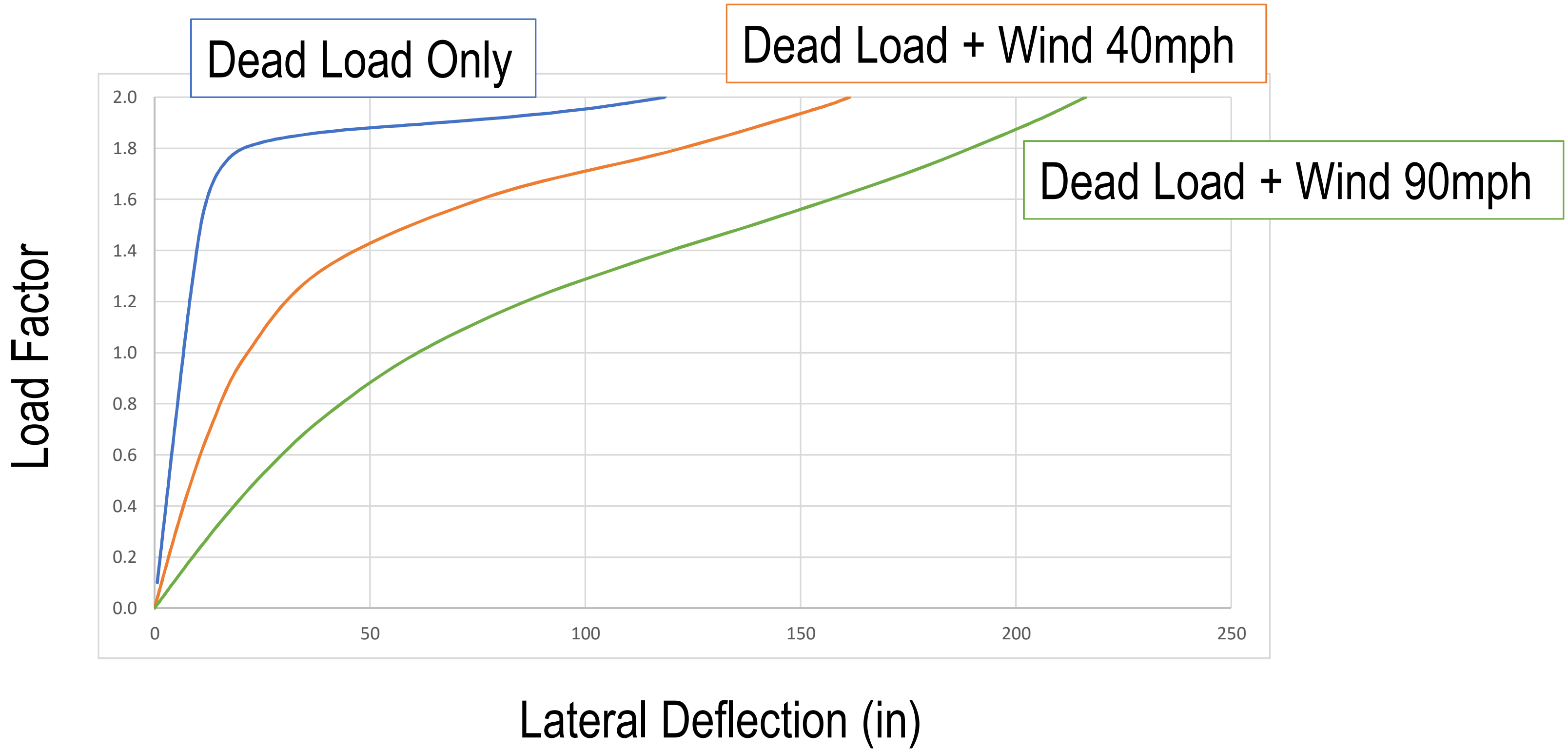
System Buckling Case Study

STAGED CONST.



System Buckling Case Study

STAGED CONST.



Steel Girder Erection

- Compression Flange Slenderness Requirements
- Picking Girders
- Staged Construction Evaluation
- Temporary Works
  - Falsework Towers
  - Geometry Control Studies
  - Girder Stiffening Truss

Falsework Towers

TEMP. WORKS

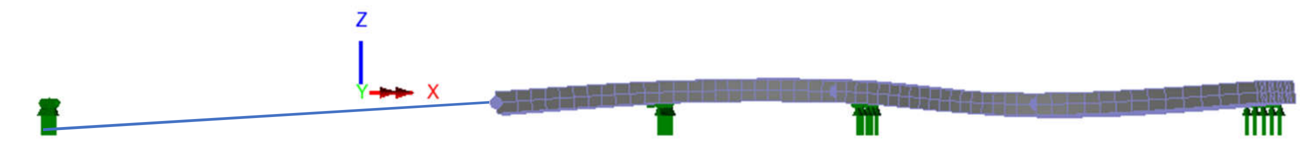
Gateway Interchange Flyovers, Johnson County, KS

Cleveland Innerbelt, Cleveland, OH

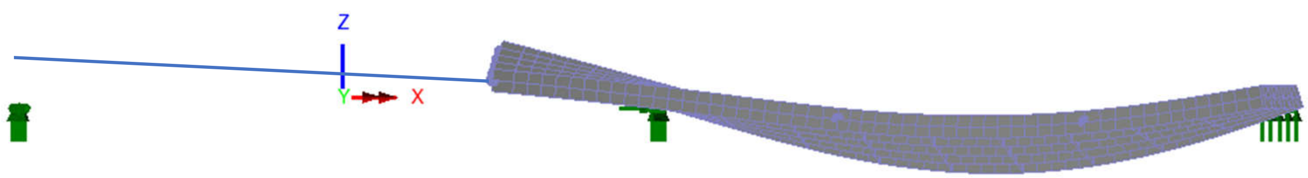
Geometry Control Studies

TEMP. WORKS

Negative Tip Deflection:



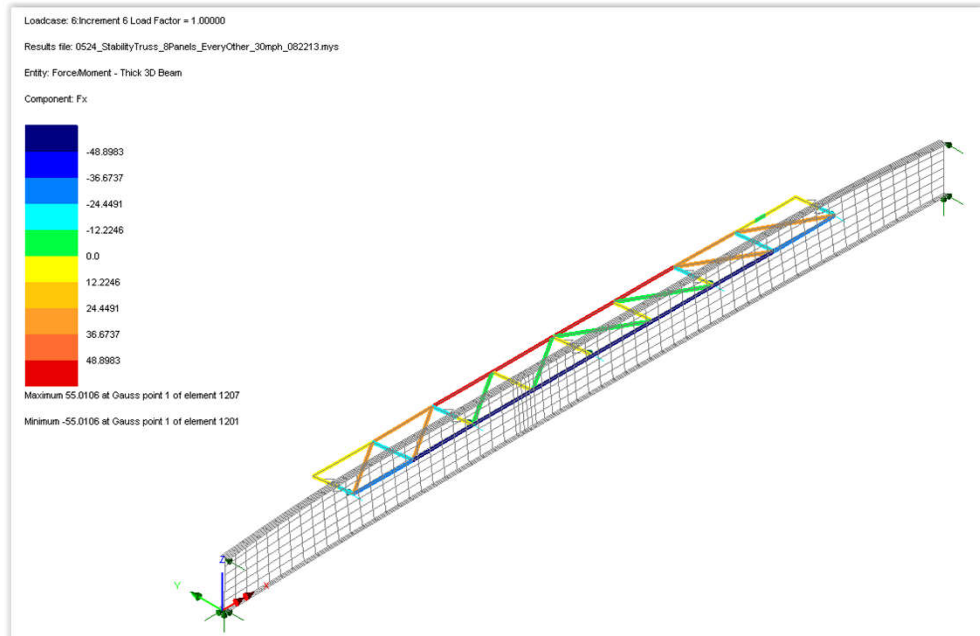
Positive Tip Deflection:



Girder Stiffening Truss

TEMP. WORKS

Whittier Memorial Bridge, Newburyport and Amesbury, MA



Precast Concrete Girder Erection

Through the Eyes of a Construction Engineer

Precast Concrete Girder Erection

- Precast Beam Bridge Considerations
- Precast Spliced Bridge Considerations

Precast Concrete Girder Erection

- Precast Beam Bridge Considerations
  - Single Crane Hoisting
  - Hoisting Stability
  - Roll-over Stability
  - Overhang Loading
- Precast Spliced Bridge Considerations

Precast Concrete Girder Erection

- Precast Beam Bridge Considerations
- Precast Spliced Bridge Considerations
  - Staged Construction Evaluation
  - Temporary Works

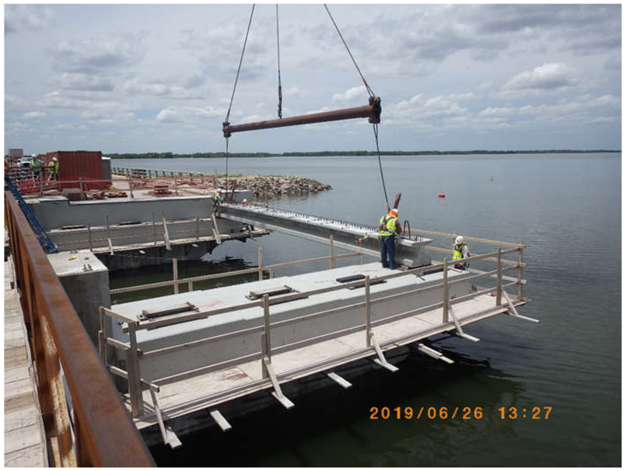
Precast Beam Bridge Considerations

PICKING

SETTING

RELEASING

US50 Over BNSF RR, Lamar, CO



Spillway Bridge, Marion County, KS

US50 Over BNSF RR, Lamar, CO

Embed Loops

Typically (2) Crane Pick
vertical at ends similar to fabricator

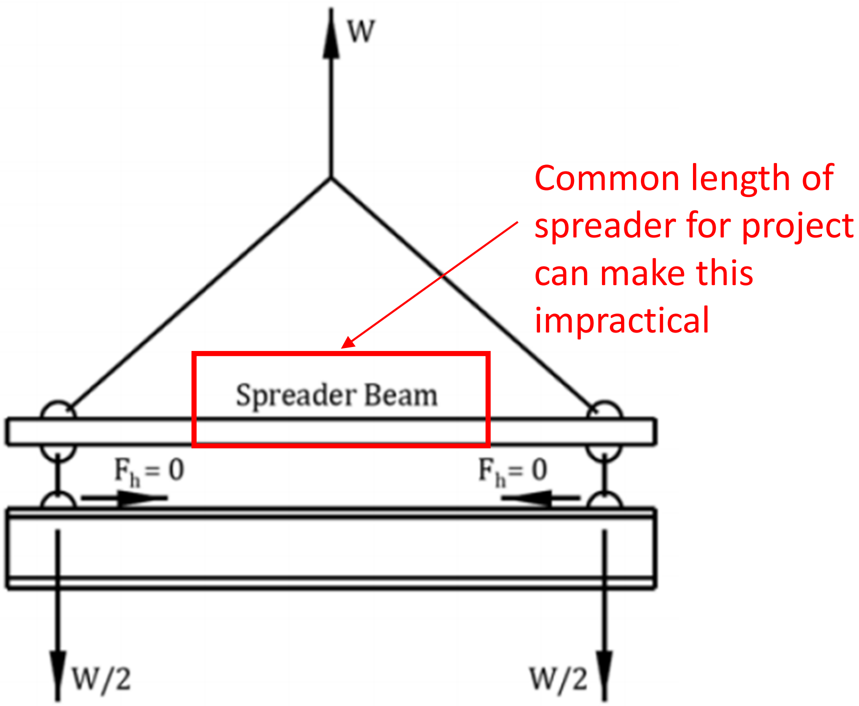
PICKING

- Strength of strand based on:
  - Length of Embedment
  - Diameter of loop
  - Strength of Concrete

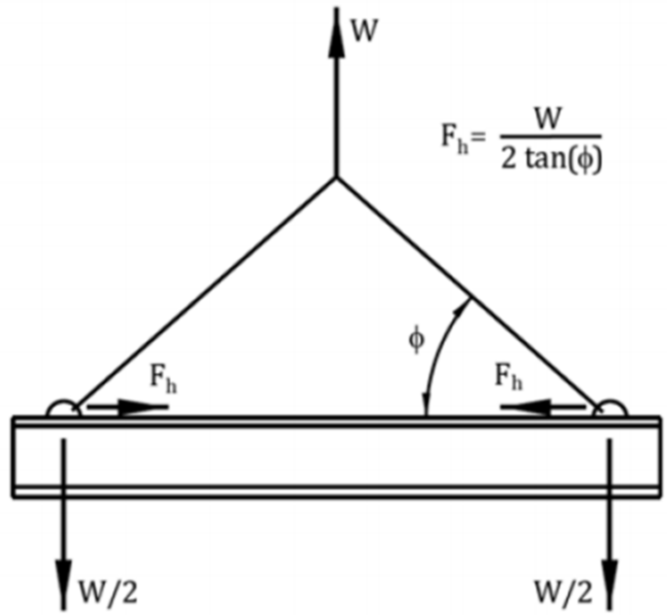
Images Courtesy of:
Engineering for Structural Stability in Bridge Construction
PCI 6th Edition Fabrication Design

Single Crane Hoisting Considerations

PICKING



OPTION 1 - SPREADER



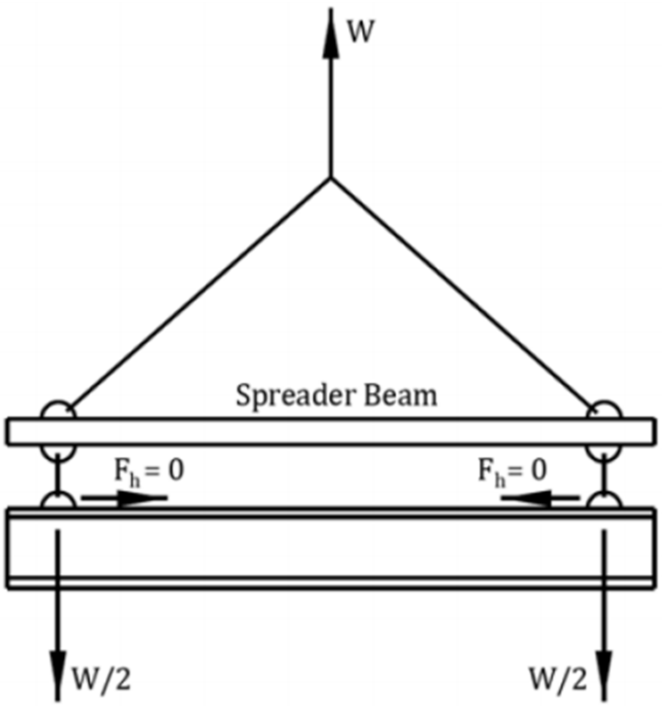
OPTION 2 - NO SPREADER

Images Courtesy of:

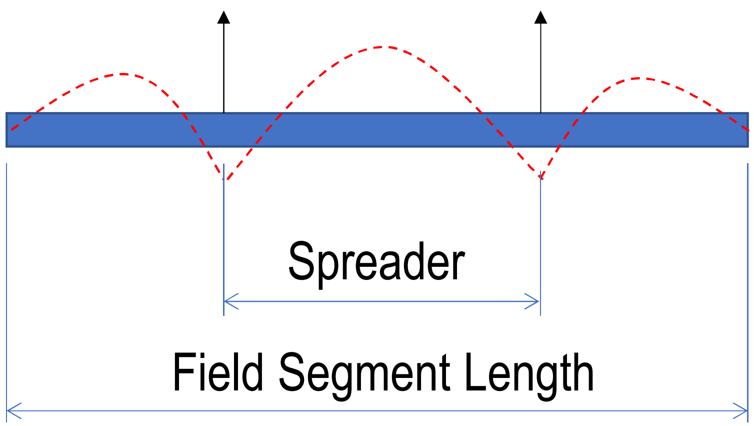
PCI 6th Edition Fabrication Design

Single Crane Hoisting Considerations

PICKING



OPTION 1 - SPREADER



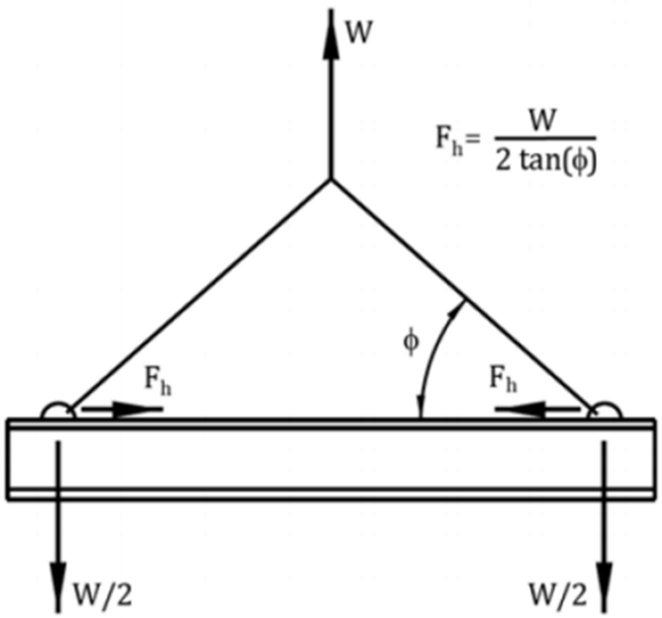
Shorter spreader can require need for additional tension reinforcement.

Images Courtesy of:

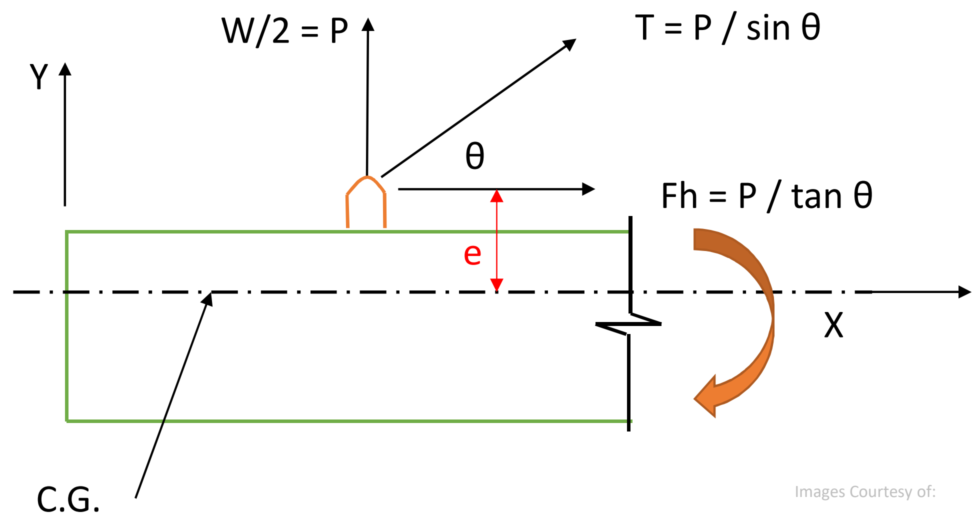
PCI 6th Edition Fabrication Design

Single Crane Hoisting Considerations

PICKING



OPTION 2 - NO SPREADER

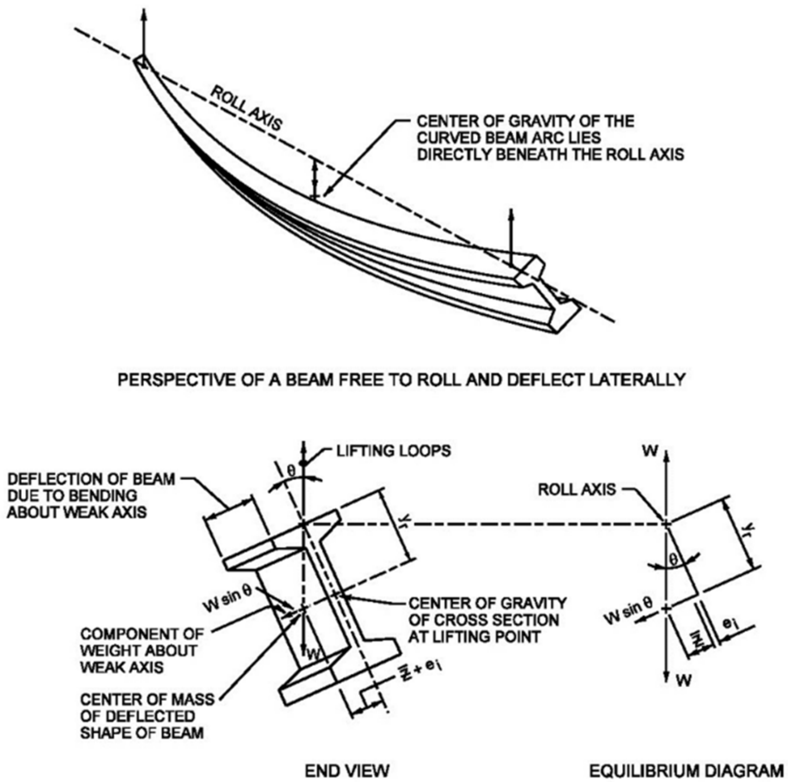


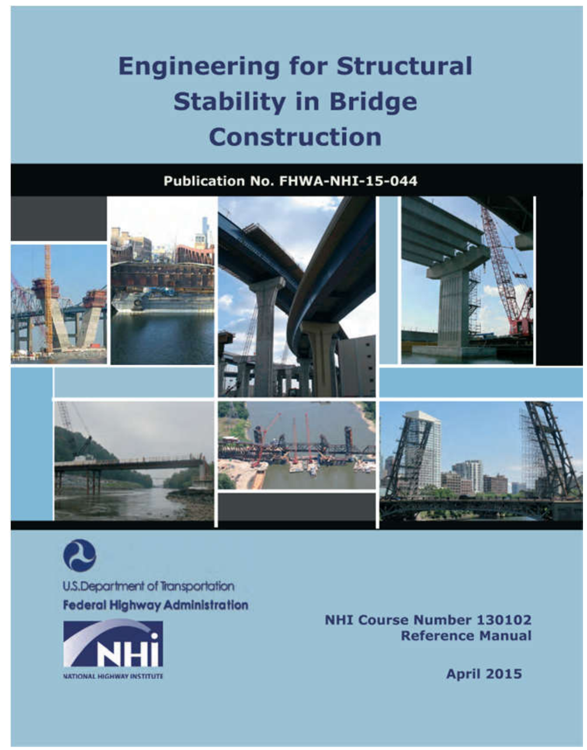
Images Courtesy of:

PCI 6th Edition Fabrication Design

Sweep Considerations

PICKING

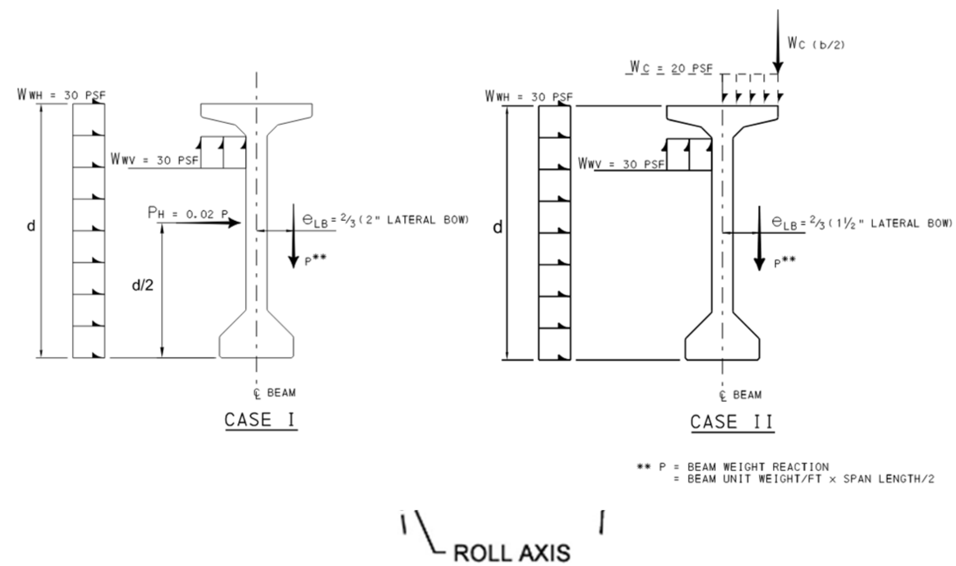




Roll Over Stability

SETTING

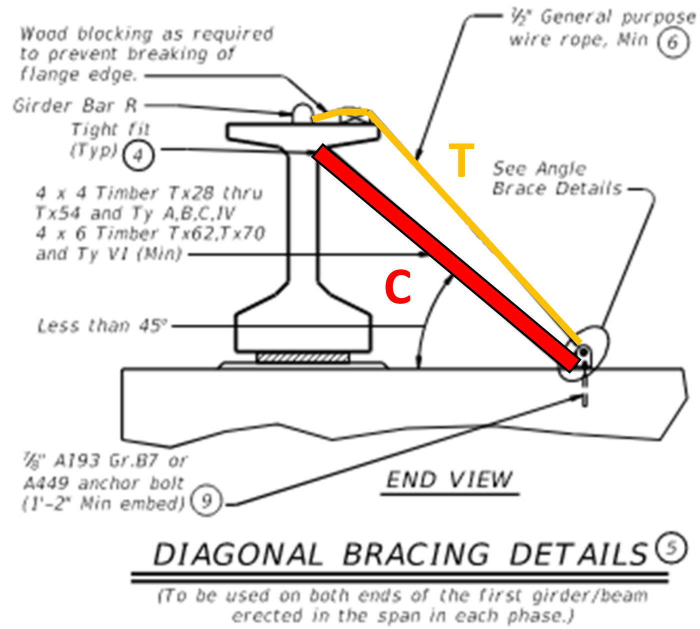
- Roll over stability main concern when setting
- Construction winds main cause for starting rollover
- Rollover impacted by several factors:
  - Bearing flexibility
  - Slope of bottom of girder
  - Fabrication imperfections (sweep)



Diagonal Bracing Design

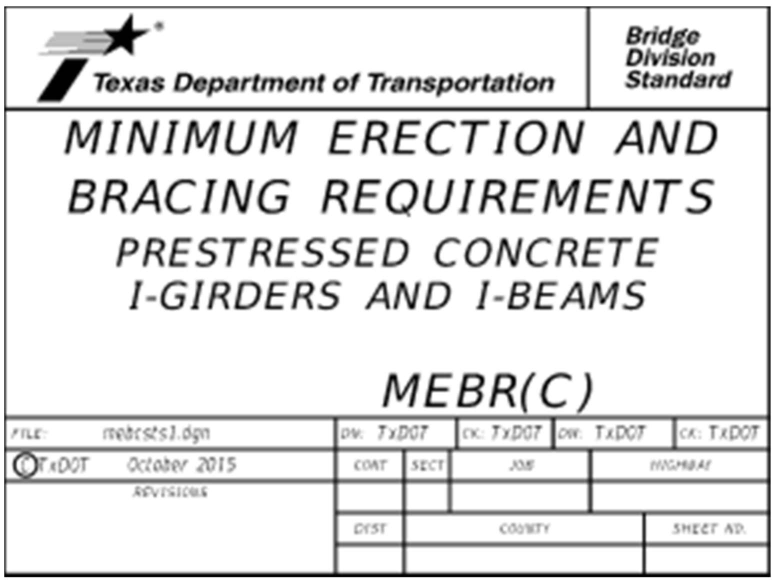
RELEASING

US50 Over BNSF RR, Lamar, CO



Sample Bracing Requirements

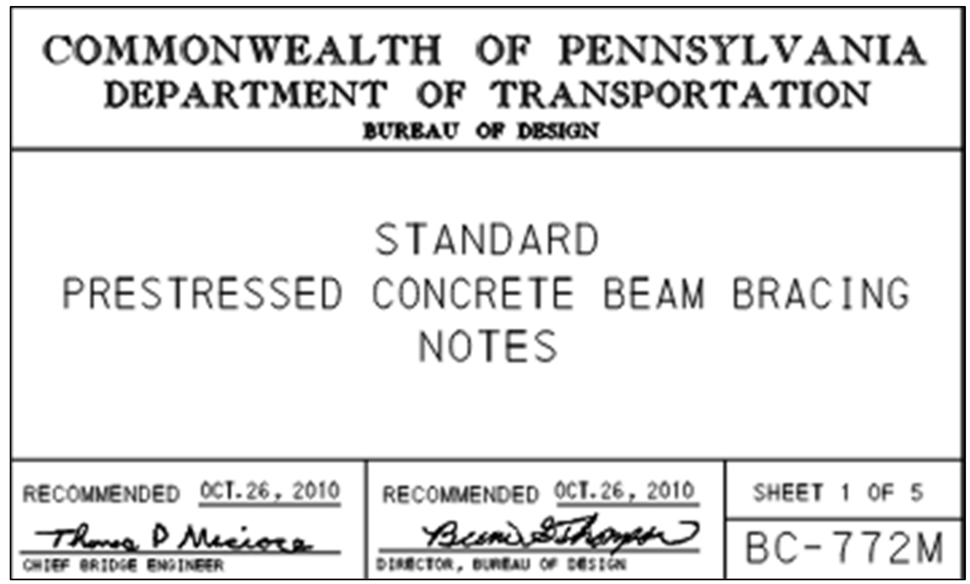
RELEASING


Texas Department of Transportation | Bridge Division Standard

MINIMUM ERECTION AND BRACING REQUIREMENTS
PRESTRESSED CONCRETE I-GIRDERS AND I-BEAMS

MEBR(C)

FILE: mebrsts1.dgn	DN: TxDOT	CK: TxDOT	DW: TxDOT	CK: TxDOT	
©TxDOT October 2015	CONT	SECT	JOB		HIGHWAY
REVISIONS					
	DIST	COUNTY			SHEET NO.


COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION
BUREAU OF DESIGN

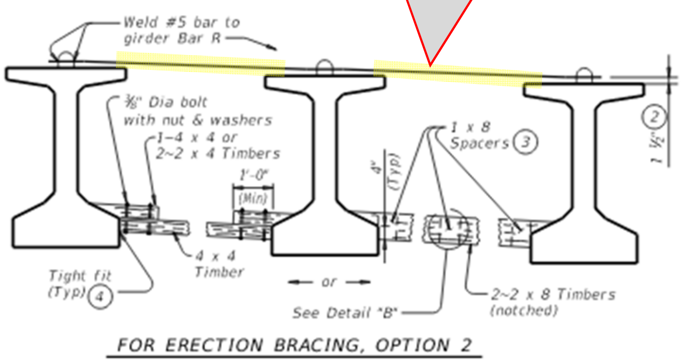
STANDARD
PRESTRESSED CONCRETE BEAM BRACING
NOTES

RECOMMENDED OCT. 26, 2010	RECOMMENDED OCT. 26, 2010	SHEET 1 OF 5
CHIEF BRIDGE ENGINEER	DIRECTOR, BUREAU OF DESIGN	BC-772M

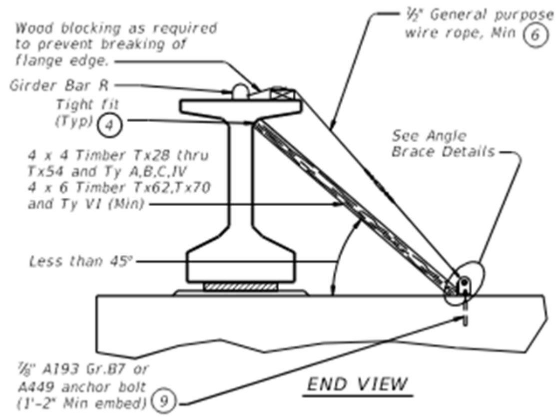
Temporary Bracing – TxDOT

RELEASING

Forms can interfere with standard detail



HORIZONTAL BRACING DETAILS ⑤



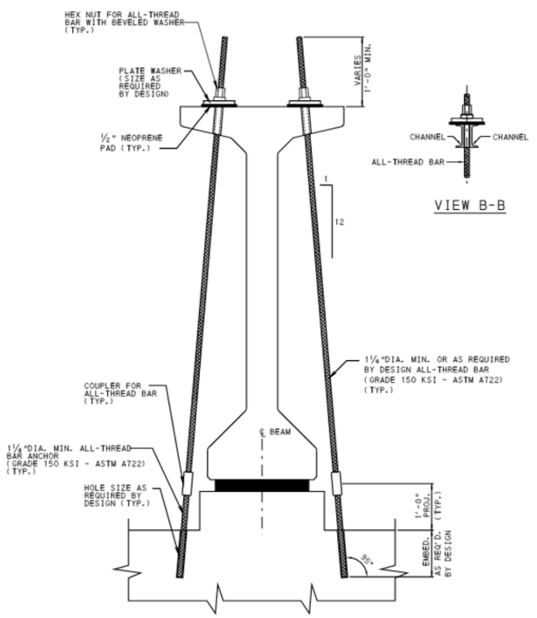
DIAGONAL BRACING DETAILS ⑤

(To be used on both ends of the first girder/beam erected in the span in each phase.)

- Provides engineered details and minimum end and erection bracing requirements
- For span lengths < 150-ft
- For specific girder types

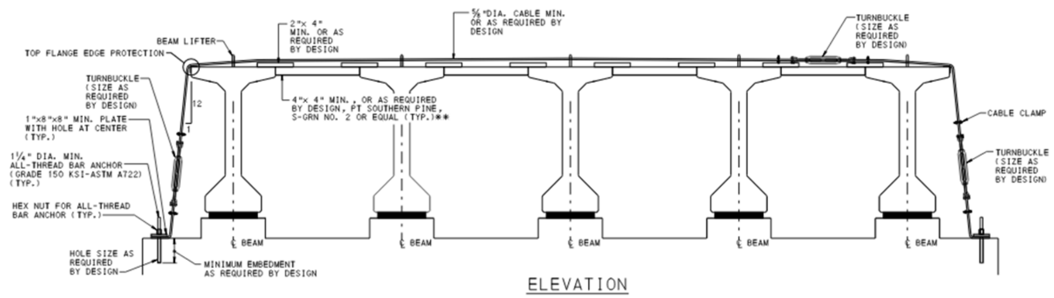
Temporary Bracing – PennDOT

RELEASING



CONCEPTUAL PRIMARY BRACING DETAILS

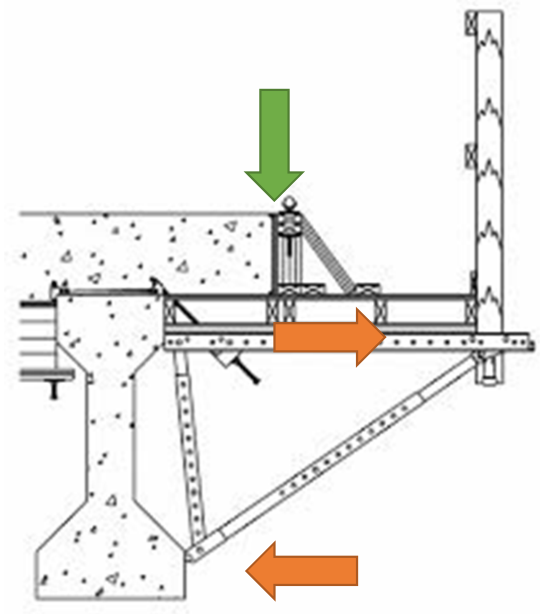
N.T.S.



CONCEPTUAL SECONDARY BRACING DETAILS

- Provides conceptual details for end and erection bracing

Other Considerations - Overhangs

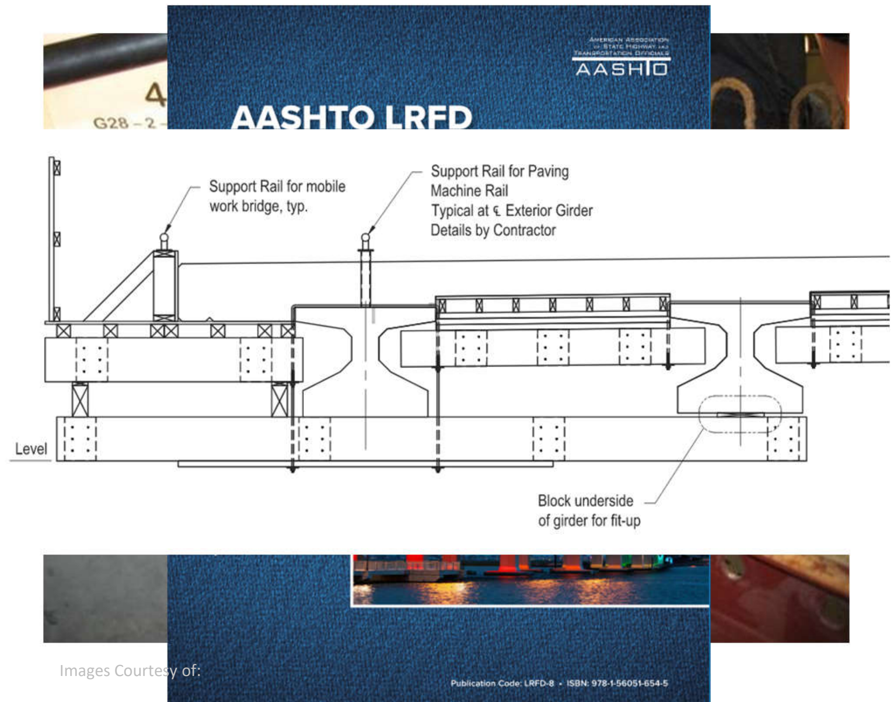


Images Courtesy of:

http://www.texsunconcrete.com
http://www.daytonsuperior.com/

Other Considerations - Overhangs

- Who is responsible for check of girder for overhang loads?
- AASHTO requires overhang check of steel I-Girder by designer. Concrete all on Contractor
- What do you check? Stability / Local Stresses / Torsion Stress / Deformation?



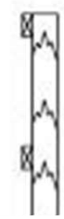
Images Courtesy of:

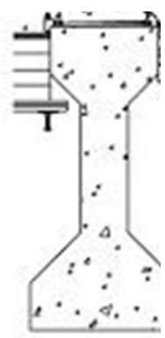
TxDOT New Standards, Amy Eskridge

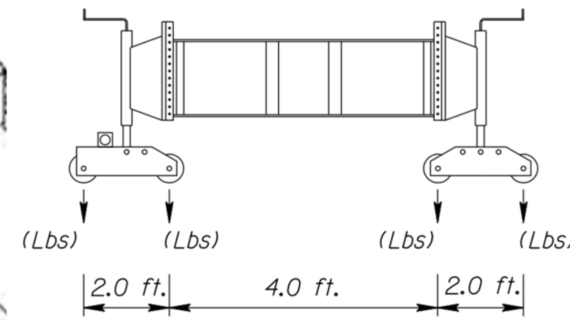
Other Considerations - Overhangs

Suggested Designer Checklist:

1. Is girder tall enough to receive conventional overhang bracket?
2. Is girder(s) stable under overhang loading (for what screed load)?
3. Designer should indicate what has been checked for overhang forming in Contract Documents







ASSUMED FINISHING MACHINE VALUES LOADING DIAGRAM

Precast Spliced Bridge Considerations

PICKING	SETTING	POST TENSIONING

Images Courtesy of:

www.post-tensioning.org
www.massman.net/project/rigolets-pass-bridge

Hoisting Considerations

PICKING

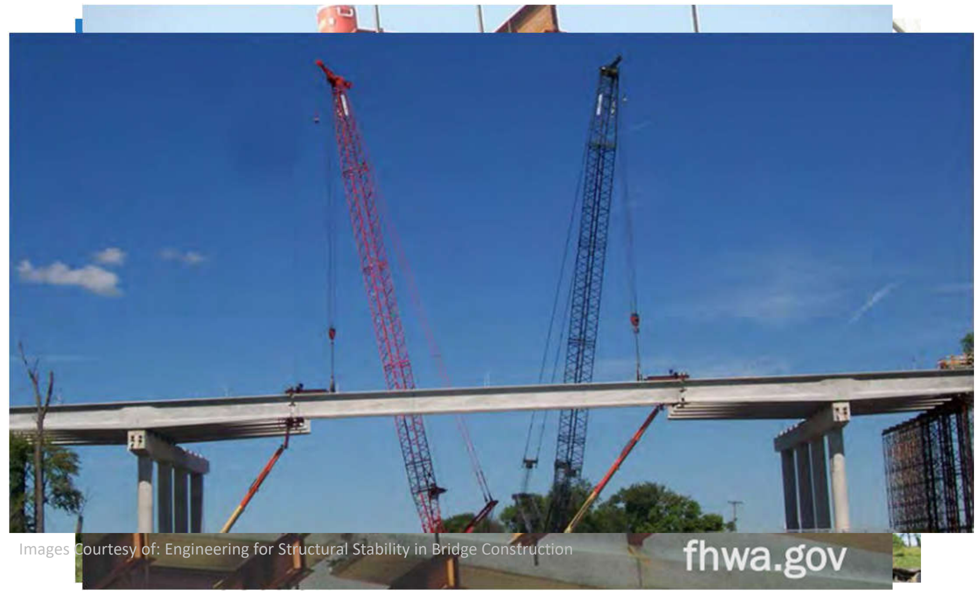
- Spliced precast sections often too heavy for single crane pick
- Conventional 2 crane picks often utilized
- Rigging can become complicated for curved / rotated members (usually U-Shape sections) similar to steel

Images Courtesy of: www.post-tensioning.org

Setting Considerations

SETTING

- Post tensioned I sections same stability concerns of prestressed simple spans.
- Spliced precast section can have drop in sections or could have FW towers at splice locations. Otherwise strong backs not required
- Because span weights, FW towers often more substantial that steel alternate



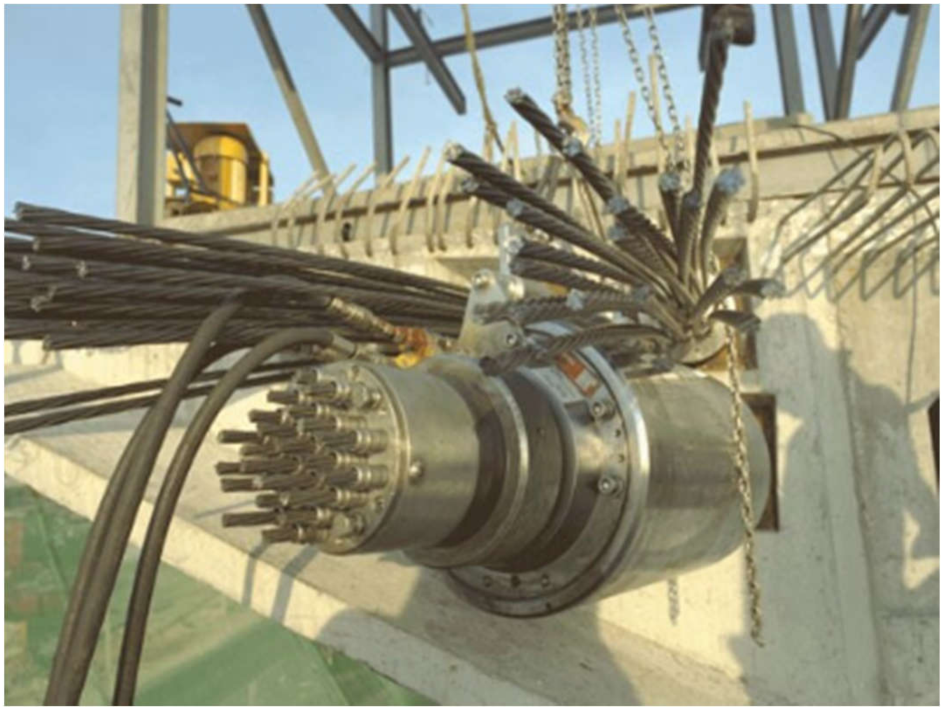
Images Courtesy of: Engineering for Structural Stability in Bridge Construction

Images Courtesy of: https://static.tti.tamu.edu/conferences/

Releasing / Post Tensioning

POST TENSIONING

- Post tensioning can add complexity/time to a girder erection but is achievable with right team in place
- Understanding of losses and time dependent phenomenon required for final design and construction analysis including:
  - Steel relaxation
  - Concrete creep and shrinkage
  - Anchor losses



Images Courtesy of: www.halfen-moment.com

Bridge Demolition and Re-Decking

Bridge Demolition and Re-Decking

- Thousands of bridges in our current infrastructure need to be replaced and/or rehabilitated
- This *"need"* for bridge replacement generates a need for safe demolition practices
- Currently is no "formal" code that specifically addresses any minimum design criteria to properly analyze a structure that is being taken out of service.
- Genesis is part of a group of engineers and contractors working towards the development of a "Best Practices" guideline for starters

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Lewis and Clark Viaduct, Kansas City, MO

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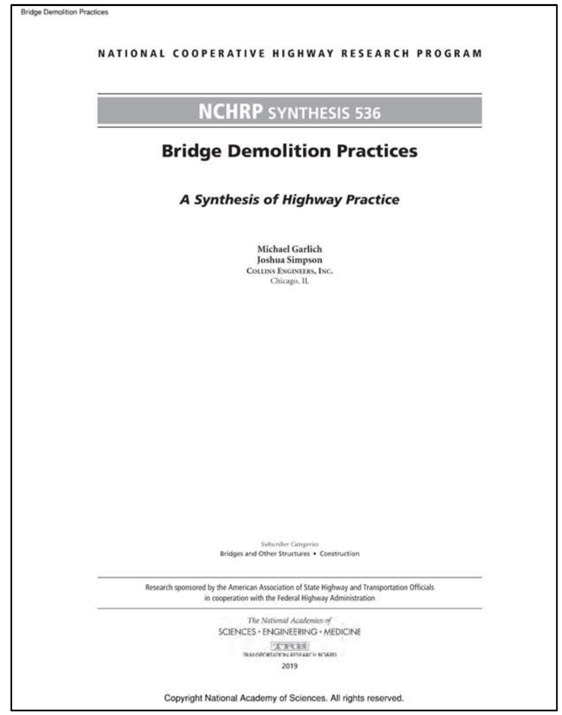
Bridge Demolition Practices

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP SYNTHESIS 536

Bridge Demolition Practices

A Synthesis of Highway Practice

Michael Garlich
Joshua Simpson
Collins Engineers, Inc.
Chicago, IL

Subscriber Categories
Bridges and Other Structures • Construction

Research sponsored by the American Association of State Highway and Transportation Officials in cooperation with the Federal Highway Administration

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2019

NCHRP Demo Practice Guides

Bridge Demolition and Re-Decking

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Complications of Bridge Demolition

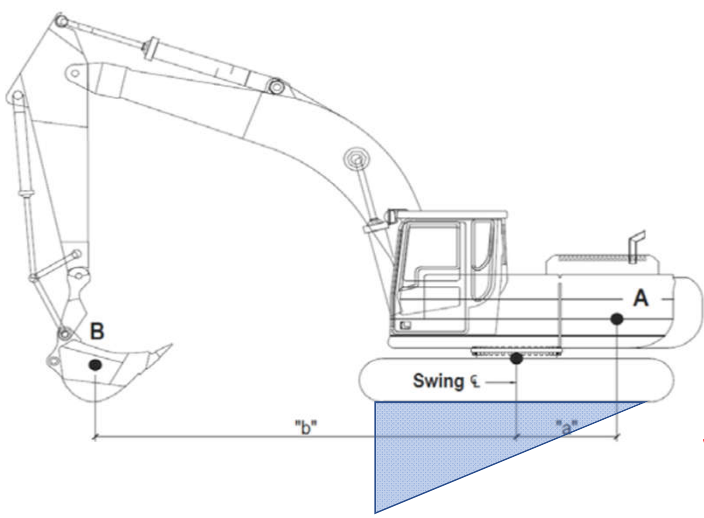
- Similar to erecting a bridge, structure stiffness and resistance change depending on stage

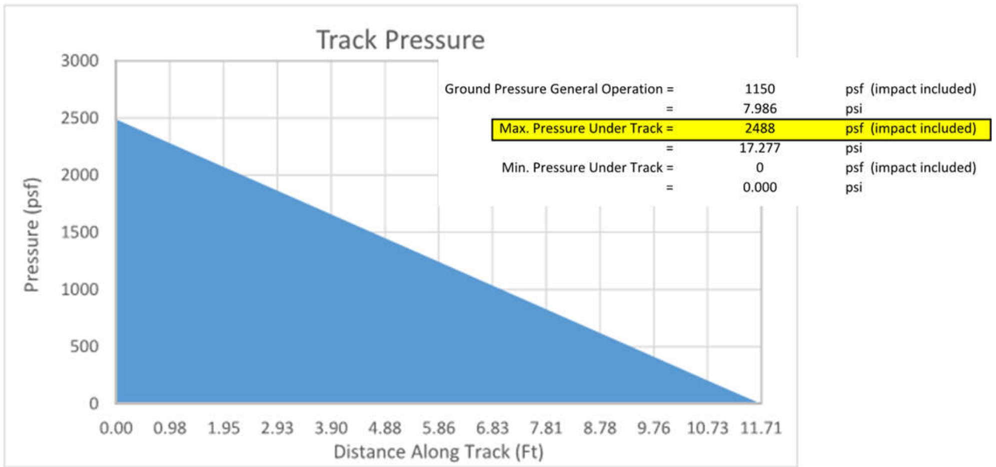
Lewis and Clark Viaduct, Kansas City, MO

I-75 Deck Replacement, Detroit, MI

Complications of Bridge Demolition

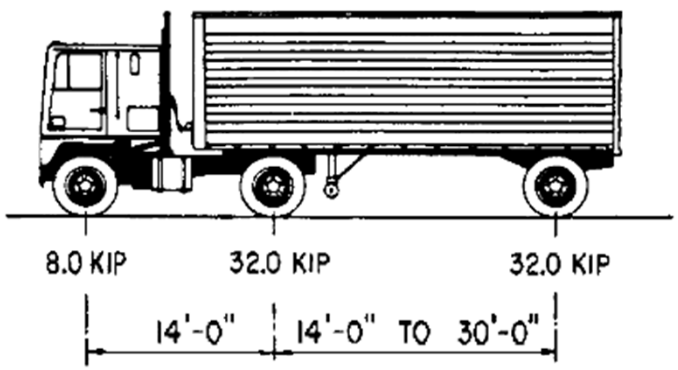
- Similar to erecting a bridge, structure stiffness and resistance change depending on stage
- Method for determination of load effects from equipment demolishing a structure is not standardized





What level of dynamic effects do you include?
Does it vary by deck removal method?

Demolition Equipment - Weight



Axle Length 28-ft to 44-ft

AASHTO 3.6.1.2.2 - DESIGN TRUCK

(72,000 lbs)

On a composite structure

Tumbler Spacing
14-ft to 16-ft

EXCAVATOR

CAT 349 (120,000 lb)

On a partially composite to noncomposite structure

Deck Removal Methods

- Breaker / Hammer
  - Contractor preference (quick)
  - Can damage flanges / cross frames
  - Protection under bridge may be required

Broadway Arch Bridge Demolition, Little Rock, AR

Deck Removal Methods

- Shear
  - Punch hole in deck with breaker/hammer and shear the rest
  - Multiple Uses:
    - Deck removal
    - Girder/material picking
    - Girder Processing

Comm Ave Bridge, Boston, MA / I40 Fast Fix 8, Nashville, TN

Deck Removal Methods

- Slab Crab / Bucket with Thumb
  - Time Consuming (Deck Cutting)
  - More Controlled
  - Protection under bridge minimal
  - Common for more complex bridges

Slab Crab

Bucket with Thumb

Paseo Suspension Bridge, Kansas City, MO

Deck Removal Methods

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  - Common for more complex bridges

I-75 Deck Replacement, Detroit, MI

Slab Crab

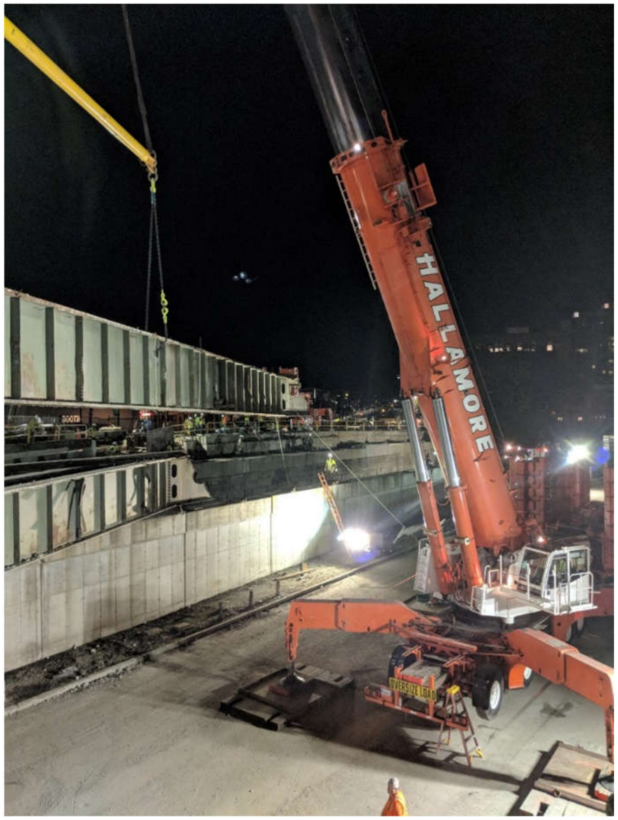
Bucket with Thumb

Deck Removal Methods

- Grapple
  - Debris mover

Images Courtesy of: equipmentland. & paladinattachments.

Girder Removal



Comm. Ave Bridge, Boston, MA

I40 Fast Fix 8, Nashville, TN

I40 Fast Fix 8, Nashville, TN

Changing Structural Integrity – Intentional

Precutting cross-frames
Prior to girder removal

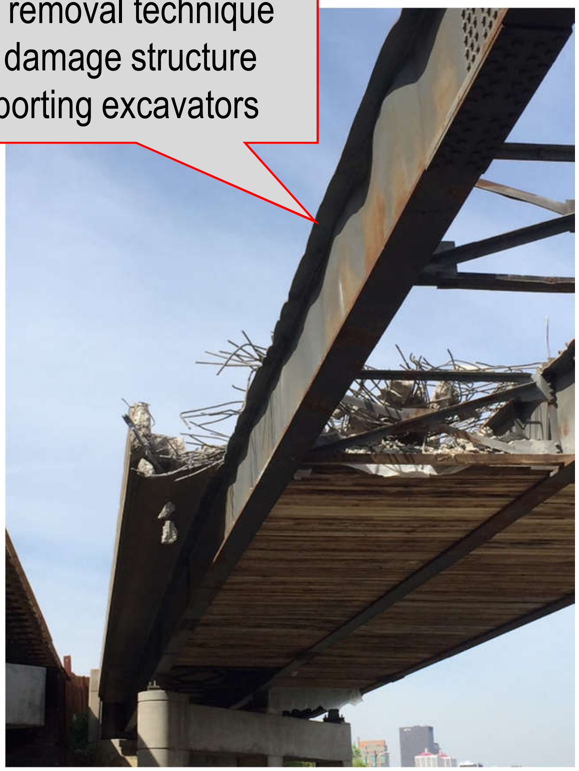
Comm. Ave Bridge, Boston, MA

Precutting or scoring deck
prior to panelized deck
removal

I-75 Deck Replacement, Detroit, MI

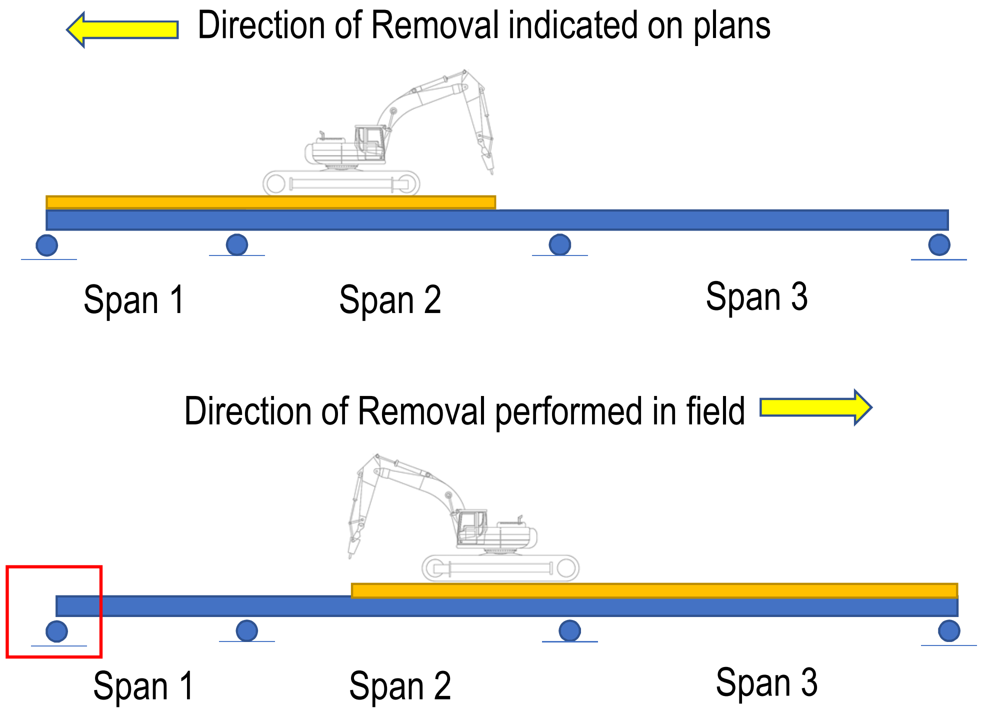
Changing Structural Integrity – Unintentional

Deck removal technique can damage structure supporting excavators

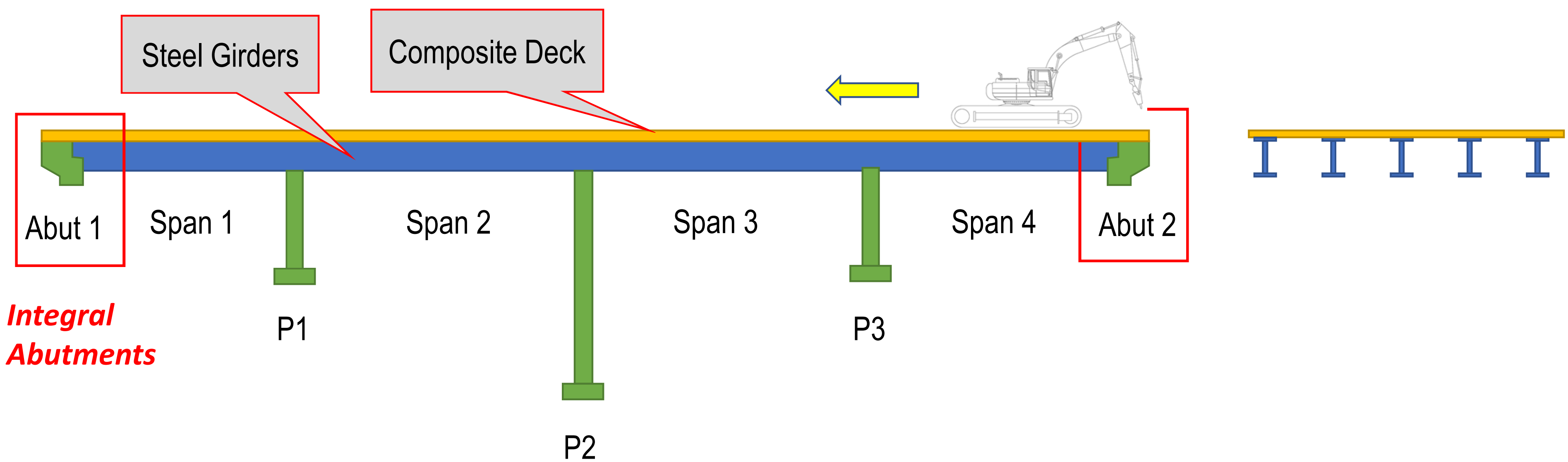


ORB Downtown, Louisville, KY

Direction of Removal Matters!



Changing Structural Integrity – Unintentional



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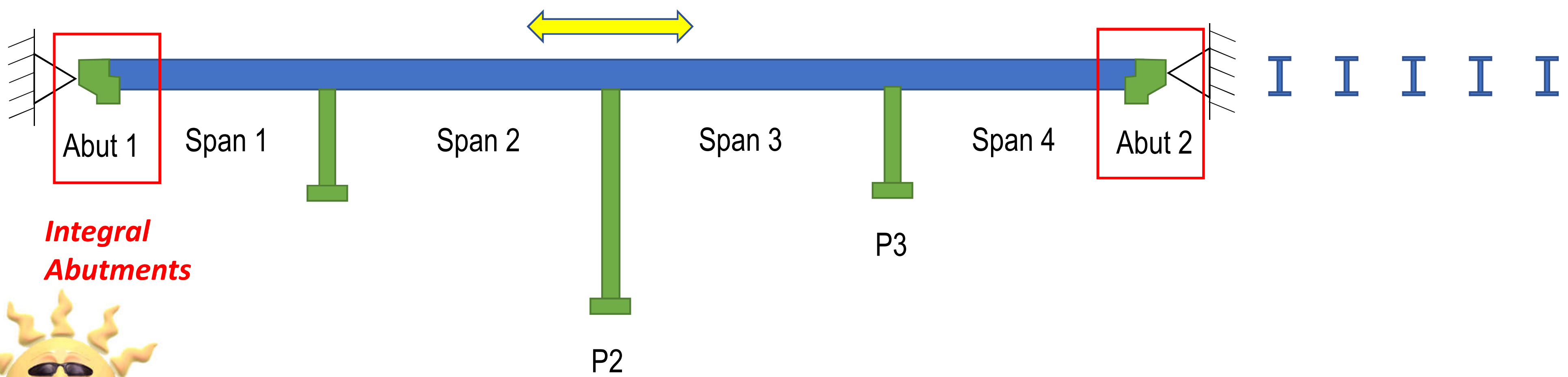

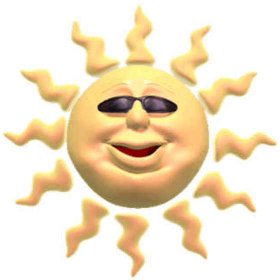

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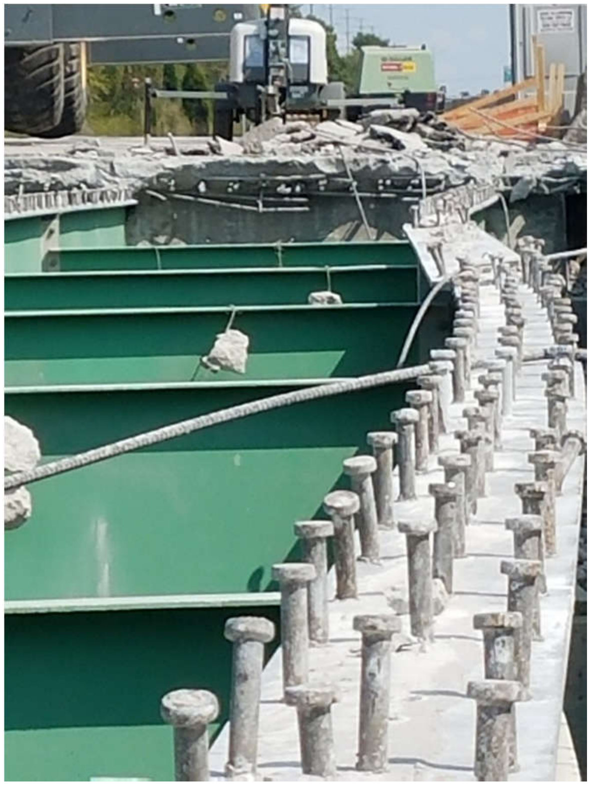

I470 Bridge Re-decking, Kansas City, MO

Demolition Summary

- Demolition is often an overlooked portion of projects with minimal formalized requirements
- Demolition engineering / analysis can be as complicated as erection engineering, and at times can be higher risk
- Goal to establish minimum requirements to increase quality and safety across industry

White River Truss Demolition, Prairie County, AR

Demolition Summary

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Fore River Lift Span Demolition, Quincy, MA

Demolition Summary

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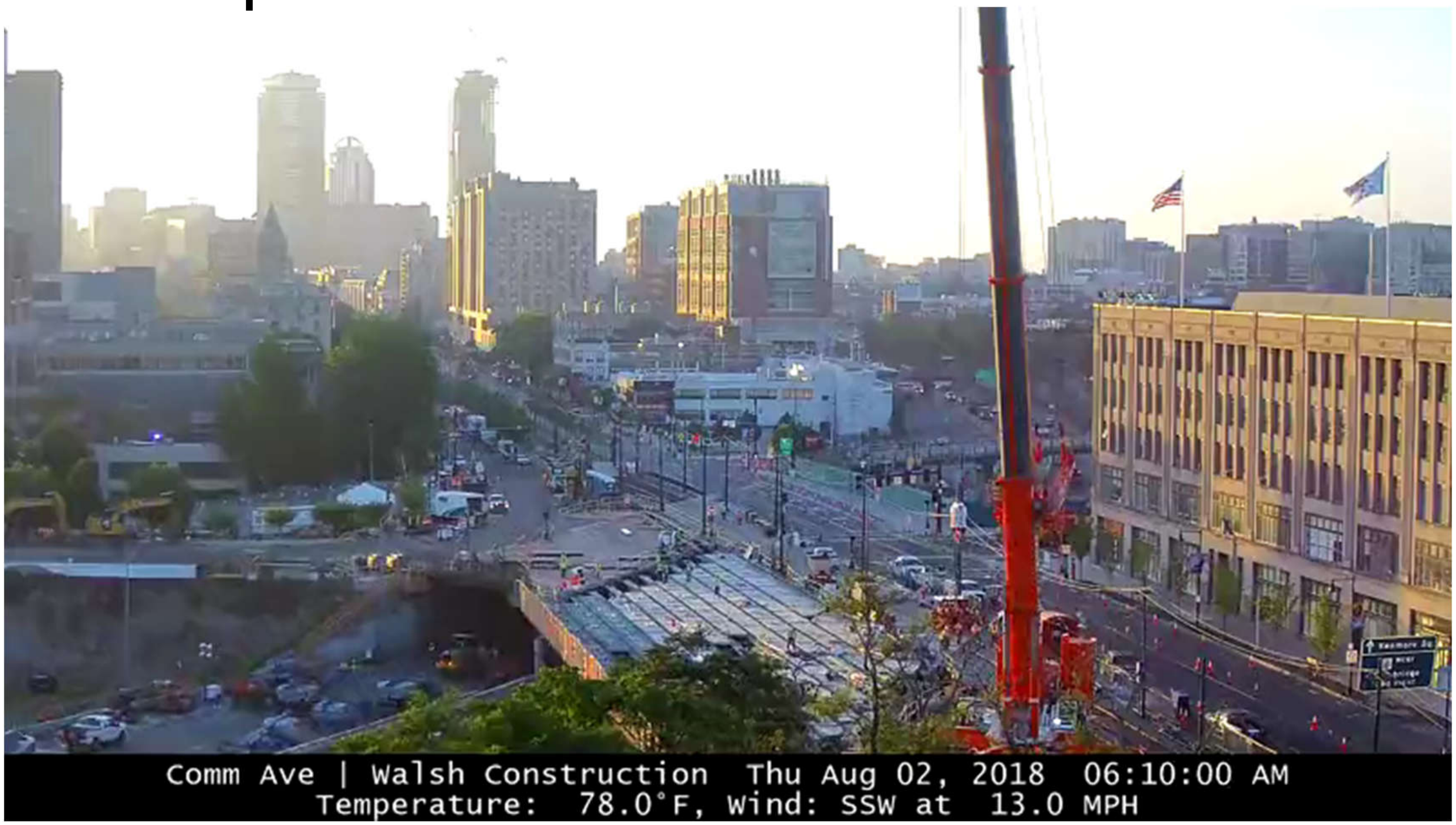
K Bridge Lift Span Demolition, New York, NY

Demolition Summary – It can be pretty fun

Paseo Suspension Bridge, Kansas City, MO

Merchants Truss Bridge, St. Louis, MO

Time Lapse of Deck and Girder Removal



Conclusions / Suggestions

Conclusions/Suggestions – Contractor's Perspective

- Perfect World
- Design-Bid-Build Contract Plans
- Precast & Steel
- Erecting Steel & Precast Girders

Conclusions/Suggestions – Contractor's Perspective

- Perfect World
  - Everyone has an important role
    - Design Engineers need to be experts in design
    - Construction engineers need to be experts in temporary works
- Design-Bid-Build Contracts
- Precast & Steel
- Erecting Steel & Precast Girders

Conclusions/Suggestions – Contractor's Perspective

- Perfect World
  - Everyone has an important role
    - Design Engineers need to be experts in design *but must understand and appreciate the challenges that face construction engineers and contractors.*
    - Construction engineers need to be experts in temporary works *and must maintain a full working knowledge and understanding of design provisions in AASHTO*
- Design-Bid-Build Contracts
- Precast & Steel
- Erecting Steel & Precast Girders

Conclusions/Suggestions – Contractor's Perspective

- Perfect World
  - Everyone has an important role
  - Design Engineers/Owners should reach out to construction engineering firms & contractors/fabricators
    - Genesis has been asked by engineering firms to provide constructability reviews but at the cost of being prohibited from then working with Contractors during the bid process
- Design-Bid-Build Contracts
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Conclusions/Suggestions – Contractor's Perspective

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  - Everyone has an important role
  - Design Engineers/Owners should reach out to construction engineering firms & contractors/fabricators
    - Genesis has been asked by engineering firms to provide constructability reviews but at the cost of being prohibited from then working with Contractors during the bid process
    - The industry can benefit from a front end and back end constructibility review service
      - Design Engineer/Owners should have "general" conversations about possible erection methods/schemes with construction engineers
      - If Design Engineer/Owners want a more thorough review of the erection sequence, there should be proper budget allowance upfront in the design phases vs. becoming a last minute check at end of project when plans are already developed.
- Design-Bid-Build Contracts
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Conclusions/Suggestions – Contractor's Perspective

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    - Genesis has been asked by engineering firms to provide constructability reviews but at the cost of being prohibited from then working with Contractors during the bid process
    - The industry can benefit from a front end and back end service
  - AASHTO would formally categorize steel girder bridges into erection categories…currently up to DOTs
- Design-Bid-Build Contracts
- Precast & Steel
- Erecting Steel & Precast Girders

Conclusions/Suggestions – Contractor's Perspective

- Perfect World
- Design-Bid-Build Contract Plans
  - Contractor is responsible for erecting parts and pieces to achieve a fully erected structure
  - Contract plans should provide a design that is stable and safe once the superstructure is fully erected
  - Contract plans should provide a viable "suggested" erection sequence (or at a min deck port sequence)
  - If the contractor strays from the "suggested", all engineering in on them
- Precast & Steel
- Erecting Steel & Precast Girders

Conclusions/Suggestions – Contractor's Perspective

- Perfect World
- Design-Bid-Build Contract Plans
- Precast & Steel – Basically Similar
  - Shorter more standard type bridges
    - Don't necessarily require "Suggest Erection Sequences"
    - Don't necessarily require formalized erection engineering submittals
    - Unless there are special site constraints
- Erecting Steel & Precast Girders

Conclusions/Suggestions – Contractor's Perspective

- Perfect World
- Design-Bid-Build Contract Plans
- Precast & Steel – Basically Similar
  - Shorter more standard type bridges
  - Complex bridges will require more formalized erection submittals
    - Do require "Suggest Erection Sequences"
    - Do require formalized erection engineering submittals
- Erecting Steel & Precast Girders

Conclusions/Suggestions – Contractor's Perspective

- Perfect World
- Design-Bid-Build Contract Plans
- Precast & Steel
- Erecting Steel & Precast Girders
  - There is a lot of planning that goes into even a simple/typical/standard highway bridge structure
    - **BOTH DURING DESIGN & DURING BIDDING**
  - AASHTO "code writers" truly intended the specification to make sure designers to be responsible for the fully erected steel superstructure

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- Perfect World
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  - AASHTO "code writers" truly intended the specification to make sure designers to be responsible for the fully erected steel superstructure ***….. But it does not specifically say this***

Questions?

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