2015 Design Training Expo

Designing for Constructability

Dennis Golabek, PE
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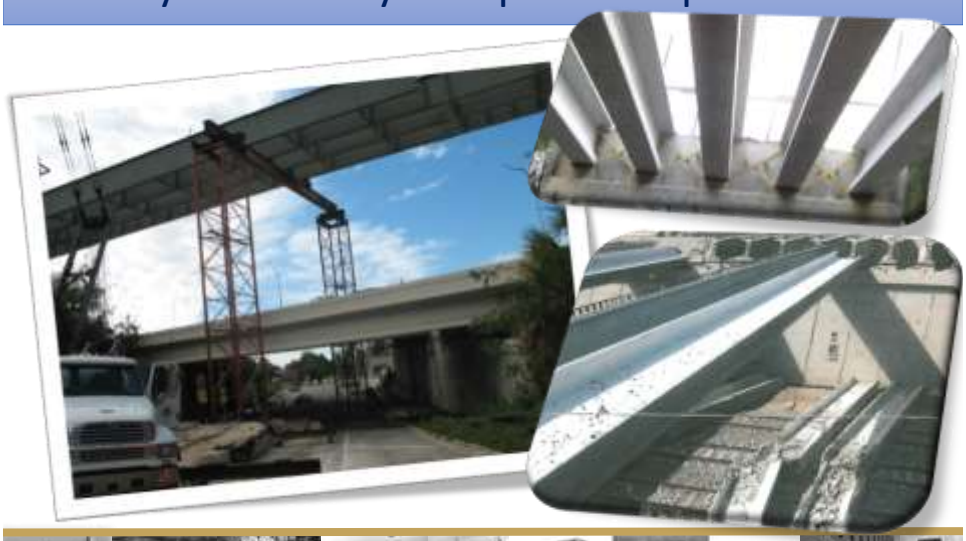
Stability of Partially Completed Superstructures



Bridge Failure during Construction

On May 15, 2004 in Golden Colorado, a steel girder on an interstate overpass bridge widening project collapsed onto an interstate killing two adults and a child travelling in an SUV.

NTSB Conclusions

- The accident was caused by the failure of the contractor's temporary bracing system.
- Issues with the Colorado DOT:
  - Lack of uniform and consistent bracing standards
  - Narrow definition of falsework, which did not include lateral bracing
  - Failure to effectively oversee safety-critical contract work for the project

FDOT Construction Specifications

- Section 5 Control of the Work
- Section 7 Legal Requirements and Responsibility to the Public
- Section 103 Temporary Works
- Sections 450 and 460

FDOT Construction Specifications

Section 5 Control of the Work

Work Items Requiring Shop Drawings

- Bridge components not fully detailed in plans
- Temporary works affecting public safety
- Beam and girder temporary bracing
- Major and Unusual Structures

Review by the Engineer

- Conformity to the Contract Documents
- Construction Affecting Public Safety

Certifications

- Inspects Item
- Special Erection Equipment, Falsework, Temporary Earthworks

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FDOT Construction Specifications

Section 7 Legal Requirements and Responsibility to the Public

Control of the Contactor's Equipment

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FDOT Construction Specifications

103 - Temporary Works

Solely to support construction equipment

FDOT Construction Specifications

Sections 450 and 460

450-16 Handling, Storage, Shipping and Erection

460-7 Erection Plan

Stability of Partially Completed Superstructures

Structures Design Guidelines

- Chapter 6.10
  Erection Scheme and Girder Stability
- Chapter 2
  Loads and Load Factors
  (Wind & Construction Loads)
- Chapter 4/5
  Girder Transportation

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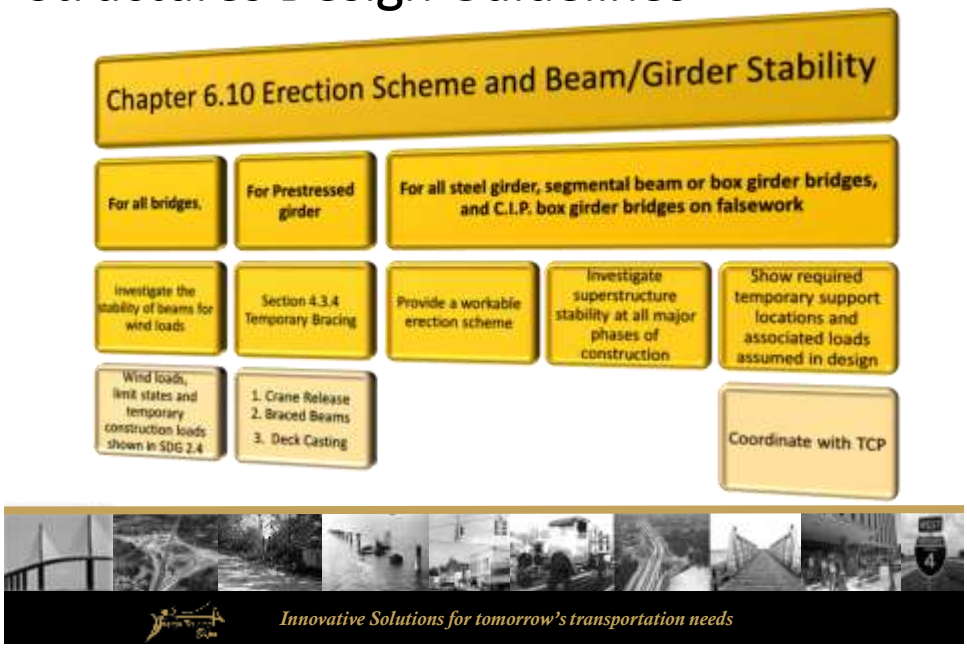
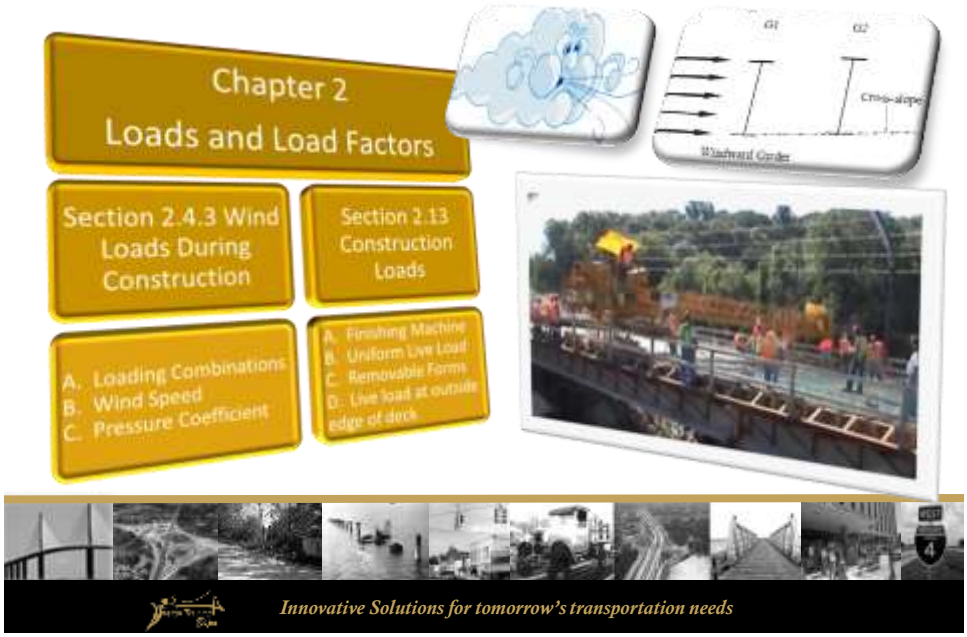
Structures Design Guidelines



Structures Design Guidelines



Section 2.4.3 Wind Loads During Construction

2:00 PM

Designing for Constructability
Until 2:50 PM

3:00 PM

Wind Loads During Construction
Until 3:50 PM

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2.13.1 Constructability Limit State Checks

In the absence of more accurate information, the following construction loads can be assumed for investigation of the strength and service limit states during construction in accordance with **LRFD** [3.4.2] and **SDG** 2.4.3, and for investigation of deck overhang bracket force effects in accordance with **LRFD** [6.10.3.4]. These loads are applicable to conventional beam or girder superstructures with cast-in-place decks. All construction loads assumed in the design of the structure shall be listed in the plans.

A. **Finishing machine load**: The finishing machine load shall be per the manufacturer's specifications and be applied as a moving load positioned to produce the maximum response. In the absence of manufacturer's specifications, assume the following loads:

W = Bridge Width (ft)	Total Weight of Finishing Machine (kips)
26 ≤ W ≤ 32	7
32 < W ≤ 56	11
56 < W ≤ 80	13
80 < W ≤ 120	16

B. Construction live load: 20 lb/sf extended over the entire bridge width and 50 feet in longitudinal length centered on the finishing machine.

C. Removable deck cantilever forms with overhang brackets: 15 lb/sf

D. Live load at or near the outside edge of deck during deck placement: 75 lb/ft applied as a moving load over a length of 20 feet and positioned to produce the maximum response.

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Stages of PS Beam Stability

1) Beam lifting
   a) Forms → dunnage
   b) dunnage → truck
   c) truck → bearings

Fabricator & Contractor

2) Beam on dunnage
3) Beam on truck
4) Crane release (single beam on bearings)
5) Two beams erected and braced at ends
6) All beams during deck casting

Project EOR

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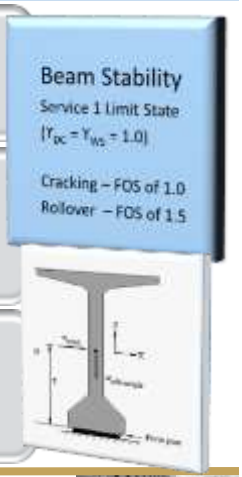
FDOT Mathcad Program
Three Stages of Construction

- Crane Release (single beam on bearings)
  Active Construction -- Wind Speed = 20 mph
  - Is anchor bracing required?

- Braced Beams (braced at ends)
  Inactive Construction –
  Wind Speed = 0.6 * Design Wind Speed
  – Is intermediate bracing required?

- Deck Casting
  Wind Speed = 20 mph
  All loads during deck pour
  - Is intermediate bracing required?



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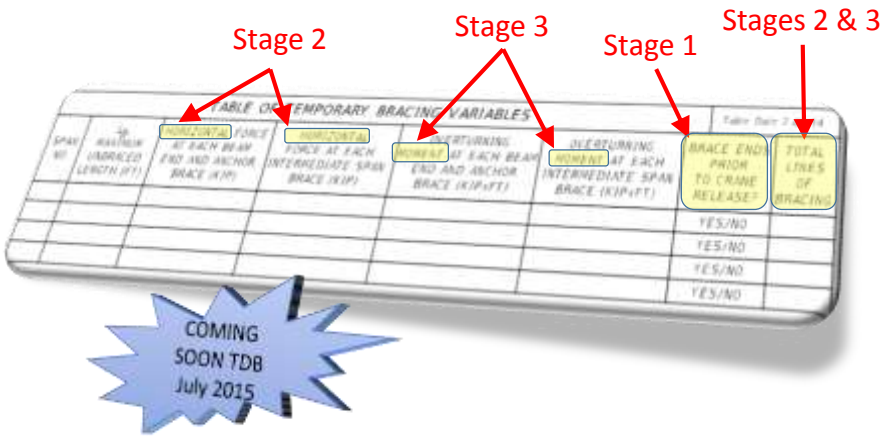
FDOT Mathcad Program
Three Stages of Construction



End of First Day of Beam Placement

Structures Design Guidelines

Chapter 4 & 5 Superstructure Concrete / Steel (4.1.3 and 5.1.2) Girder Transportation

The EOR is responsible for investigating the feasibility of transportation of heavy, long and/or deep girders

A. Longer than 145 /130 feet
B. Weighing more than 160,000 pounds (requires coordination through the Department's Permit Office)
C. Depths exceeding 9'-0"

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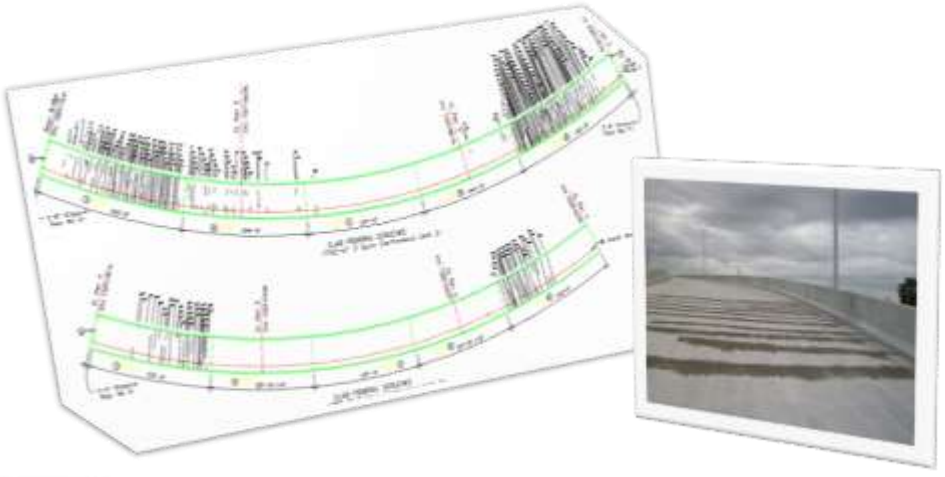
CIP Decks on Continuous Steel Girder Bridges



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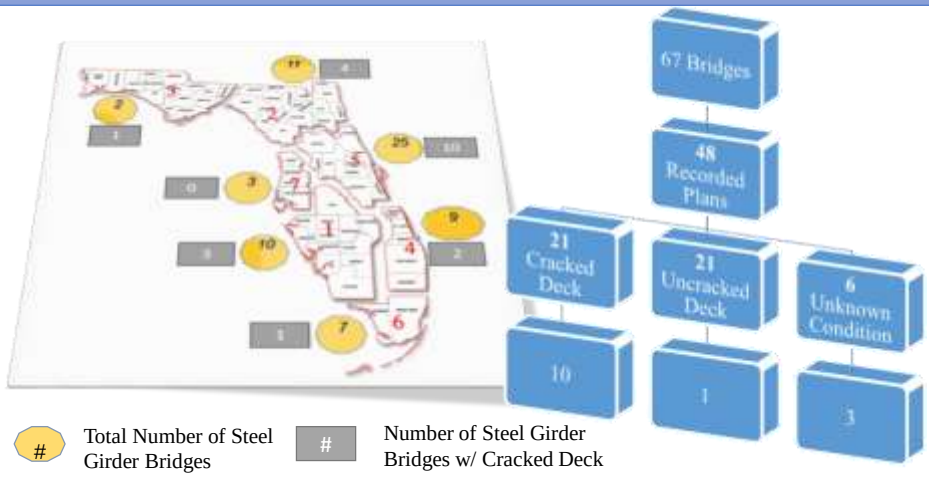
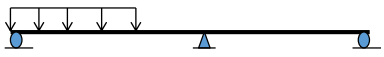
FDOT SURVEY

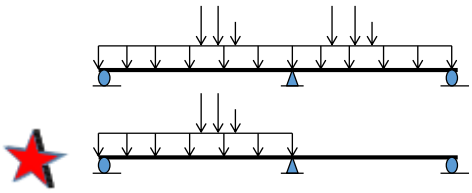


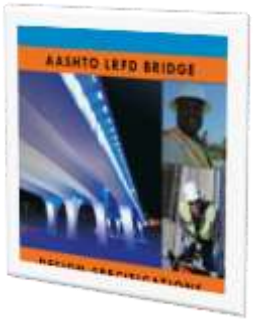
AASHTO LRFD BDS

- 6.10.1.7 & 6.10.3.2.4 –
  - **Factored Construction Loads = 1.25 DL+ 1.5 CL**



  - Load Combination Service II = 1.0 DL + 1.3 (LL+IM)

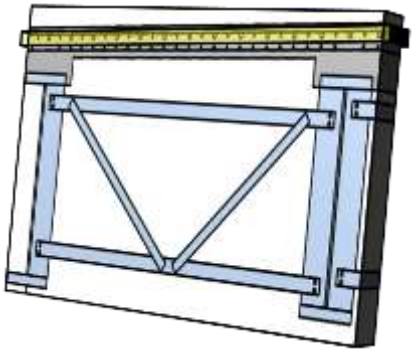




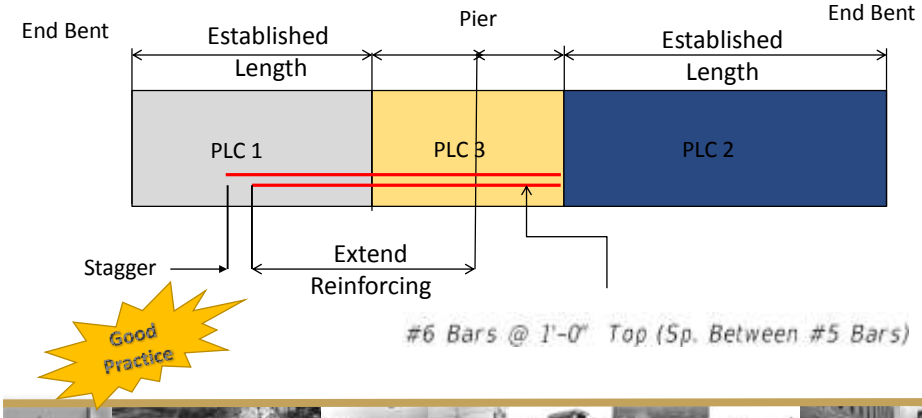
  - Check Deck Tensile Stresses < Modulus of Rupture ($\Phi f_r = 0.24\sqrt{f`_c}$)
  - 1% Reinforcing Steel Requirement → 2/3 Top Layer

Reinforcing Detailing

- SDG 4.2.11 Temp & Shrinkage
  - **No. 4 Min. at 12-inch Sp. Max.**
- LRFD BDS 6.10.1.7
  - **No. 6 Max., 12-inch Sp. Max.**
  - **1% Steel – 2/3 in top layer**



Reinforcing Detailing



Global Stability of Narrow Steel I-Girder Systems

- Narrow ramp bridges
- Phased construction
- Widening

Global Buckling

- Not addressed in AASHTO LRFD BDS
- Limit of system buckling resistance is reached before the elastic buckling resistance of the girders
- Partially erected framing system - SDL Phase Construction / Widening – wet deck

Global Disp. Ampl.

- New AASHTO BDS design requirement (2015 Interim Revisions)
- Large lateral system displacements which can make geometry control difficult and be an indication that system is approaching buckling
- Fully erected framing with wet deck load

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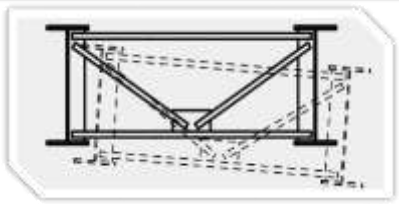
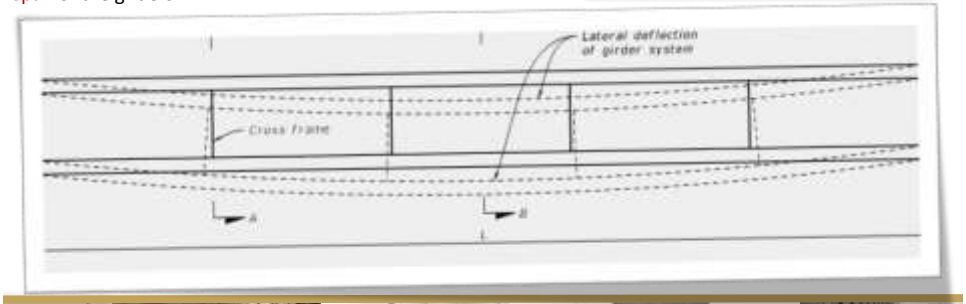
What is Global Buckling?

Definition being added to AASHTO LRFD

Global Lateral-Torsional Buckling:

Buckling mode in which a system of girders buckle as a unit with an unbraced length equal to the clear span of the girders.





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Global Buckling

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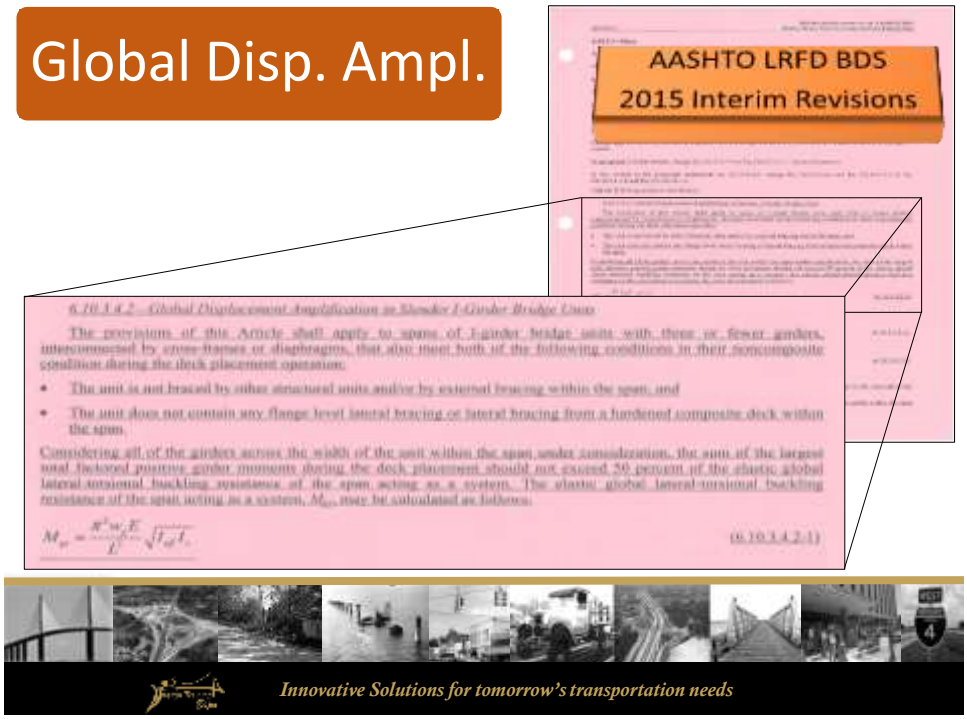
Global Disp. Ampl.



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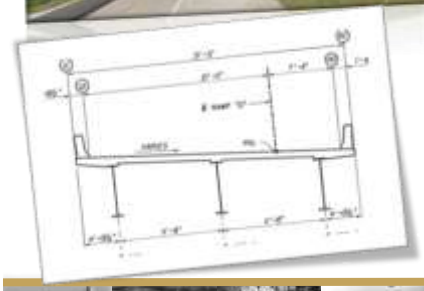
Global Displacement Amplification



- Three-span continuous unit
- 167-ft maximum span c/c bearings
- 3 girder lines at 11'-8"
- AASHTO 6.10.3.4.2
- M_l/M_{el} = 118% > 50%
- No Good

How much lateral bracing? (or) Evaluate 2nd order displacements

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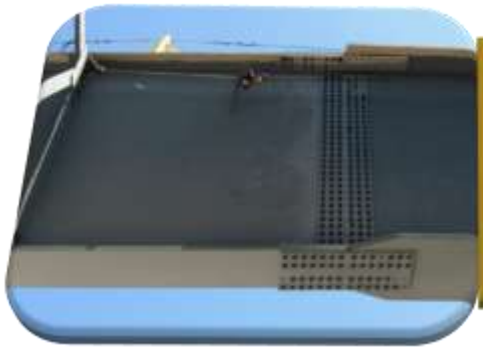
What's New – Construction Specs



- 460-7.7
  - 50% of the web connections
  - 50% of the flange connections

What's New – Construction Specs

- Diaphragms or cross-frames
  - Uniformly distributed between all the bolt groups
  - The 50% requirement may be waived if a reduced percentage is calculated as sufficient and shown on the approved erection plan

What's New – Construction Specs

- 400-4.4 Bridge Deck Overhang Falsework for Steel I-Girders

- Locate within 6 inches above the bottom flange.
- If more than 6 inches or if the deck overhang is 4 feet or greater, submit shop drawings and calculations to the Engineer in accordance with Section 5 and Chapter 11 of the Structures Design Guidelines (SDG).

Designing for Constructability

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Questions/Comments