Steel Girders

Nick Haltvick
Jessica Wahl Duncan
Bridge Design Engineers

Presentation Navigation

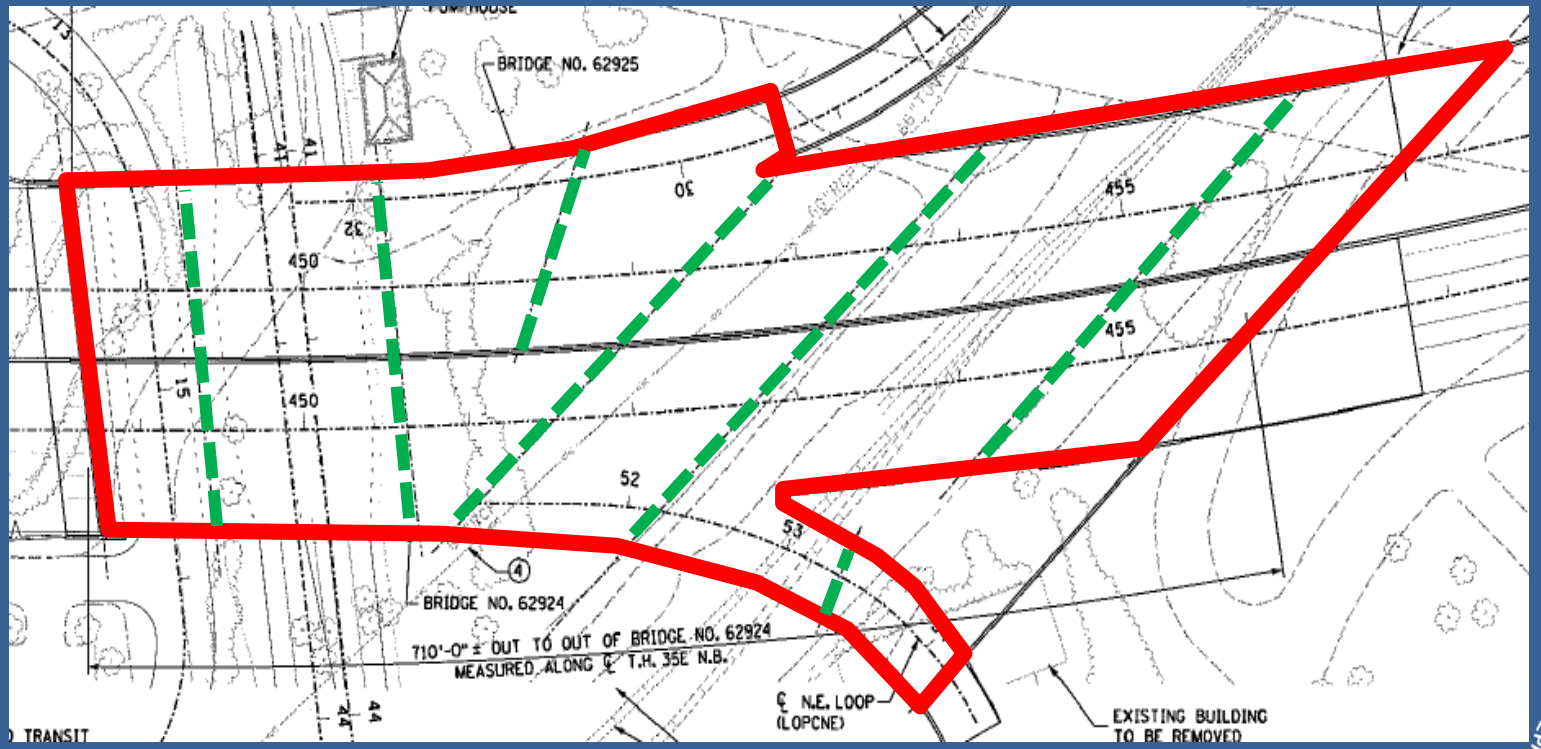
- Introduction, Design Aids, References, Misc.
- Design Topics
- Fabrication
- Constructability
- Deck Placement Sequences
- Software Issues
- Drafting & Detailing
- Review Submittals

Why use Steel Girders?

- In MN, the preference is concrete due to the harsh environment.
- However, steel can be a more economical solution when:
  - Need shallower or lighter beams
  - Very long spans
  - Curved alignment
  - Specialty structures (i.e. Lafayette Bridge)
- NSBA *Selecting the Right Bridge Type*

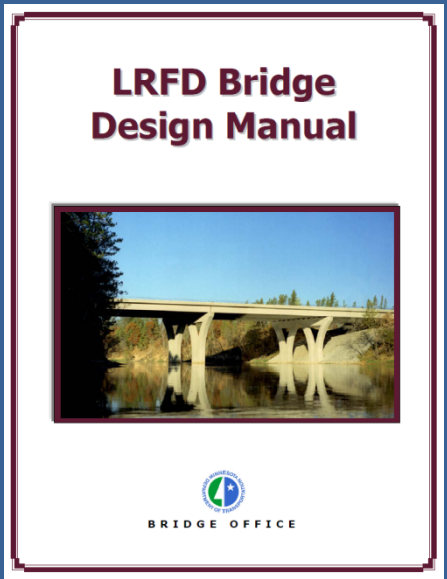
Why use Steel Girders?

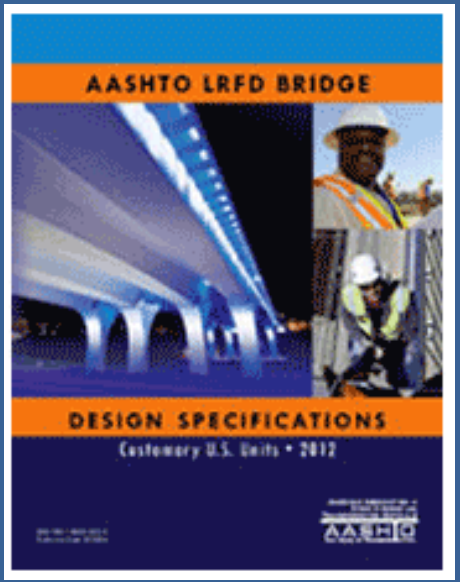
- Limited right-of-way available
- Tight geometric constraints
- Challenging roadway design



Design Requirements & Aids

- AASHTO & MnDOT LRFD Bridge Design Manual
- AASHTO/NSBA Steel Bridge Collaboration Documents (www.steelbridges.org)
- NHI Courses





Design Requirements & Aids

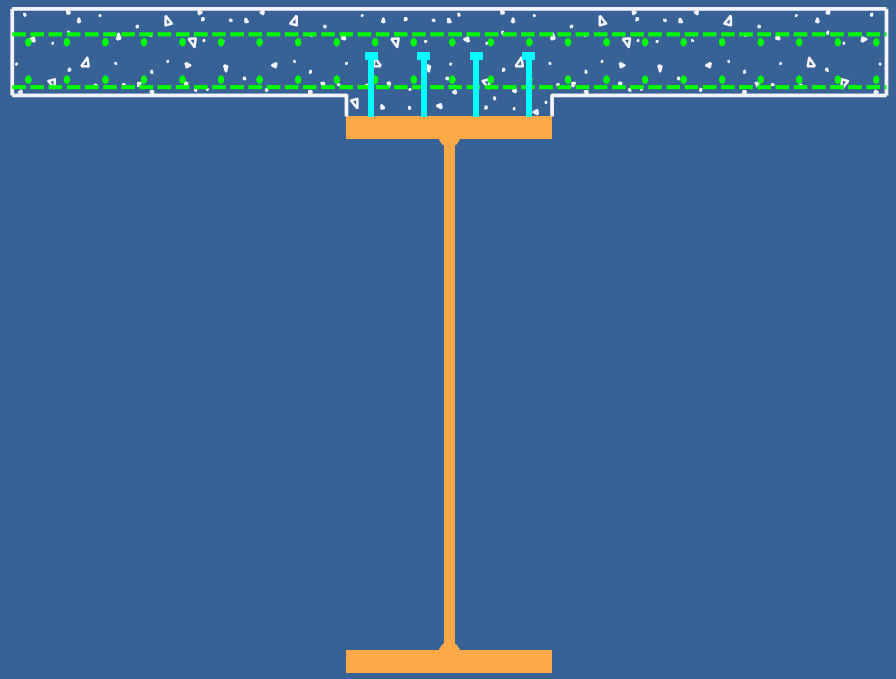
- With the MnDOT Project Manager, please coordinate *any deviations* from the AASHTO or MnDOT Bridge Design Manual *prior* to implementation.

Design – General Procedure

- Common Misconception (aka “Rules of Thumb”)
  - Lightest Girder = Cheapest Girder
- Reality (Currently)
  - Least Labor ≈ Least Cost
  - Use simple custom details

Design – General Procedure

- Select baseline element sizes based on final condition



- Modular ratio
  - Non-composite Dead Load = n
  - Live Load = n
  - Composite Dead Load = 3n

Design – General Procedure

- Consider constructability requirements
  - Erection of girders
  - Stability
  - Deck placement sequence
- Only increase from baseline plate sizes

Design – Plate Sizing

- Span Lengths & Arrangements
- Global Need of Large Projects
- MnDOT LRFD 6.5

CHANGE IN SLIDE ORDER

Design – Plate Sizing

ELEMENT	STRAIGHT	CURVED
WEB	$D \geq {}^{L}/_{30}$	$D \geq {}^{L}/_{25}$
	${}^{D}/_{t_w} \leq n$ *n = 150 w/o long. stiff.* *n = 300 w/ long. stiff.*	
	Uniform Depth	
	Min. ½" thick	

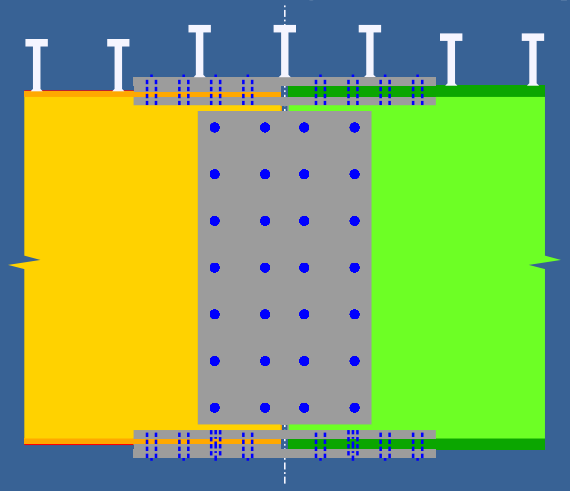
CHANGE IN TEXT

Design – Plate Sizing

ELEMENT	STRAIGHT	CURVED
FLANGES	$b_{fc} \geq {}^{L}/_{85}$	$b_{fc} + (2" \text{ to } 3") \geq {}^{L}/_{85}$
	$^{b_f}/_{2t_f} \leq 12$	
	$b_f \geq {}^{D}/_{6}$	
	$t_f \geq 1.1t_w$	
	$0.1 \leq {}^{I_{yc}}/_{I_{yt}} \leq 10$	
	Min. ¾" x 14"	

Design – Flange Sizing

- Max of three thickness changes per field section
- Constant top flange width within field sections
  - –Bottom flange width over entire length of bridge
- Welded Shop Splices
  - –Reduce by < ½ of the area of the thicker plate
  - –Many pieces cut from single wide plate

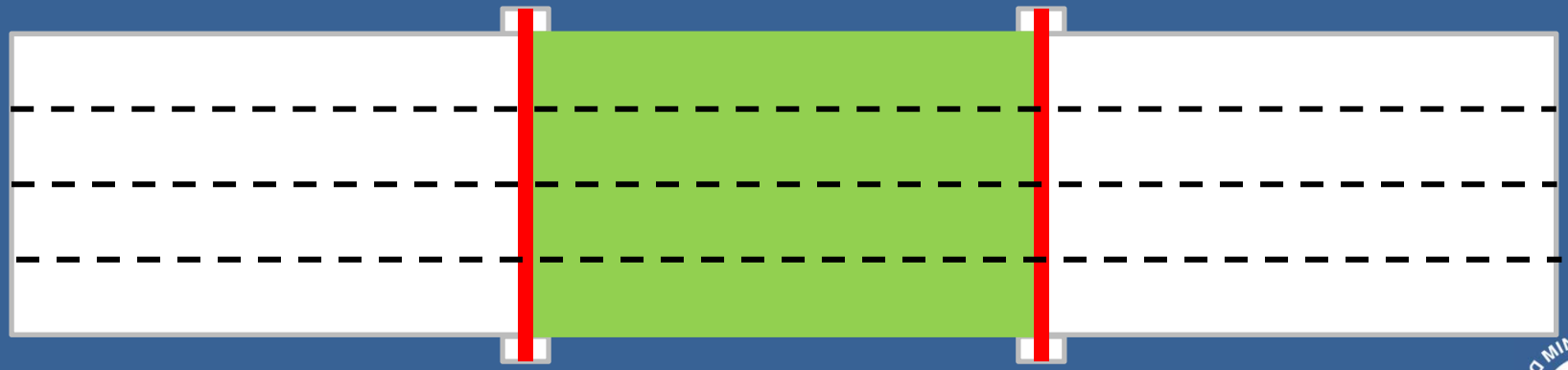


Design – Plate Sizing

- Consider Fabrication Methods

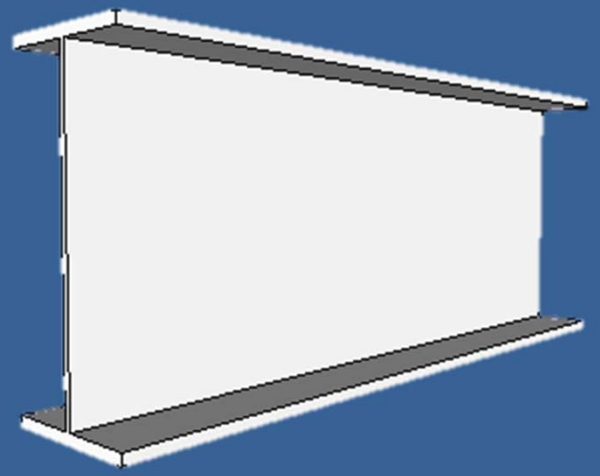
  - Single Piece Splice

  - Slab Welding (Multiple Pieces)



Design – Structural Steel

- MnDOT LRFD 6.1
- Weathering Steel
- Spec
  - 3309 = Grade 50W
  - 3316 = HPS Grade 50W
  - 3317 = HPS Grade 70W
- Toughness requirement for Zone 3



Design – High Performance Steel (HPS)

- MnDOT Spec 3317 (HPS 70W)
- Can be economical when used as:
  - Bottom flange in positive moment regions
  - Both flanges in negative moment regions
- Cost of material
  - Comparable by weight for thickness < 2”
  - Limited plate lengths available (50’ to 55’)
- Before use, check with
  - MnDOT Project Manager
  - NSBA or Fabricators

Design – High Performance Steel

- Goal = Logical use of 70 ksi steel
  - Why:
    - Fabrication requirements
    - Availability
    - Cost
- Minimize number of plate thickness
- Consider transition at field splices
  - Metallurgical issues
  - CJP welds limited

Design – Fracture Critical

- Non-redundant structures only
- Limits
  - Fabricators certified
  - Available shifts due to inspector
- Increases cost

- Specify on unique structures?
  - Not preferred!
  - Belief = Stricter material testing results in an “elite material”
  - Reality = Elite material is HPS

Design – Area 'A'

- Composite design for full length of bridge.
- MnDOT LRFD 6.2

CHANGE IN TABLE TEXT

Design – Diaphragms

Straight & Slightly Curved

- MnDOT LRFD 6.2
- Secondary Members
- Detail B407
- Unbraced compression flange

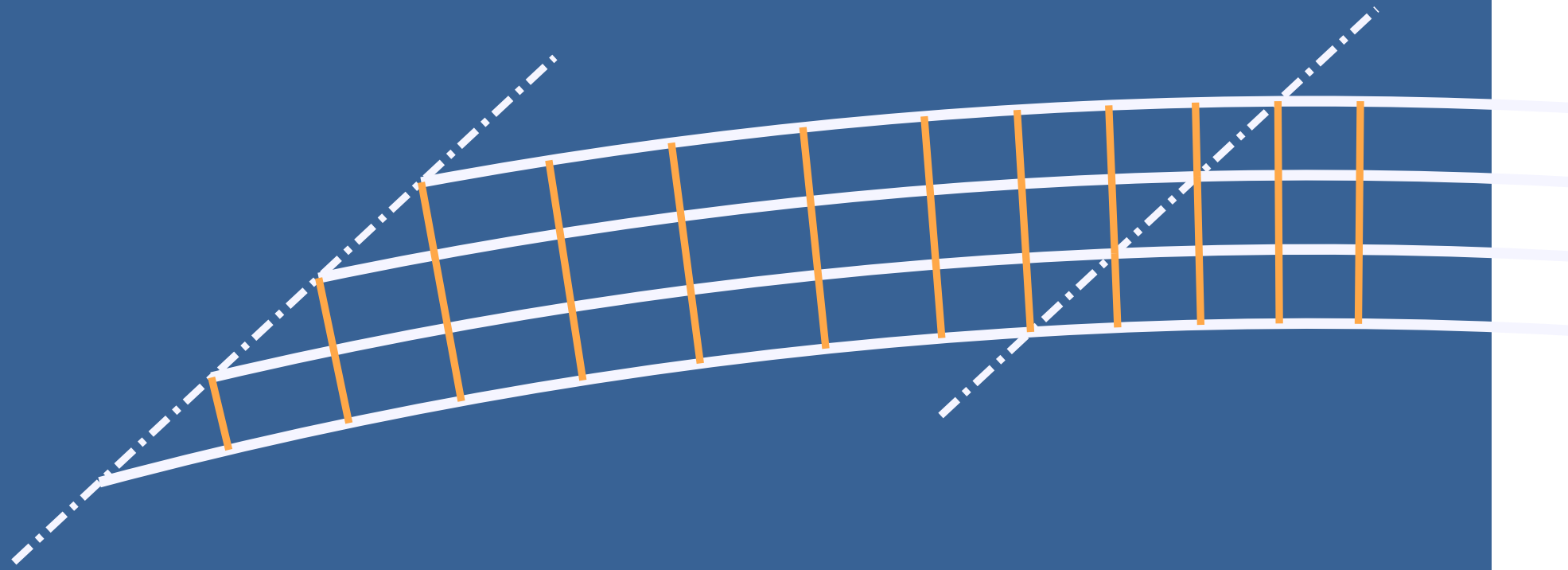
Complex & Curved

- MnDOT LRFD 6.6
- Primary load members
- Detail B408 or B402
- Lateral flange bending and structure stiffness

MAX SPACING	
(+M) ≈ 25’ to 30’ (-M) ≈ 15’ to 20’	Lesser of: Radius/10 25’ (MnDOT)

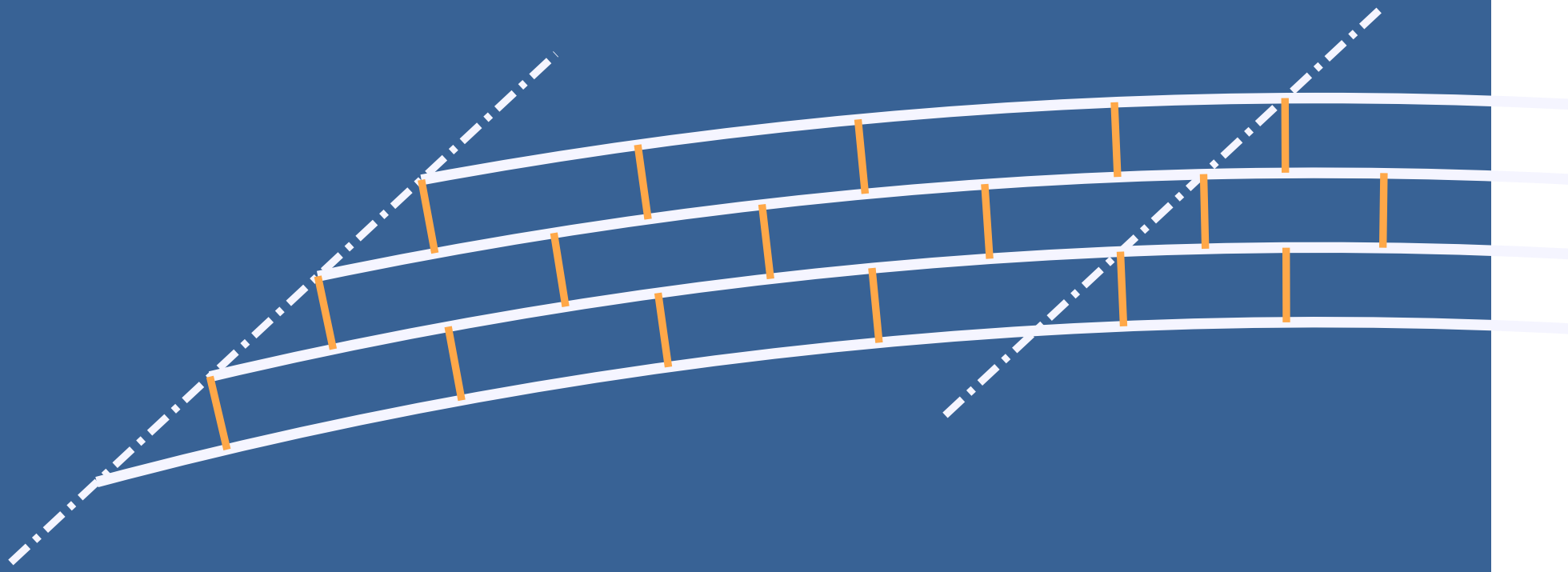
Design – Diaphragms

Continuous Framing Arrangement



Design – Diaphragms

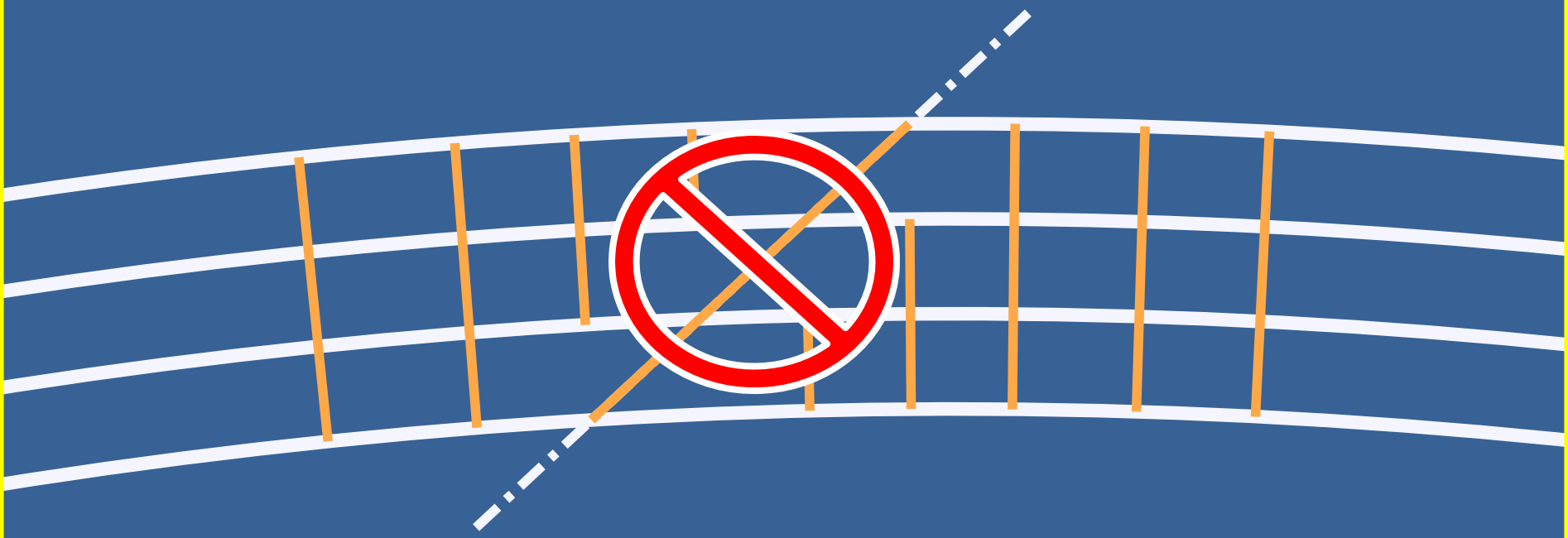
Discontinuous Framing Arrangement



CHANGE IN SLIDE ORDER

Design – Diaphragms

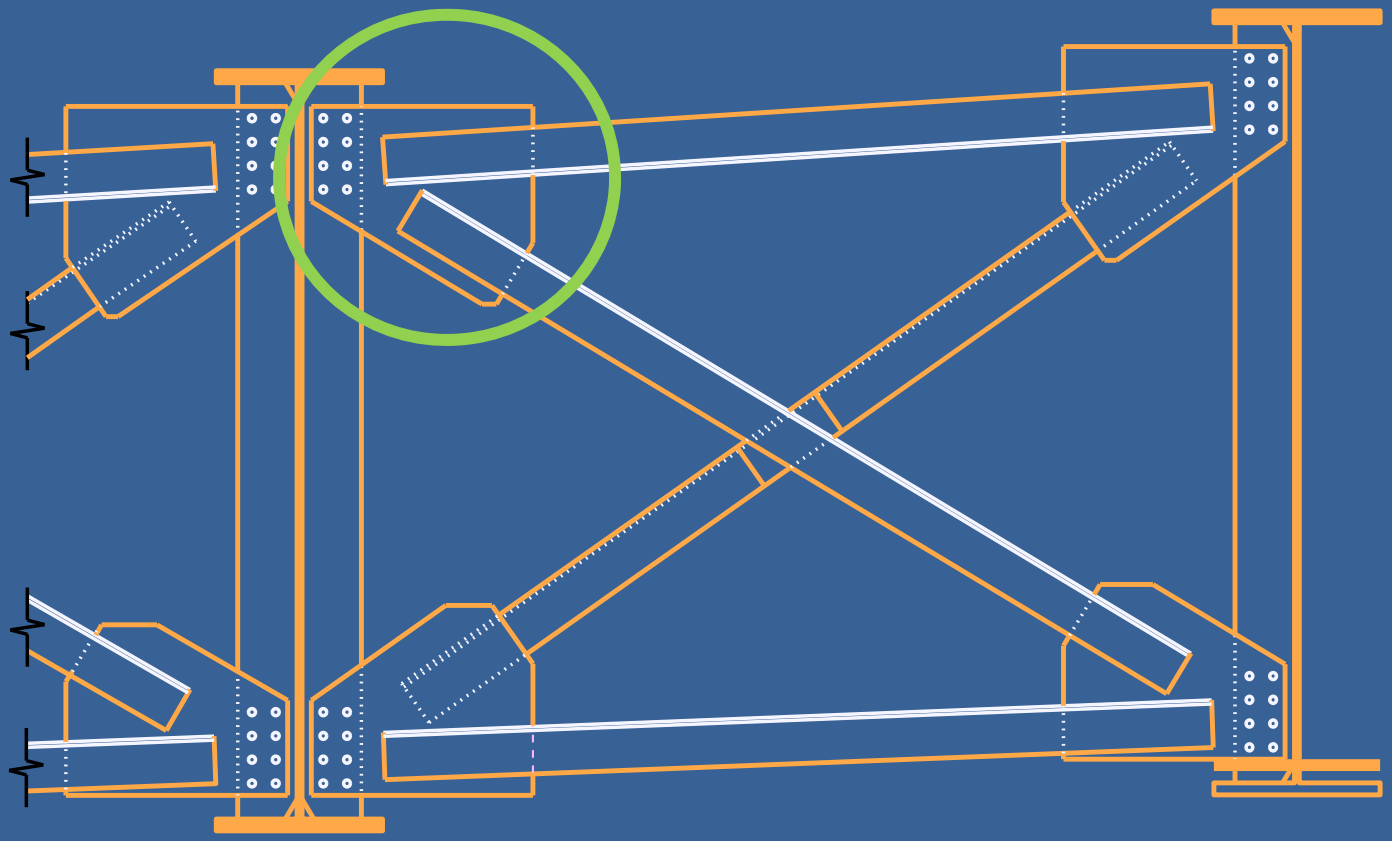
Not skewed over piers with θ > 20°



CHANGE IN SLIDE TEXT & IMAGE

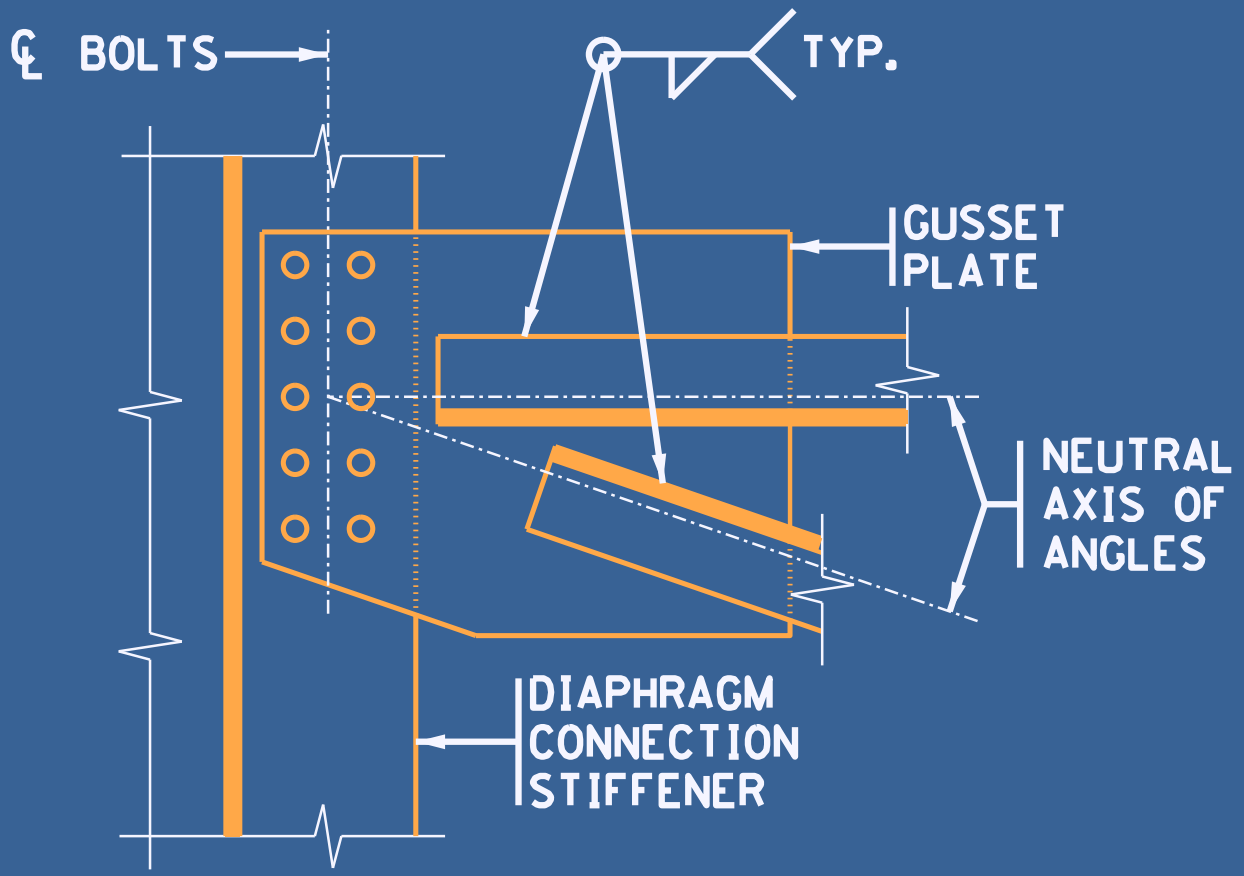
Design – Diaphragms

- Detail to accommodate cross-slope
- Connections

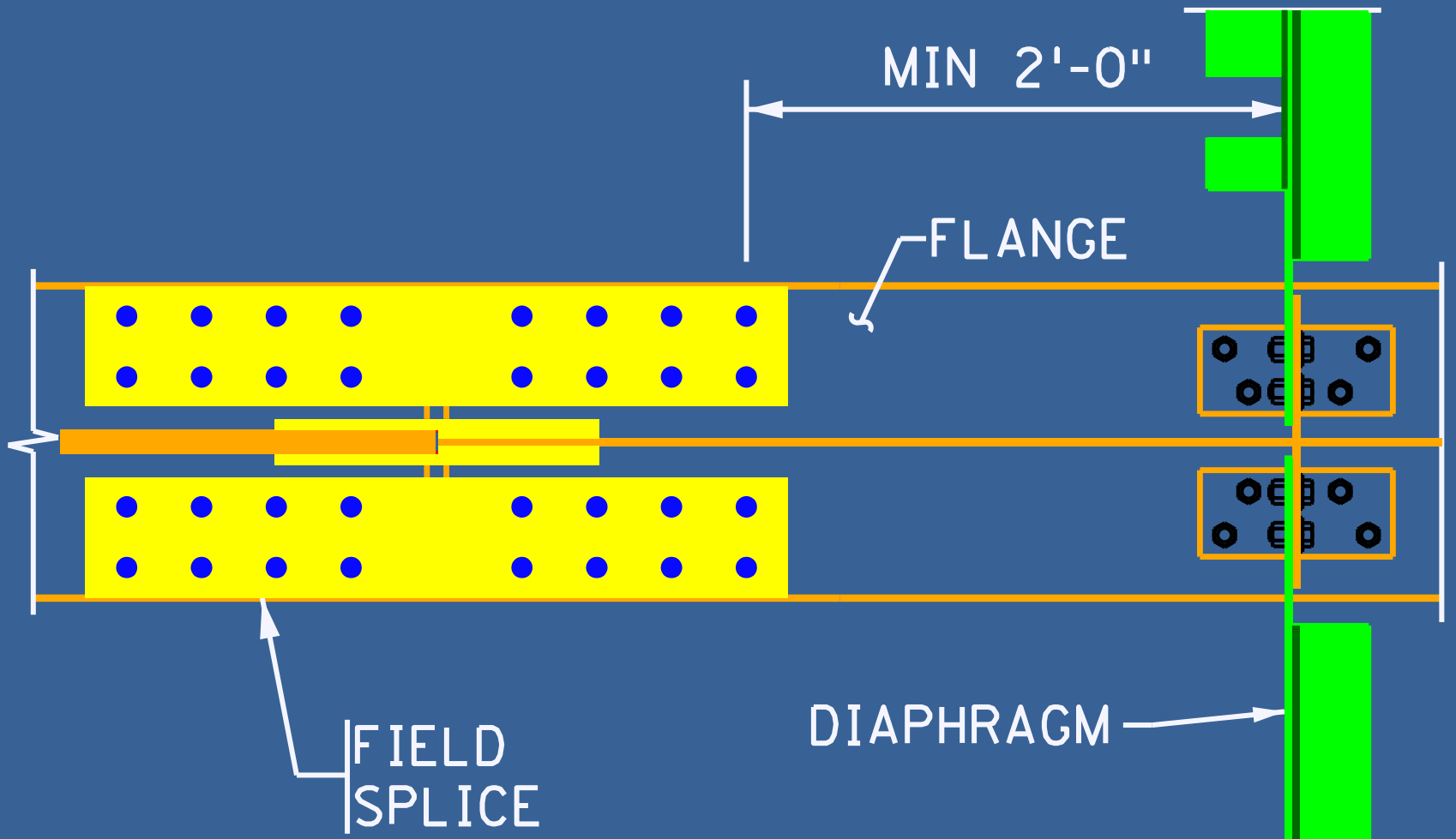


Design – Diaphragms

- Welded connections – All around welds
- Bolted connections – Gusset to Stiffener



Design – Diaphragms

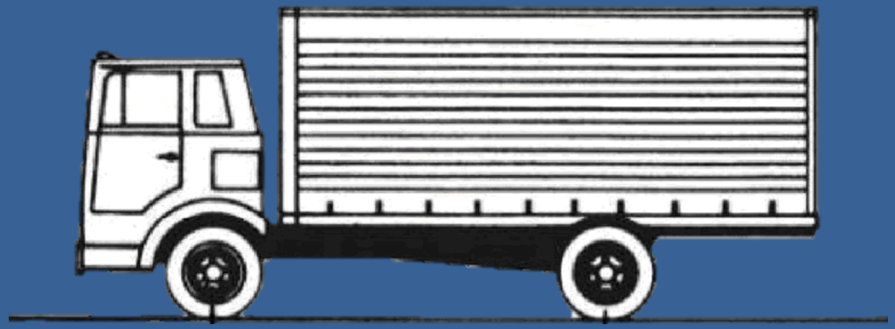


Design – Dead Loads

- Steel Weight Estimates
  - 15% for Prelim. Design Only (MnDOT LRFD 6.3)
    - Estimates “all” accessories
  - 1.5% for Quantities Only (MnDOT LRFD 6.2)
    - Beam only => To account for welds & bolts
  - 2% to 5% for Rating Only
    - Welds, splices, bolts, connection plates, etc…
  - Components (MnDOT LRFD 6.2)
  - Distribution

Design – Live Loads

- MnDOT LRFD 4.2.2.1
  - Skew effects distribution of live load
  - MnDOT deviates from AASHTO 4.6.2.2.2e
    - Do not reduce Moment
  - MnDOT adheres to AASHTO 4.6.2.2.3c
    - Magnify Shears and Reactions



Design – Live Loads

- Memo To Designers 2005-01
  - For continuous spans
  - Deviation for moment from AASHTO 3.6.1.3.1
  - Increase HL-93 double truck effect from when longest span:
    - L_{span} < 100ft — See AASHTO (90%)
    - 100ft ≤ L_{span} ≤ 200ft — [90 + (L_{span} – 100) x 0.2]%
    - 200ft < L_{span} — 110%
  - Applies to Moment and Reaction
  - Purpose – Ensures load ratings are acceptable

Design – Load Modifiers

- Load Modifiers (η)
  - MnDOT LRFD Table 3.2.1
  - Multiple criteria
  - Applies to *entire* superstructure design

Design – Analysis

- What level is needed?
  - Straight
  - Skews
  - Curves
  - Bifurcations or Splays

- Downstream Consequences?
  - Line (aka Special) vs. Full Assembly
  - Differential Deflections
  - Erection Issues
  - Rating Issues

Design – Analysis

- MnDOT & AASHTO Bridge Design Manual

- Methods of Analysis
  - NCHRP 12-79
  - Line Girder
  - 2D
    - Grillage
    - Plate & Eccentric Beam
    - V-Load *(Gut-Check)*
  - 3D Finite Element Analysis

Design – Analysis

- Neglect of Curvature
- AASHTO 4.6.1.2.4
  - ☑ Eccentricity of segment between nodes < 2.5% of segment length
  - ☑ Concentric girders
  - ☑ Skews from radial ≤ 10°
  - ☑ Similar girder stiffnesses
  - ☑ $\frac{Arc\ Length}{Girder\ Radius} < 0.06\ radians$
    - ➢ See AASTHO for arc length definition

Fabrication

- Common Misconception (aka “Rules of Thumb”)
  - Lightest Girder = Cheapest Girder
- Reality (Currently)
  - Least Labor ≈ Least Cost
  - Use simple details

http://www.koike.com

Fabrication – Camber

- MnDOT LRFD 6.3.4
  - Match profile grade
  - Offset dead load deflections
- Residual Camber
  - For architectural reasons
  - Straight Girders
  - Curved Girders – no longer required

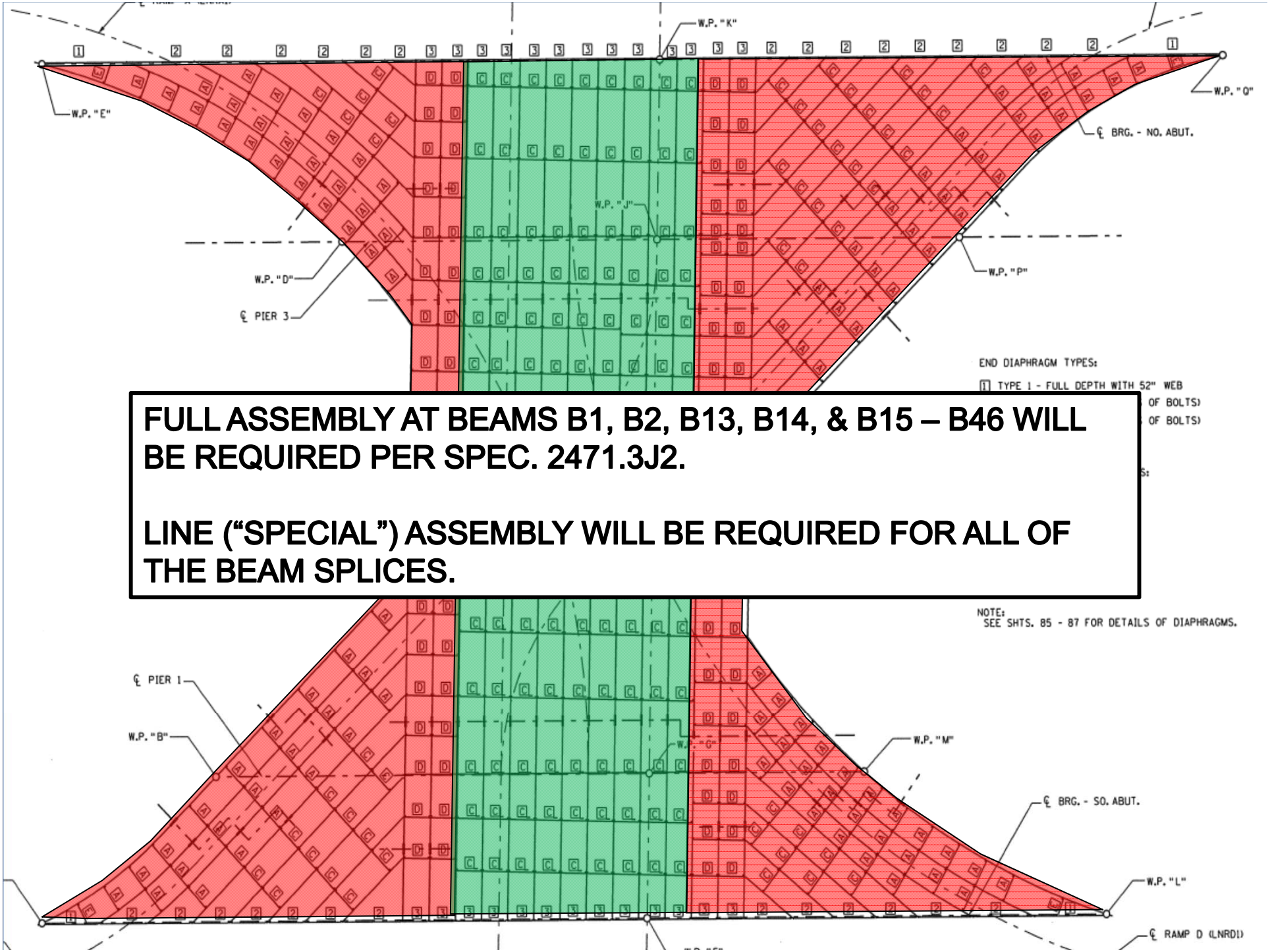
Fabrication – Assembly

Line Assembly (2471.3J1)

- aka “Special” Assembly
- Oversized bolt holes
- Detail diaphragms for cross-slope

Full Assembly (2471.3J2)

- Standard bolt holes
- Girders drilled in “No-Load Condition”
- Limit area required when possible
- Beam rollover


W.P. "K"
W.P. "E"
W.P. "Q"
℄ BRG. - NO. ABUT.
W.P. "J"
W.P. "D"
W.P. "P"
℄ PIER 3
END DIAPHRAGM TYPES:
[1] TYPE 1 - FULL DEPTH WITH 52" WEB
OF BOLTS)
OF BOLTS)
FULL ASSEMBLY AT BEAMS B1, B2, B13, B14, & B15 – B46 WILL BE REQUIRED PER SPEC. 2471.3J2.
LINE ("SPECIAL") ASSEMBLY WILL BE REQUIRED FOR ALL OF THE BEAM SPLICES.
NOTE:
SEE SHTS. 85 - 87 FOR DETAILS OF DIAPHRAGMS.
℄ PIER 1
W.P. "B"
W.P. "G"
W.P. "M"
℄ BRG. - SO. ABUT.
W.P. "L"
℄ RAMP D (LNRD1)

CHANGE IN SLIDE ORDER

Constructability

- Construction Assumptions

CHANGE IN TEXT

Constructability

ELEMENT	STRAIGHT	CURVED	
CHORD LENGTH	L ≤ 145ft	L ≤ 100ft	L ≤ 145ft
CHORD MIDORDINATE	n/a	3ft ≤ M ≤ 6ft	< 3ft
FLANGE WIDTH	$b_{fc} \geq {}^{L}/_{85}$	$b_{fc} + (2" \text{ to } 3") \geq {}^{L}/_{85}$	
SHIPPING HEIGHT	≤ 13'-6"		

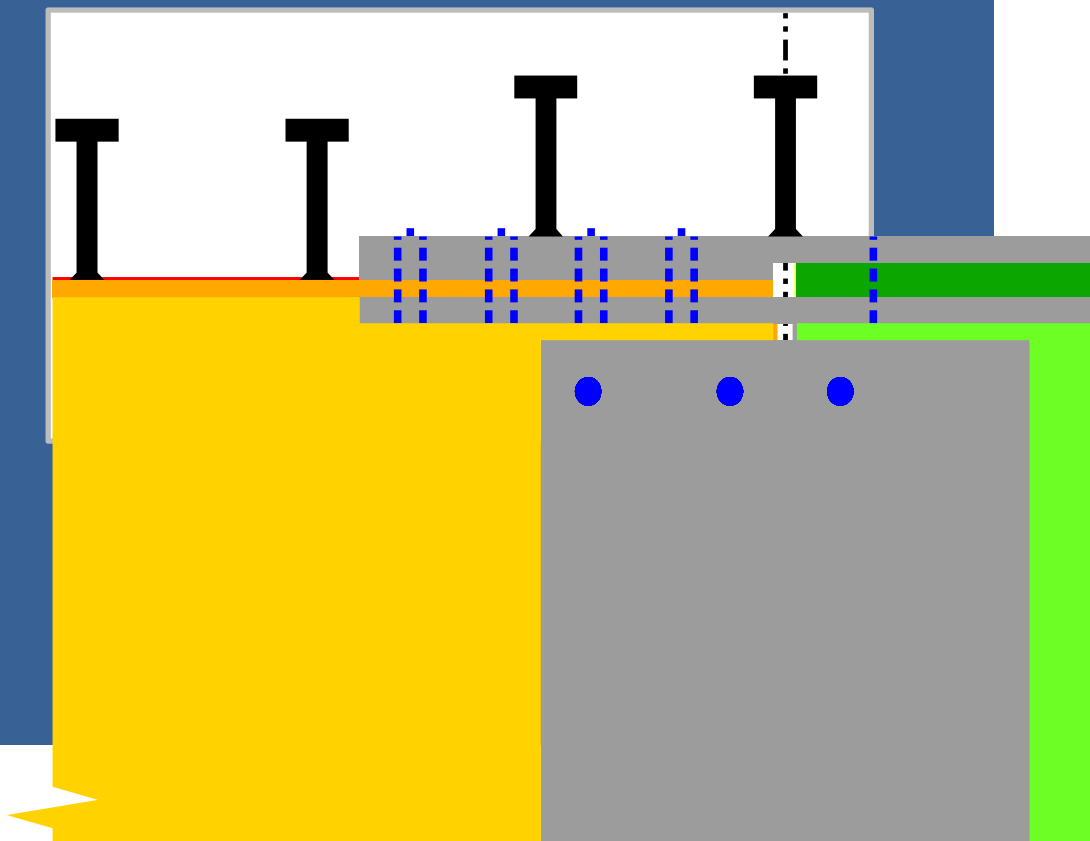
Constructability

Stool Heights

- Min. Stool = 1.5”

Shear Connectors

- 2” above deck bottom
- 3” below top of deck



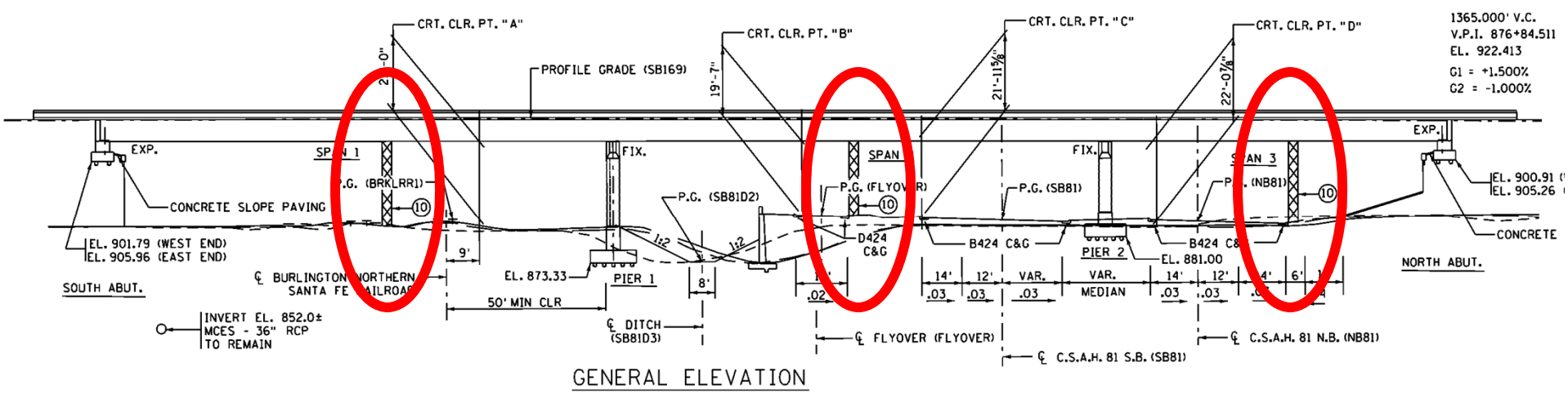
Constructability

Constructability

- Temporary Tie-Downs
  - Uplift at abutments
  - Global stability

Constructability

- Shoring Towers locations must be shown on GP&E plan sheets for MnDOT Projects



GENERAL ELEVATION

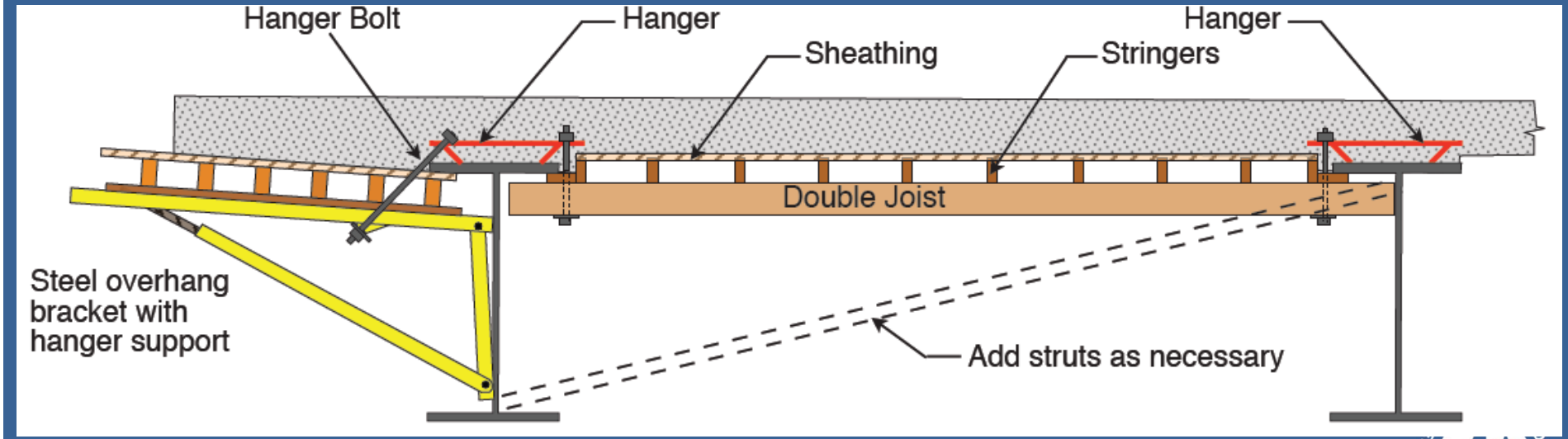
Constructability

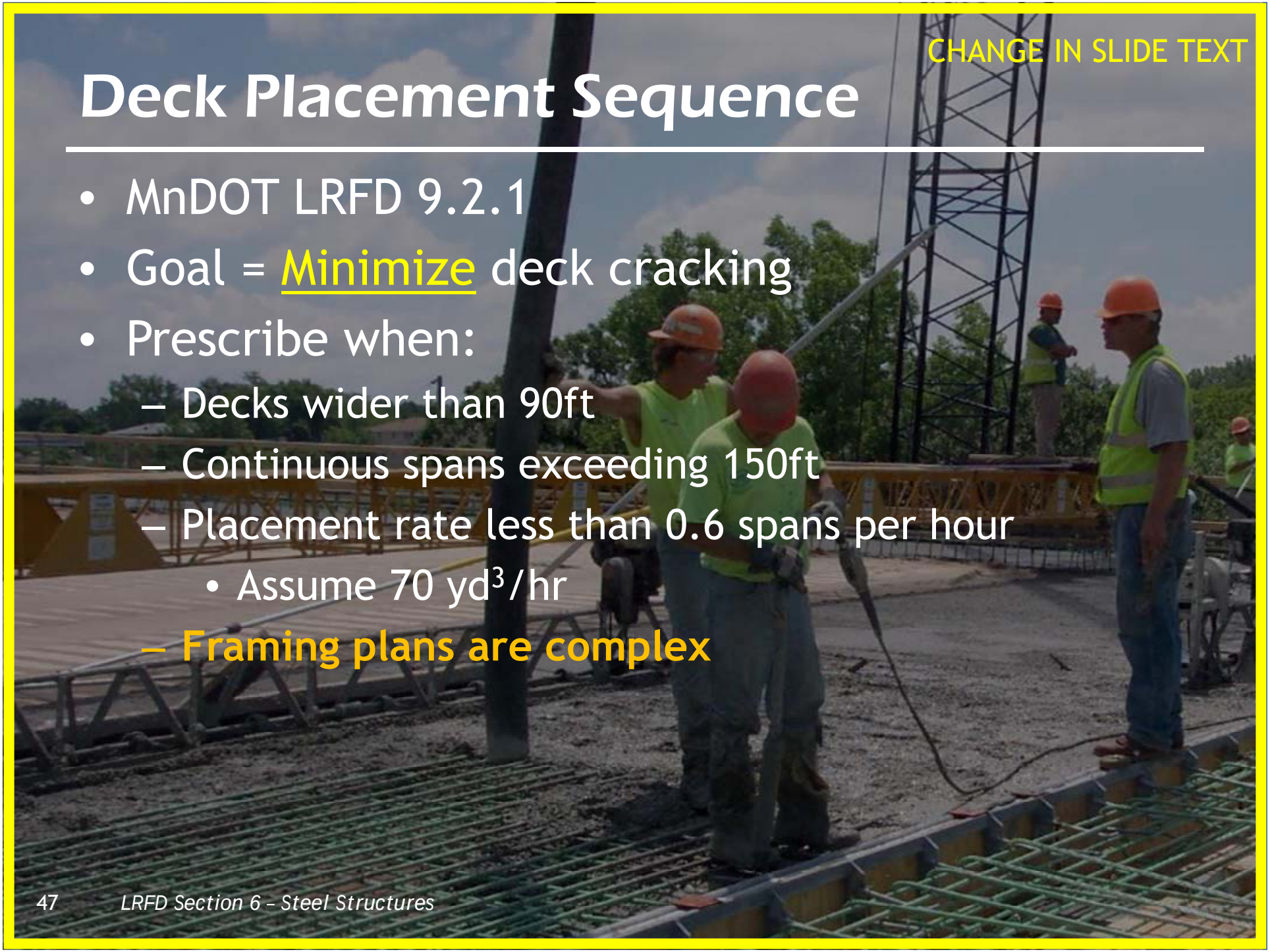
Constructability

- Shoring Towers required for:
  - *Stability*
    - Unless contractor's methods/calculations can prove otherwise
    - Minimizes locked-in stresses
  - *Geometry Control*
    - Ensures the quality of the final product

Constructability – Loads

- Dead loads
  - Formwork
  - Wet Concrete
  - Hardened Concrete
- Live loads
- Other Transient Loads
  - Wind
  - Water
  - ~~Seismic~~ <= Not in MN!
- Locked-In Stresses





CHANGE IN SLIDE TEXT

Deck Placement Sequence

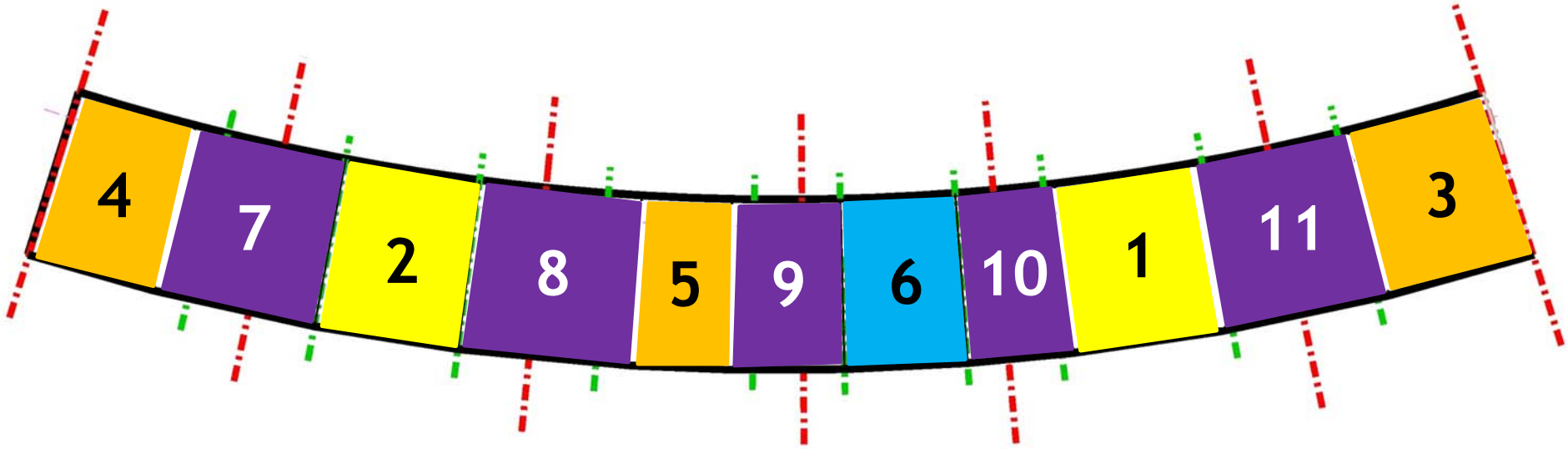
- MnDOT LRFD 9.2.1
- Goal = Minimize deck cracking
- Prescribe when:
  - Decks wider than 90ft
  - Continuous spans exceeding 150ft
  - Placement rate less than 0.6 spans per hour
    - Assume 70 yd^3/hr
  - **Framing plans are complex**

Deck Placement Sequence

- Dependent on length of spans
  - 150ft to 200ft Spans
  - Greater than 200ft
  - Unique Span Arrangement / Framing
- 72 hour waiting period between adjacent positive moment pours
- Min. Pour Rate

Deck Placement Sequence

- Positive Moments First
- End Spans & Short Positive Moment
- Negative Moments



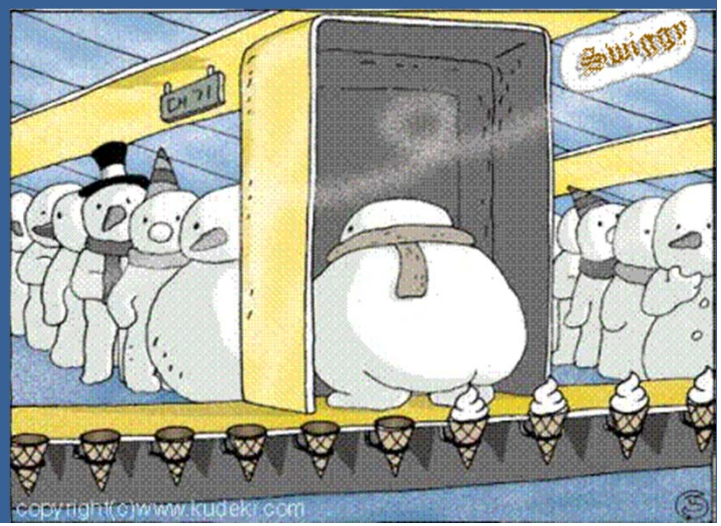
Deck Placement Sequence

- Beam Stresses
- Deck Stresses
- Uplift
- Deflection
- Camber

Software

Consider the geometry:

- Straight beam lines
- Concentric/non-concentric beam lines
- Large internal angles
- Changes in curvature mid-span
- Skewed abutments
- Bifurcation or splayed layout



Software

- Loads
  - Steel dead loads
  - Formwork and construction loads
  - Live load application
- Deck placement sequences
- Direction of global axis
- Fixity of beams and bearings
- User-defined commands
  - i.e. MDX includes “MnDOT Exceptions”

Detailing & Drafting

- Clear and concise details
- Dimension labels
- Significant figures
- Standard notes (MnDOT LRFD Appendix 2)
  - Assembly type
  - *Standard* vs. *Oversized* bolt holes
  - Well defined
  - Plan sheet location

Detailing & Drafting

- Sole Plate
  - Include in girder quantities
- Galvanized Type III Weathering Steel Bolts
  - Field Painted Bridges
- Weld Symbols
- Temperature
  - Include on plan sheets

Reviews – Please include

- Plan Sheets
  - Framing Plan
  - Cross-sections
  - Structural Steel Details
    - Beams
    - Diaphragms
    - Splices
    - Camber
  - Pour Sequence (when applicable)

Reviews – Please include

- Design Calculations
  - Code References!
  - Software Runs (digital is best)
  - Load assumptions and computations
  - Description of methodology for determining element sizes
  - Other assumptions
  - Tabulated results of iterations effecting design
  - Notes related to incomplete portion of the design

Questions

- Top
- Design
  - General
  - Plates
  - Diaphragms
  - Loads
  - Analysis
- Fabrication
- Constructability
- Deck Placement
- Software
- Detailing
- Reviews

Thank you for
your participation!