Prestressed Elements

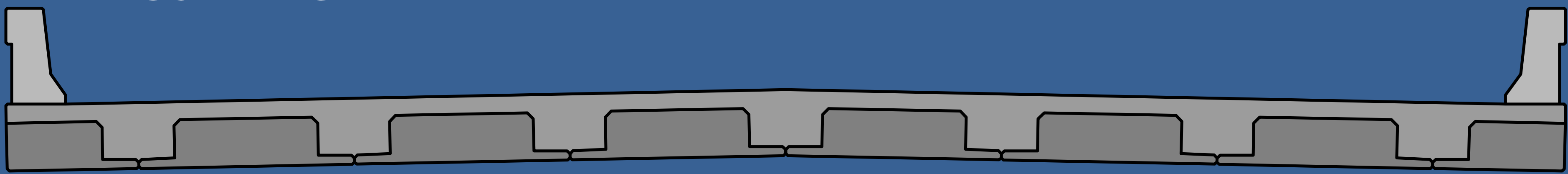
Ben Jilk
Bridge Design Engineer

Outline

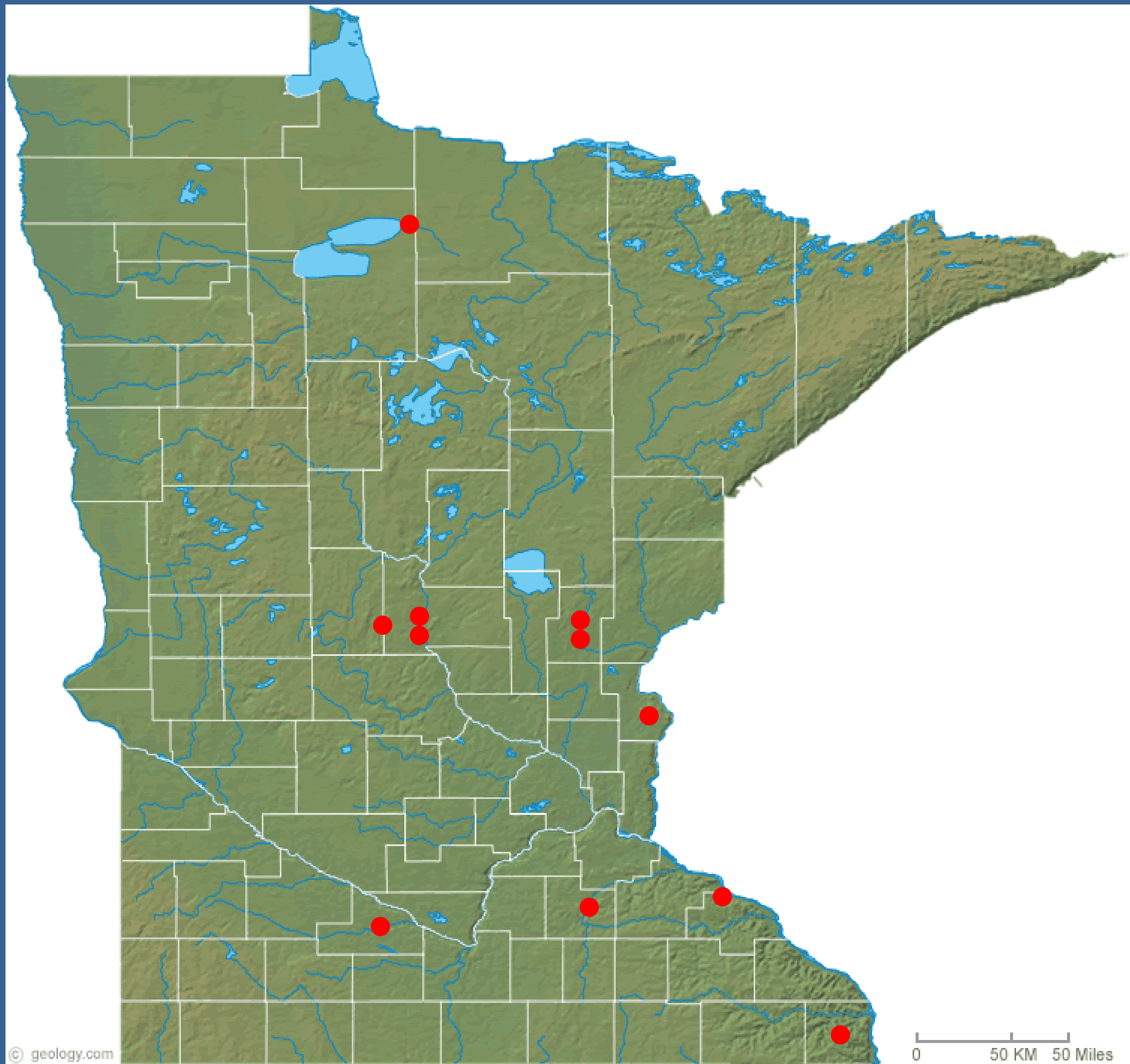
- Inverted tees
- New MW-shapes and archiving M-shapes
- Camber study
- Curved bridge design

Inverted Tees

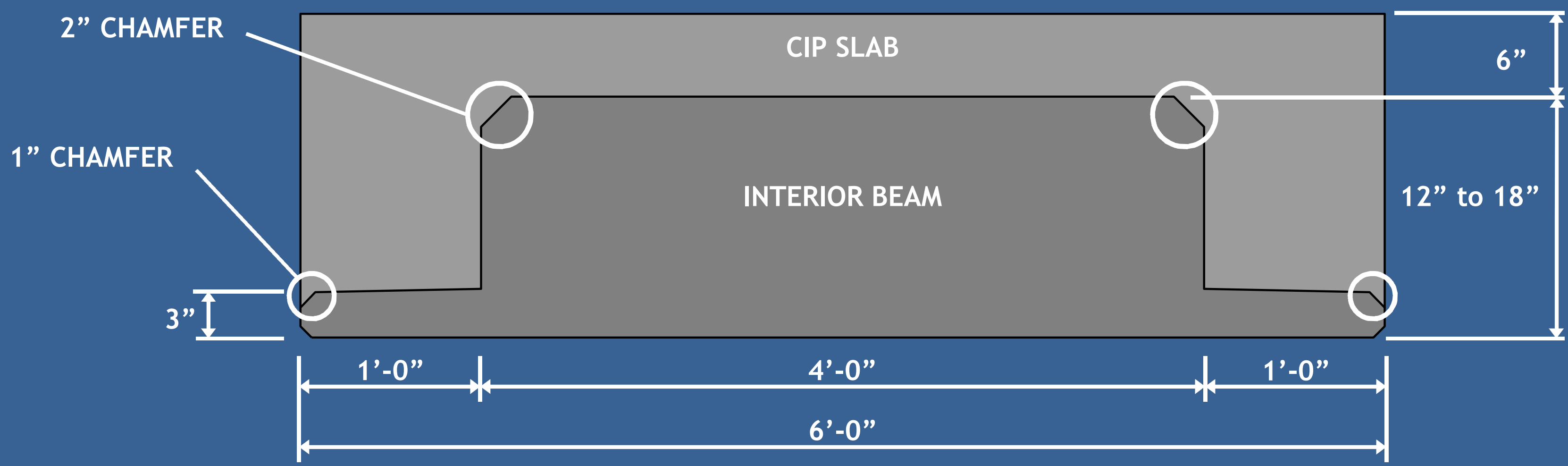
- Developed in 2004 as an alternative to slab span bridges
- Spans up to ≈45’
- Typically not used on skewed bridges
- Intended to speed up construction
- 4 generations built, 5th to be designed this summer

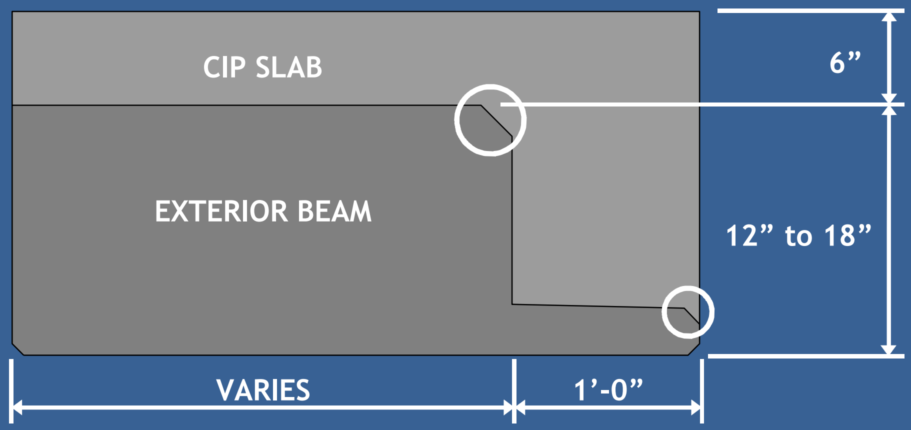


Inverted Tees - Locations

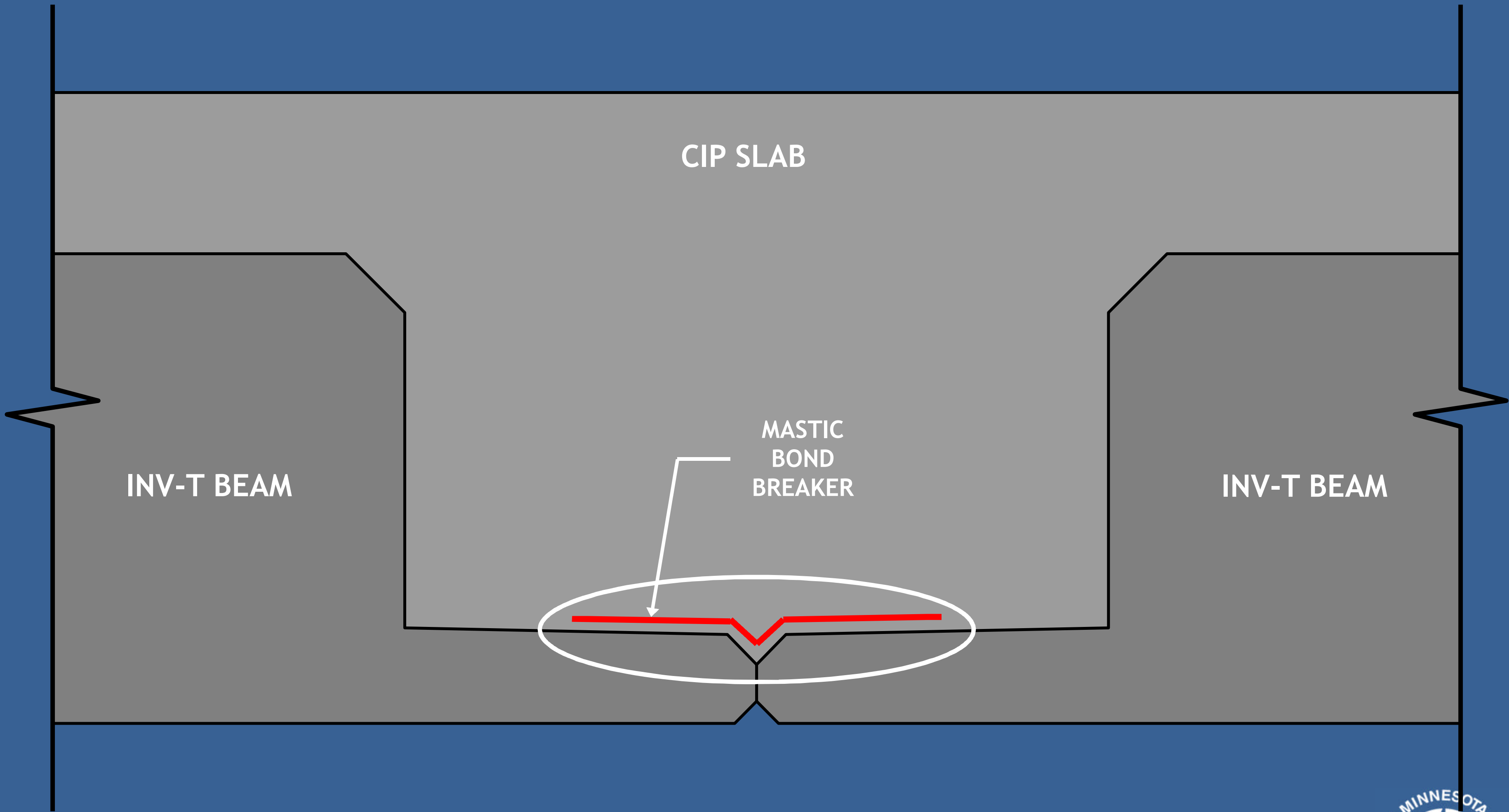


Inverted Tees - Geometry

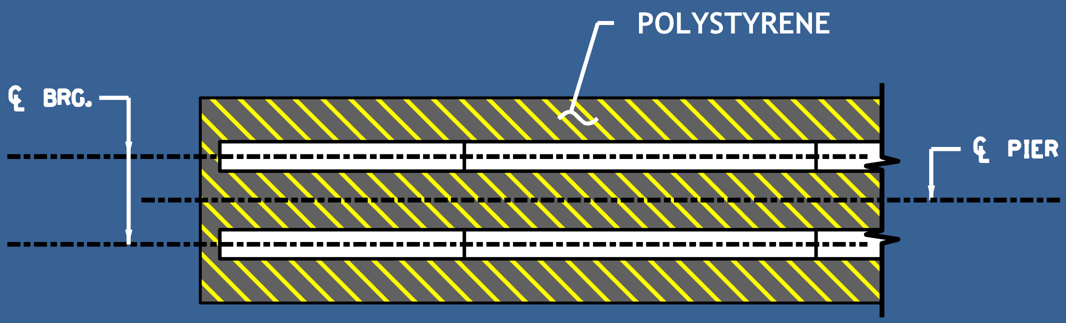




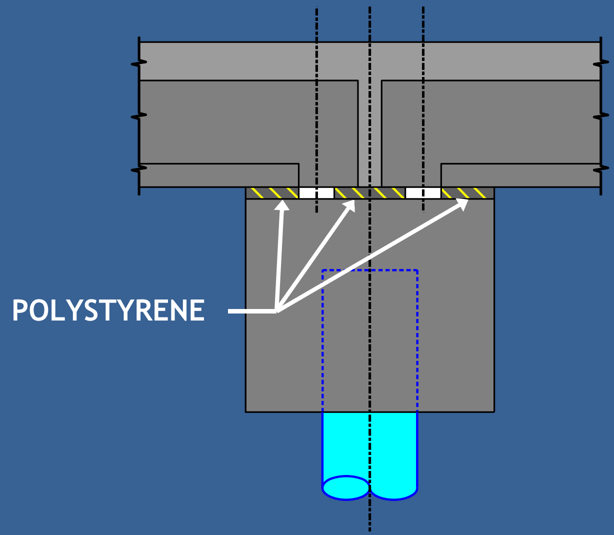
Inverted Tees - Geometry



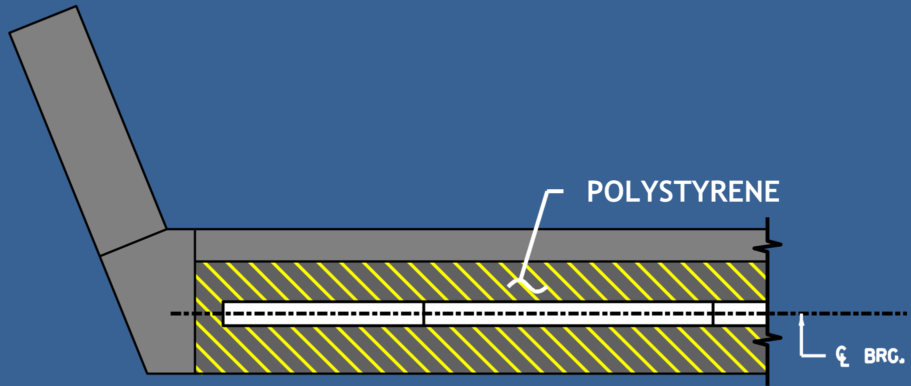
Inverted Tees



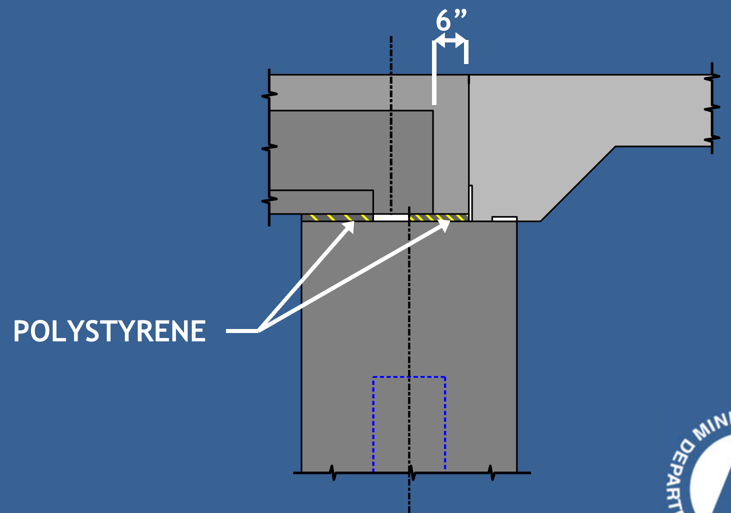
PIER



PIER



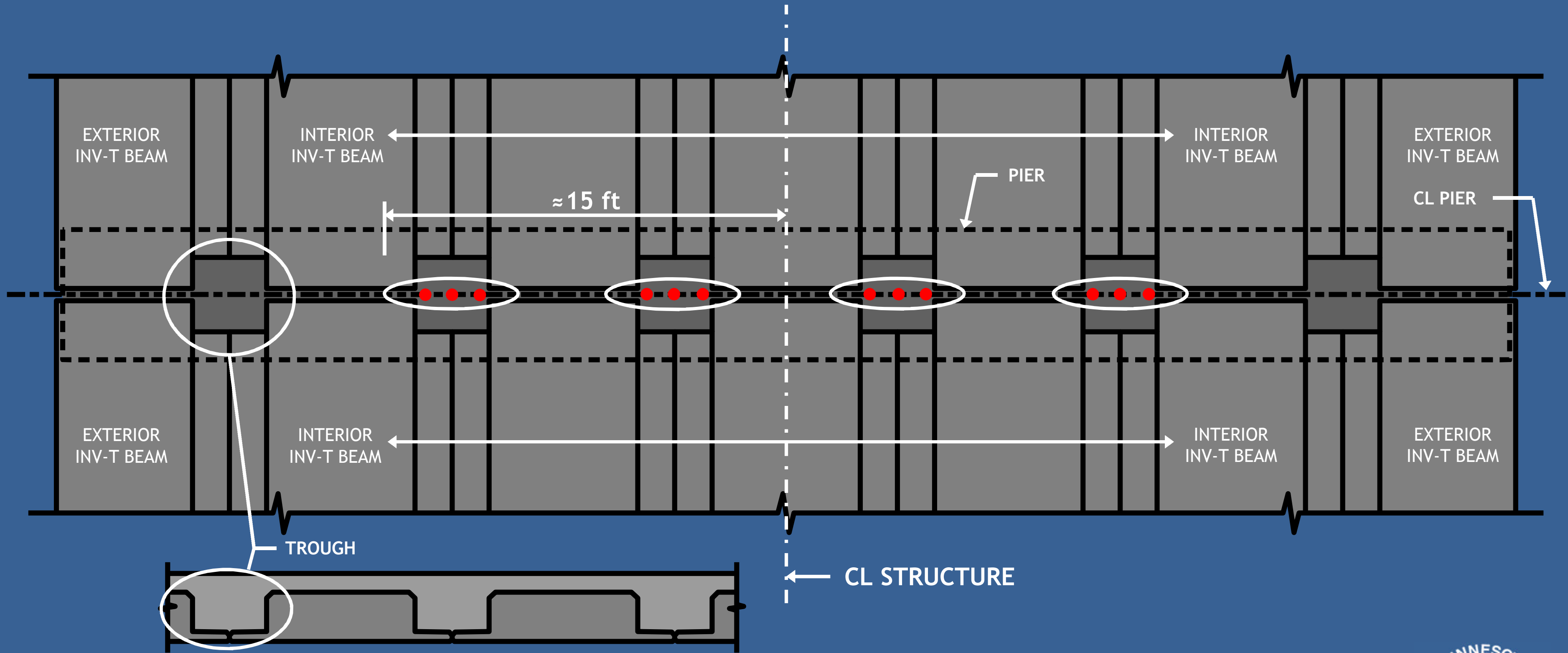
ABUTMENT



ABUTMENT

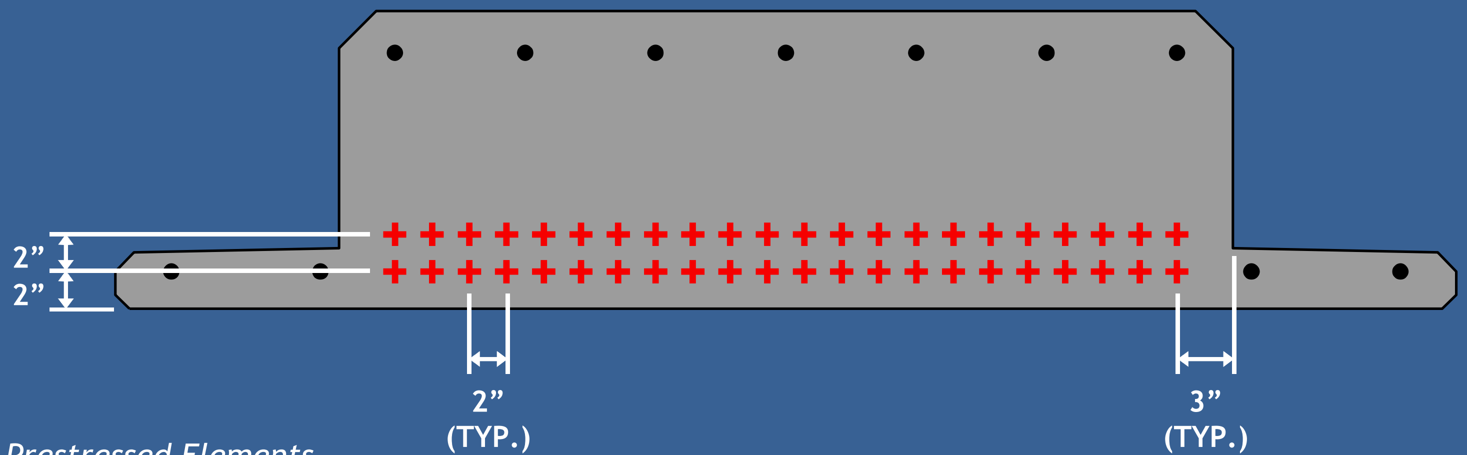
Inverted Tees

- Stainless steel
- Wrapped at piers, not abutments



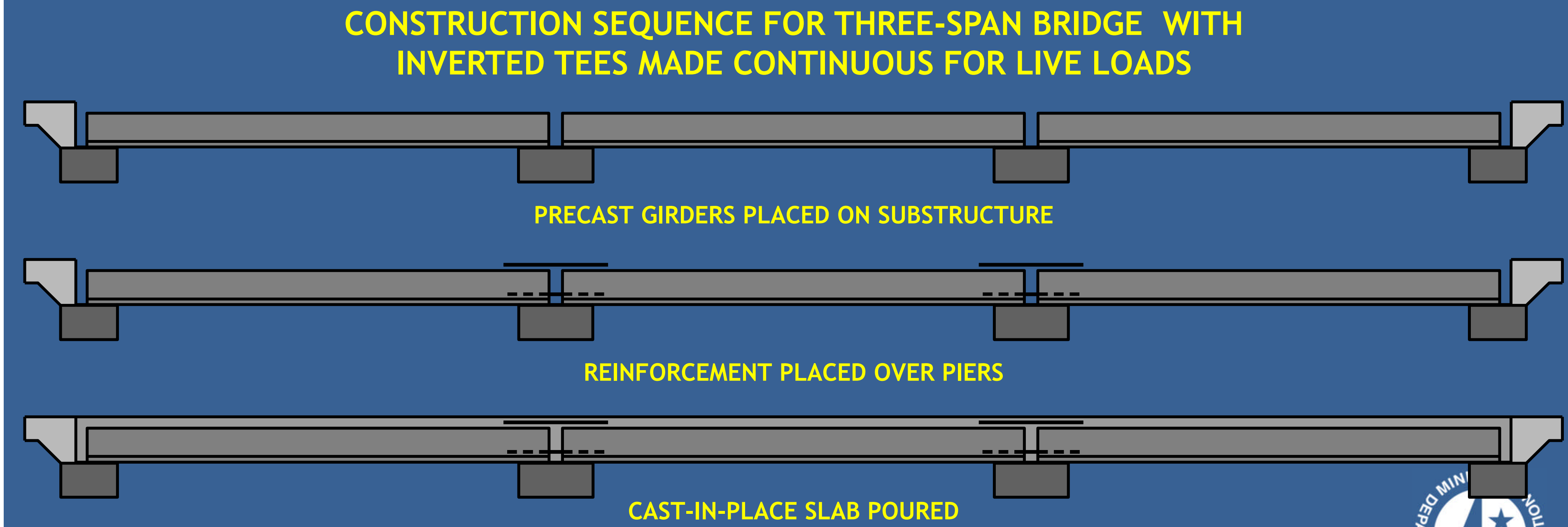
Inverted Tees - Materials

- Beam Concrete
  - f'_{ci} = 4 ksi
  - f'_{c} = 6 ksi
- Slab Concrete
  - f'_{c} = 4 ksi
- ½" diameter 7-wire low-relaxation strands



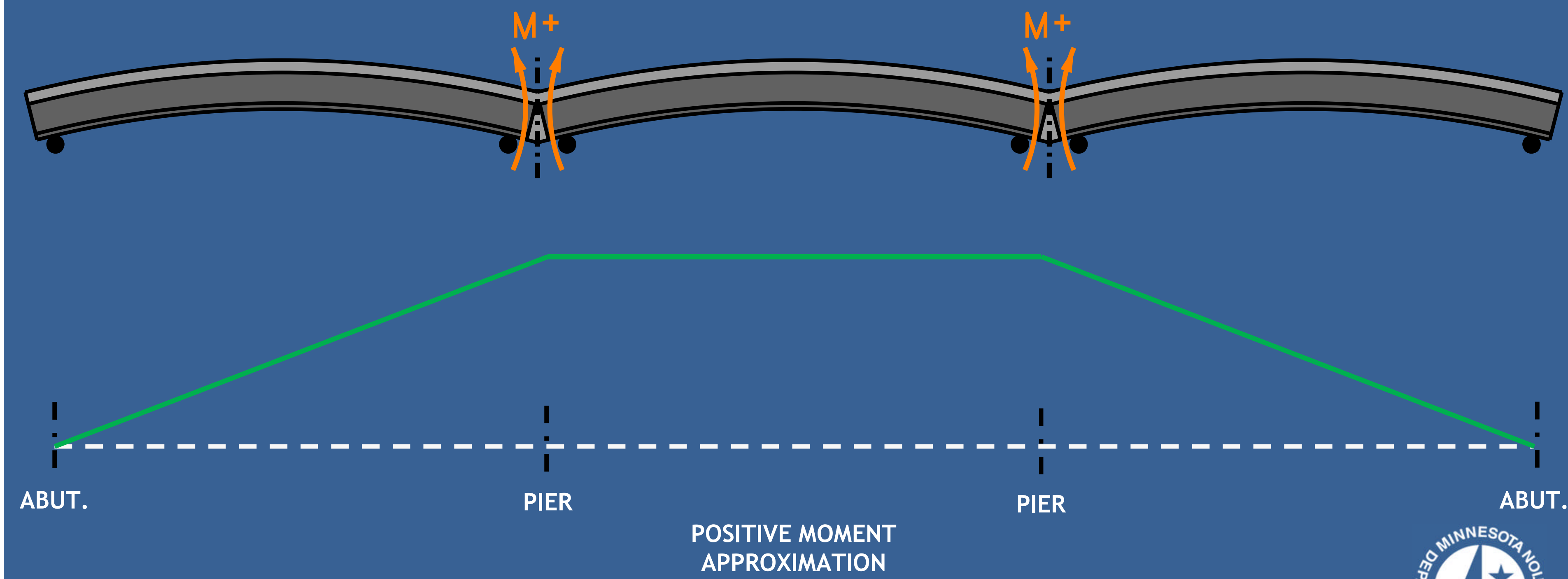
Inverted Tees – Design

- LLDF calculated assuming slab-type bridge
- Additional loads:
  - Restraint moment (time dependent)
  - Thermal gradient



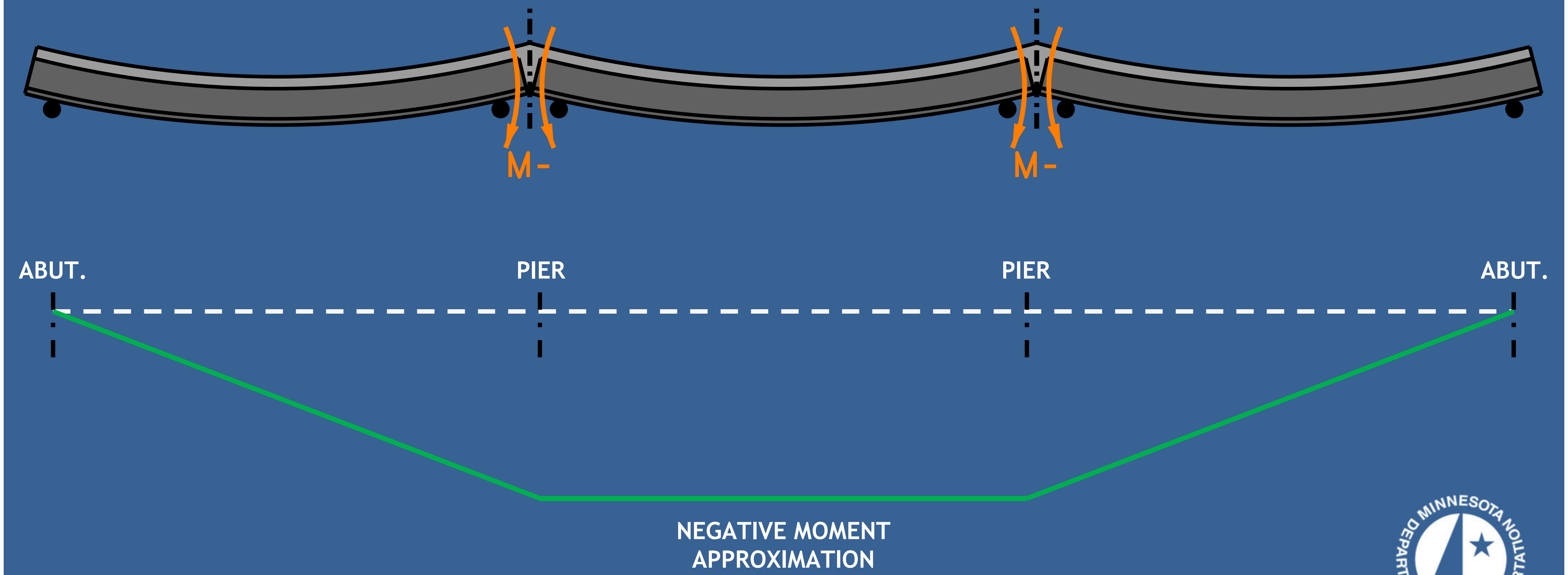
Inverted Tees - Design

- Positive restraint moments
  - Beam prestress creep
- Positive thermal gradient



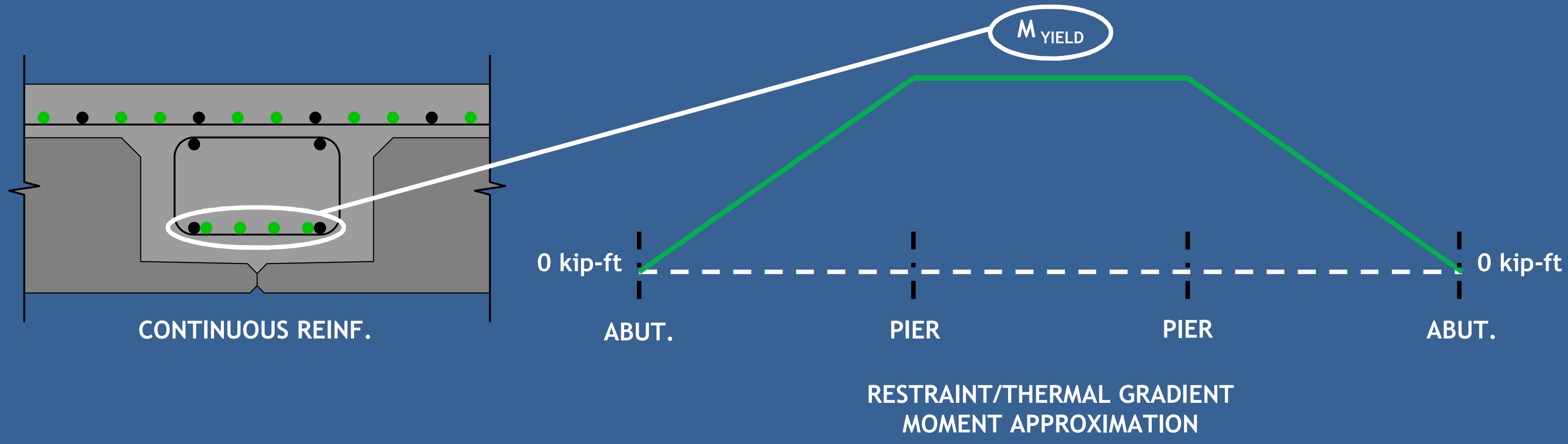
Inverted Tees - Design

- Negative restraint moments
  - Dead load creep (beam self-weight, CIP deck weight)
  - Deck shrinkage
- Negative thermal gradient



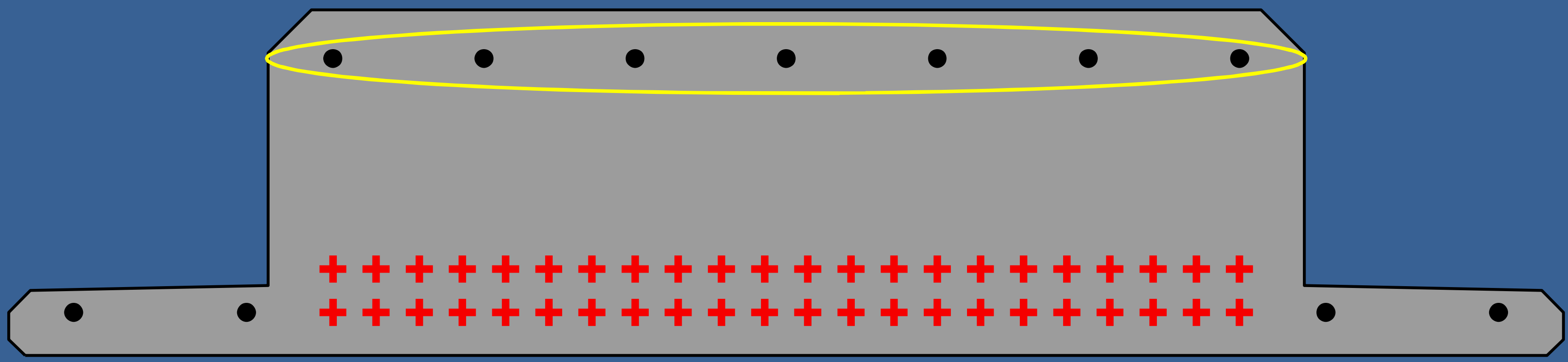
Inverted Tees – Design

- Designed as simple-span
- Restraint moments and thermal gradient included by taking yield moment of trough reinforcement continuous over the piers



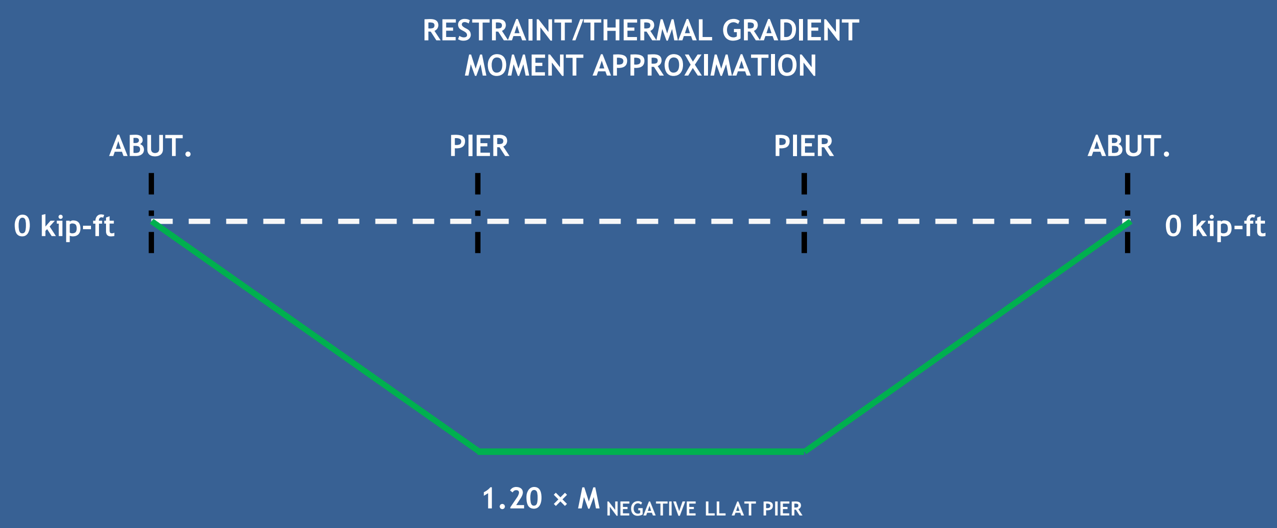
Inverted Tees – Beam Design

- Tension at release limited to $0.24\sqrt{f'_{ci}}$ rather than $0.0948\sqrt{f'_{ci}}$ or 200 psi used for typical prestressed beams



Inverted Tees – Slab Design

- Designed as continuous for loads applied after slab cures (barrier, FWS, LL)
- Restraint moments and thermal gradient included by applying a factor of 1.20 to the negative LL moment at the piers

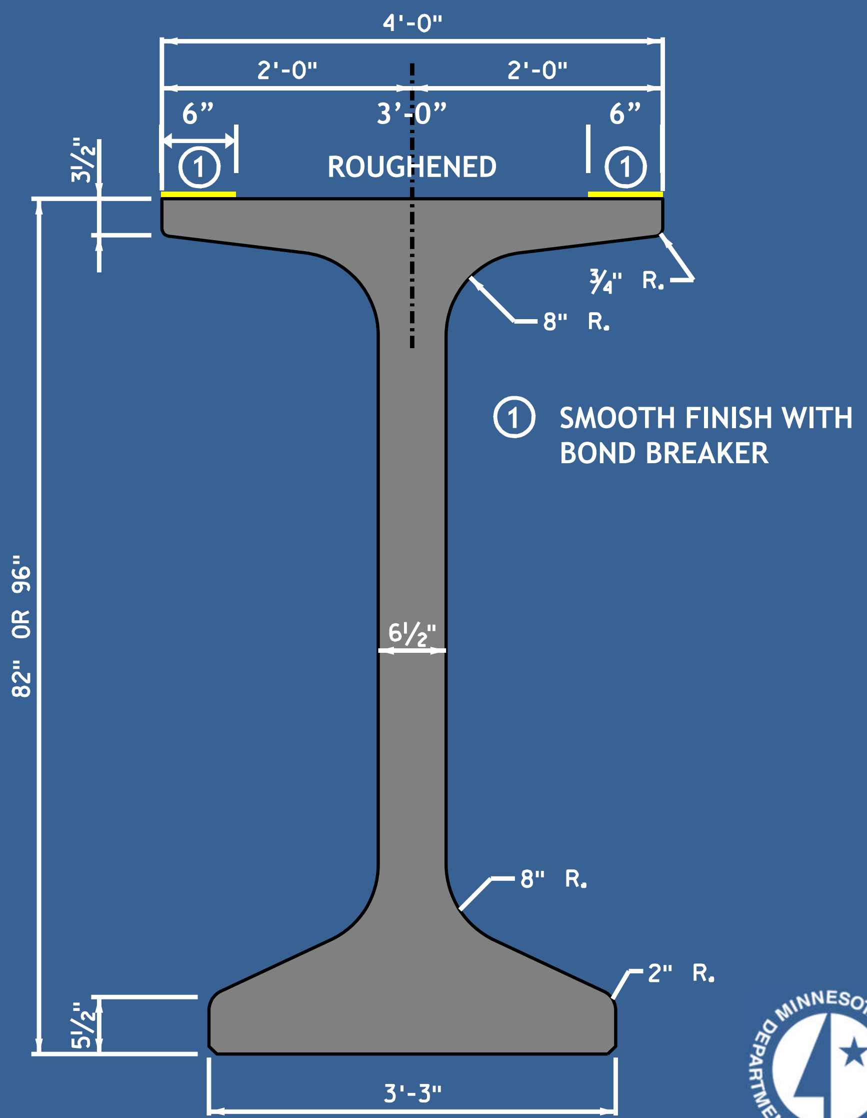


Inverted Tees

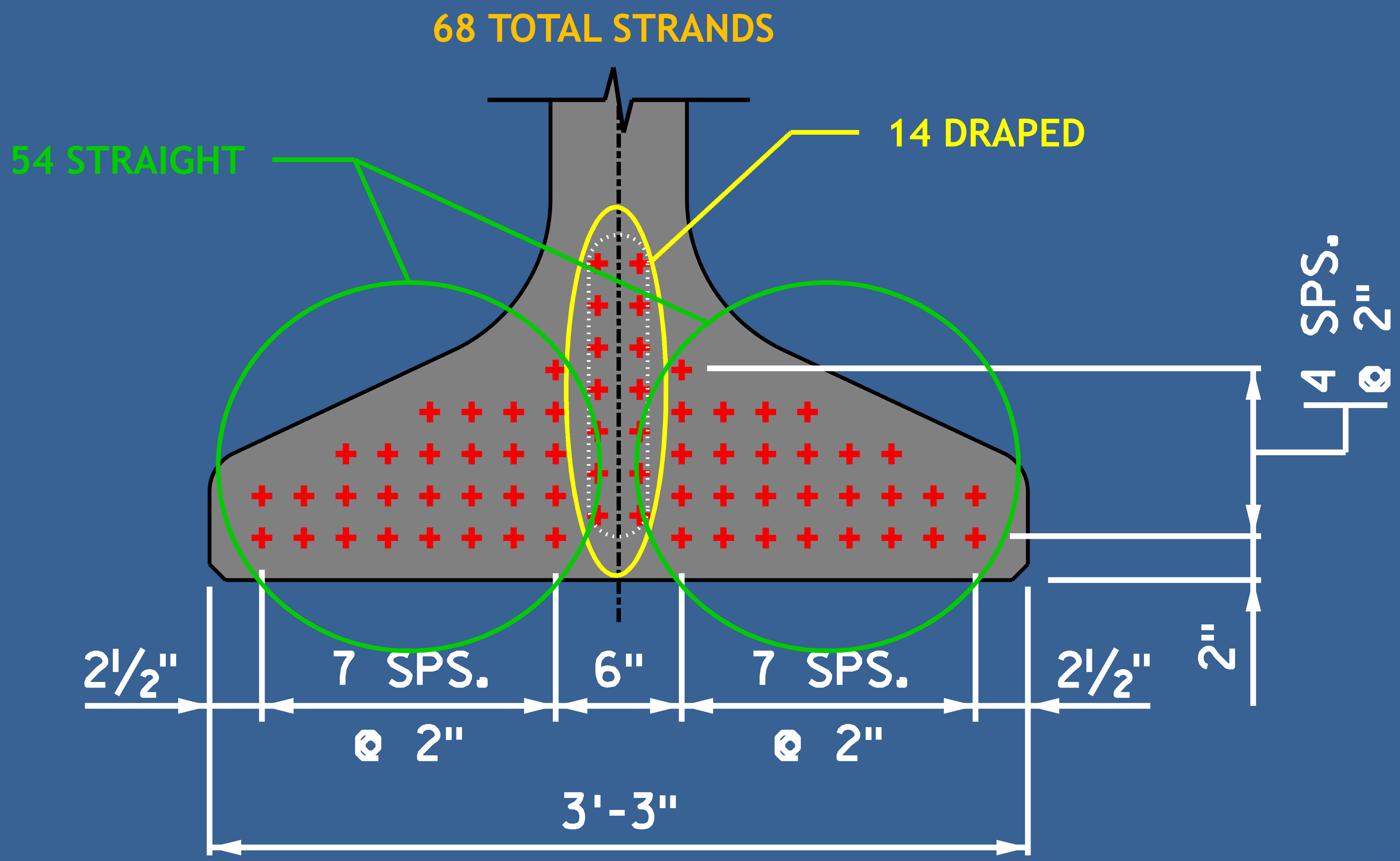
- MnDOT is currently in the process of developing guidelines for Inverted Tees which will be released once completed.

MW Shapes

- Goal to develop:
  - Beams that span farther than existing shapes OR
  - Beams that could be used at a wider spacing
- 82” and 96” MW Beams
- MnDOT Memo to Designers (2011-01), July 29, 2011

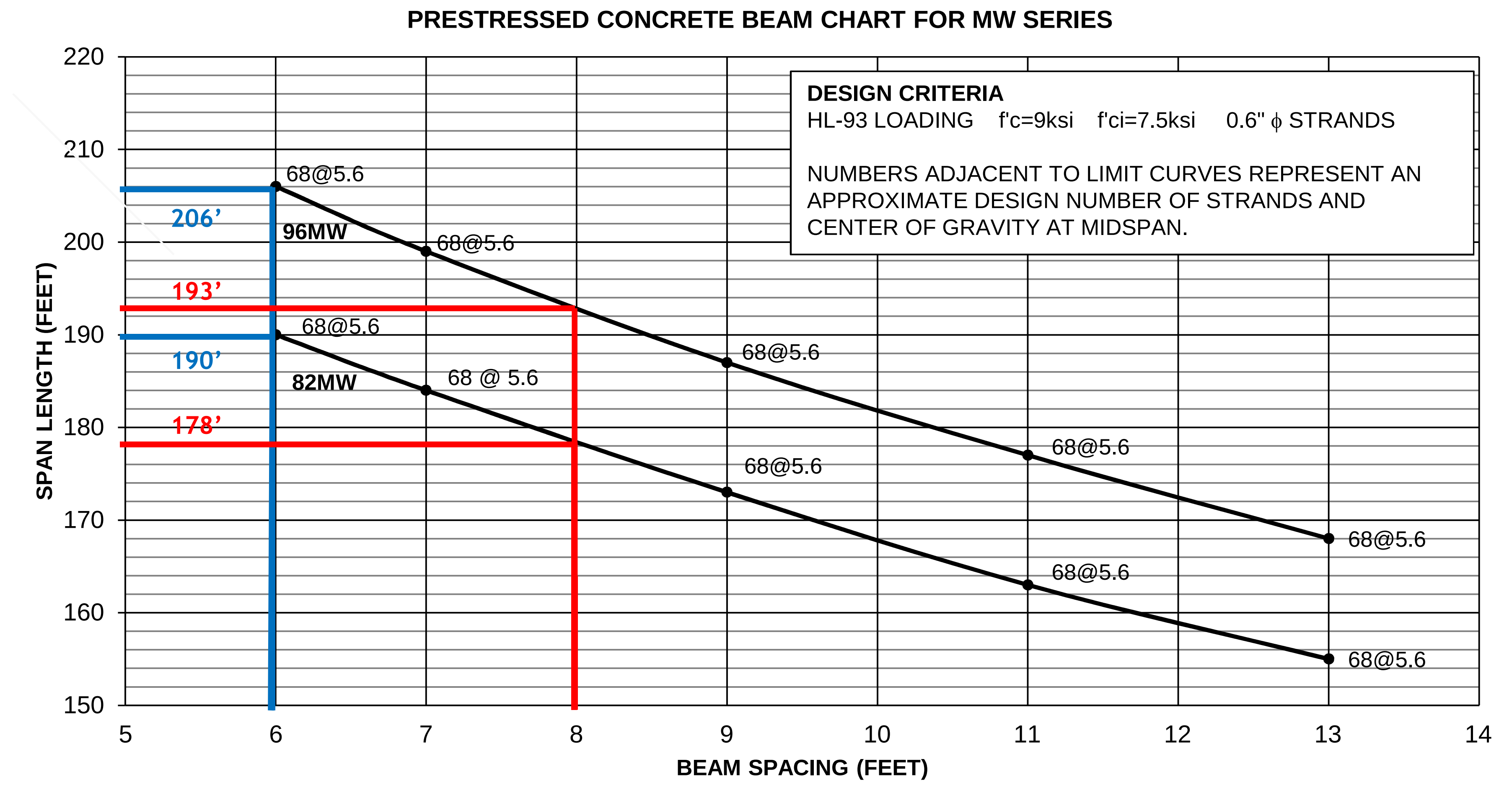


MW Shapes



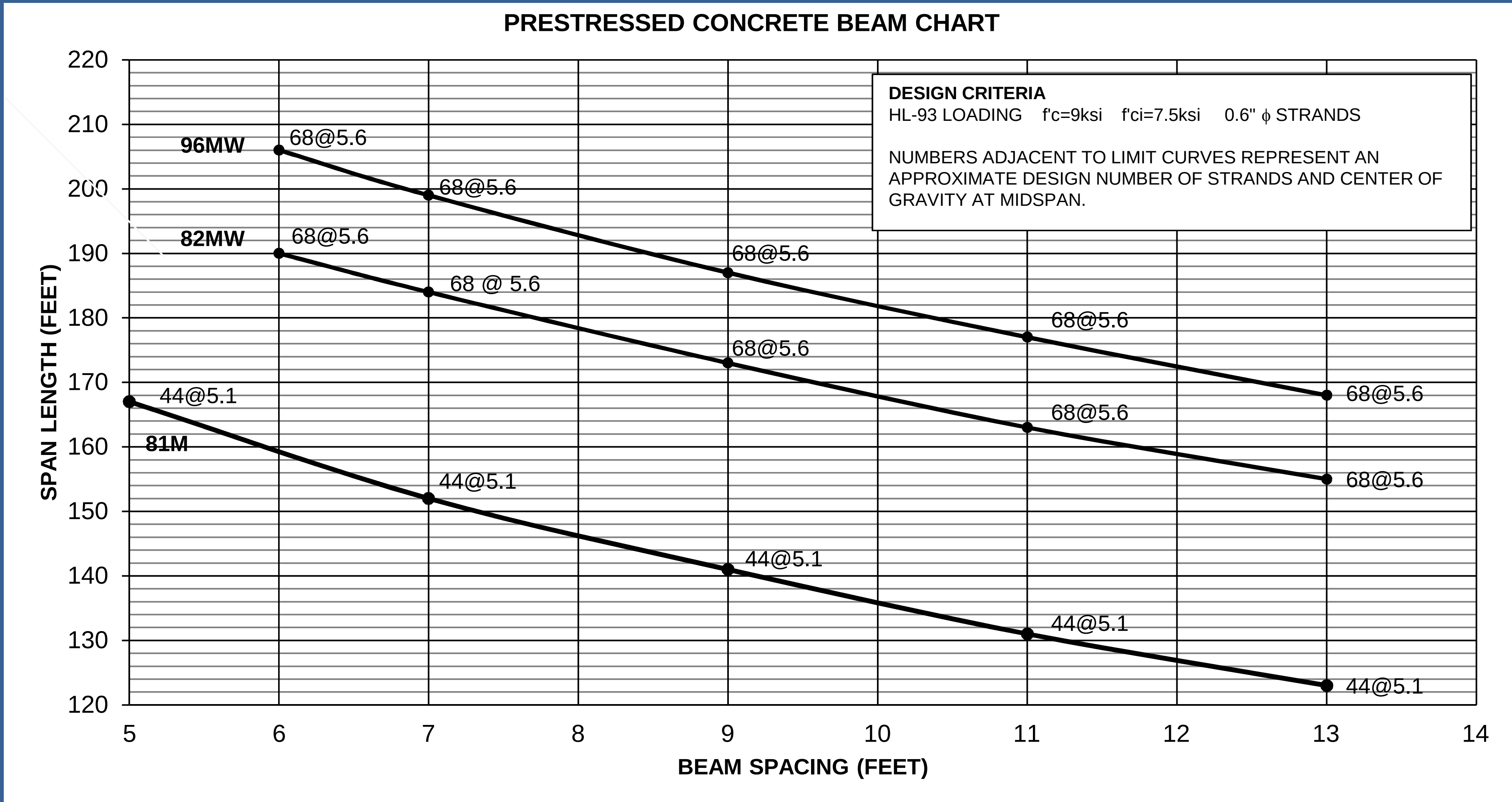
68 TOTAL STRANDS
54 STRAIGHT
14 DRAPED
4 SPS. @ 2"
2"
2½"
7 SPS. @ 2"
6"
7 SPS. @ 2"
2½"
3'-3"

MW Shapes

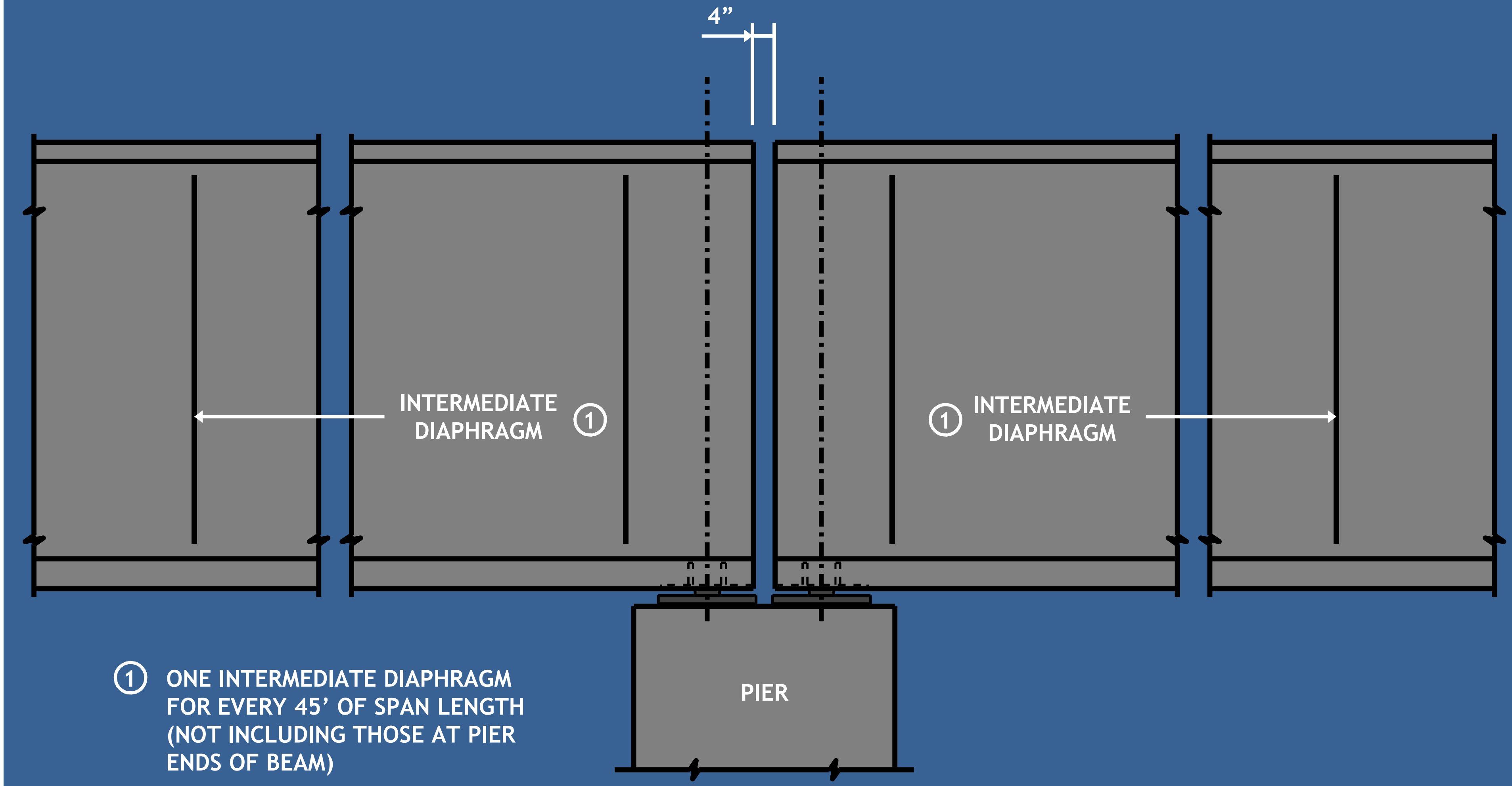


PRESTRESSED CONCRETE BEAM CHART FOR MW SERIES
DESIGN CRITERIA
HL-93 LOADING f'c=9ksi f'ci=7.5ksi 0.6" ϕ STRANDS
NUMBERS ADJACENT TO LIMIT CURVES REPRESENT AN APPROXIMATE DESIGN NUMBER OF STRANDS AND CENTER OF GRAVITY AT MIDSPAN.
SPAN LENGTH (FEET)
BEAM SPACING (FEET)
220
210
200
190
180
170
160
150
5
6
7
8
9
10
11
12
13
14
206'
193'
190'
178'
96MW
82MW
68@5.6
68 @ 5.6

MW Shapes


PRESTRESSED CONCRETE BEAM CHART
DESIGN CRITERIA
HL-93 LOADING f'c=9ksi f'ci=7.5ksi 0.6" ϕ STRANDS
NUMBERS ADJACENT TO LIMIT CURVES REPRESENT AN APPROXIMATE DESIGN NUMBER OF STRANDS AND CENTER OF GRAVITY AT MIDSPAN.
96MW
82MW
81M
68@5.6
68 @ 5.6
44@5.1
SPAN LENGTH (FEET)
BEAM SPACING (FEET)
220
210
200
190
180
170
160
150
140
130
120
5
6
7
8
9
10
11
12
13
14

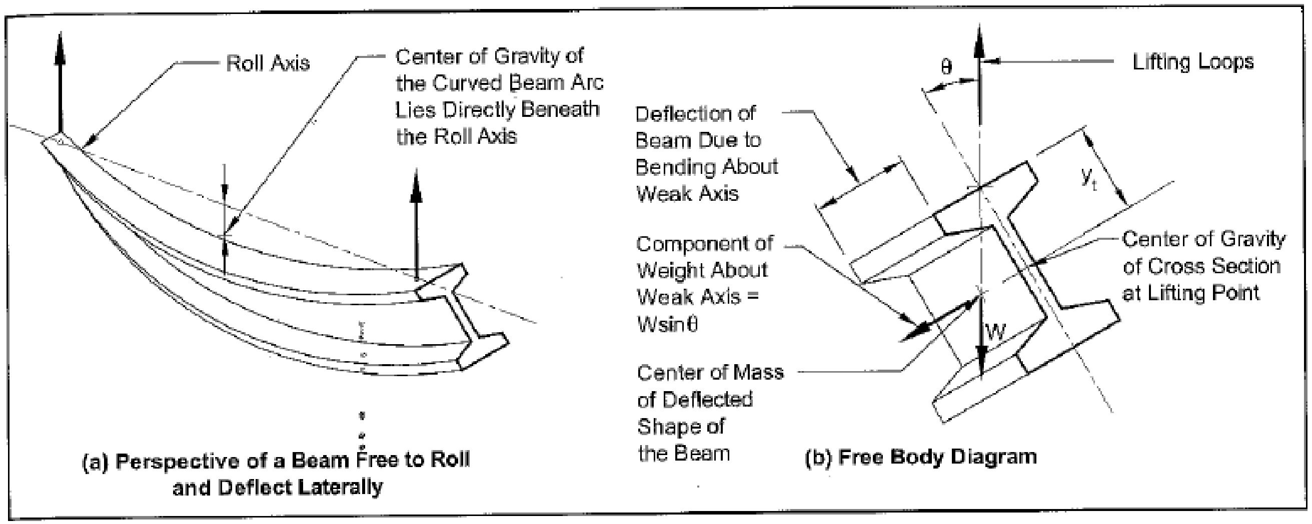
MW Shapes


4”
INTERMEDIATE DIAPHRAGM ①
① INTERMEDIATE DIAPHRAGM
PIER
① ONE INTERMEDIATE DIAPHRAGM FOR EVERY 45’ OF SPAN LENGTH (NOT INCLUDING THOSE AT PIER ENDS OF BEAM)

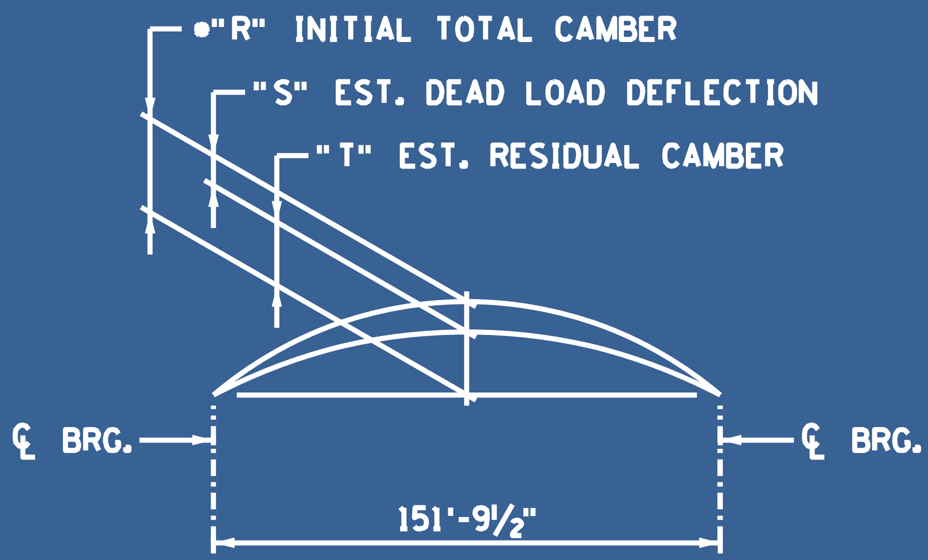
MW Shapes

- Shipment/handling of beams - lateral instability
- Deck pour sequence should be investigated
- Camber tracking required
  - Estimated cambers given in tabular form varying with age of girder

Figure 5.4.1.1 Equilibrium of beam in tilted position



MW Shapes – Camber Example



ESTIMATED CAMBER			
DAYS	"R"	"S"	"T"
30	5.37"	4.08"	1.29"
60	5.79"	4.08"	1.71"
90	5.99"	4.08"	1.91"
180	6.17"	4.08"	2.09"
360	6.28"	4.08"	2.20"

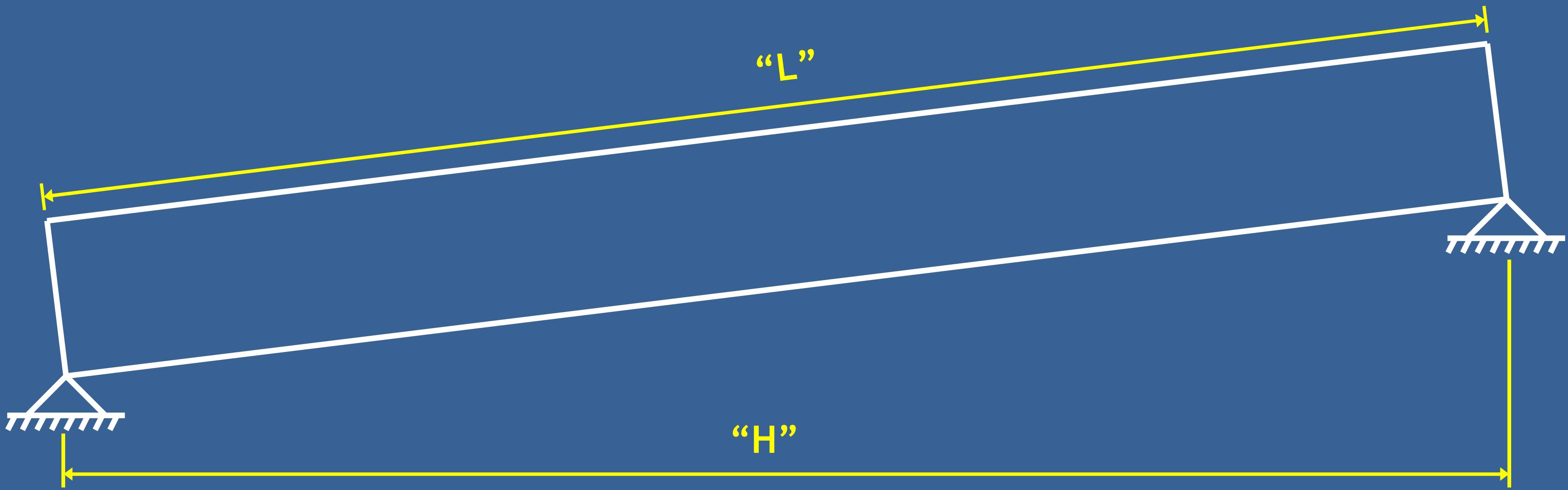
CAMBER NOTES

●CONTRACTOR SHALL MONITOR CAMBER OF BEAMS PRIOR TO ERECTION AND TAKE PRECAUTIONS TO ENSURE ACUTAL CAMBER AT ERECTION IS WITHIN 1" OF INITIAL TOTAL CAMBER.

BEARING SEAT ELEVATIONS BASED ON 180 DAY CAMBER. IF CAMBER GREATER THAN REPORTED, ADJUST BEARING SEAT ELEVATIONS.

MW Shapes

- Beam length on slopes
  - Use “L” in plan sheets when “L” - “H” ≥ ½”

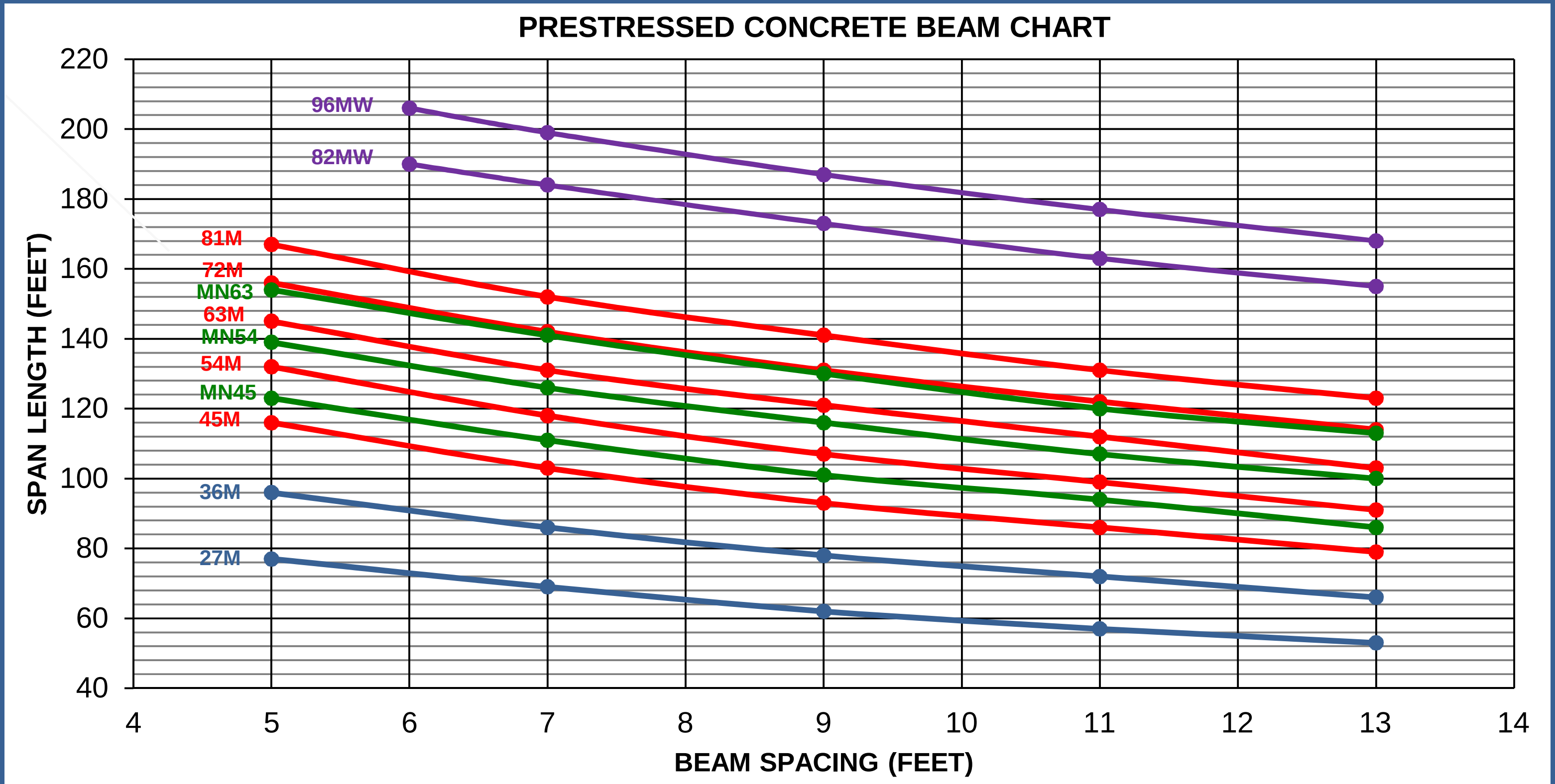


MW Shapes – Standard Plans and B-Details Developed/Modified

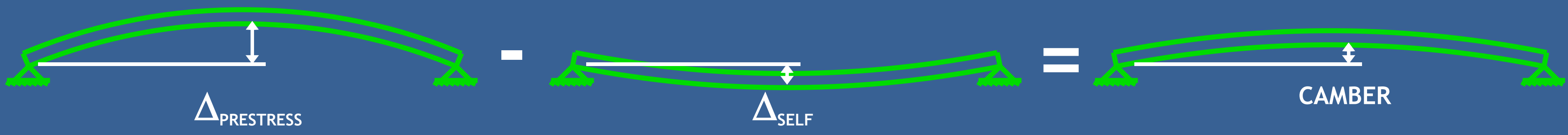
- Standard Plans
  - 5-397.531 82MW Prestressed Concrete Beam
  - 5-397.532 96MW Prestressed Concrete Beam
- B-Details
  - B303 Sole Plate
  - B310 Curved Plate Bearing Assembly - Fixed
  - B311 Curved Plate Bearing Assembly - Expansion
  - B412 Steel Intermediate Bolted Diaphragm (All MW Prestressed Beams)
  - B814 Concrete End Diaphragm - Parapet Abutment

Archiving M Shapes

- Archiving 45M through 81M beams
- Similar depth MN and MW shapes more efficient
- 27M and 36M still available



Camber Study - Background



- Estimation of camber at erection:
  - PCI: 1.85 for self-weight, 1.80 for prestress
    - Girders arriving at bridge site with cambers much lower than predicted
  - MnDOT: 1.50 for self-weight and prestress based on limited internal study
- Study by University of Minnesota to investigate MnDOT's factors

Camber Study – Methodology

- Historical camber data
  - Fabricator records for 1,067 girders from 2006-2010
  - Erection records for 768 of 1,067 girders
- Instrumentation/monitoring of 14 girders
- Measurement of compressive strength/elastic modulus of samples from two precasting plants
- Parametric study to investigate time-dependent effects using PBEAM

Camber Study – Girder Fabrication Recommendations

- Pouring Schedule/Management
- Strand Tensioning and Temperature Corrections
- Bunking/Storage Conditions

Camber Study – Release Camber Prediction Considerations

- Increase f'_{ci} by multiplying by a specified factor for camber calculations
- Use a different equation to calculate concrete modulus of elasticity
- Reduce the stress in the strands at release for camber calculations

Camber Study – Long-Term (Erection) Camber Prediction Suggested Changes

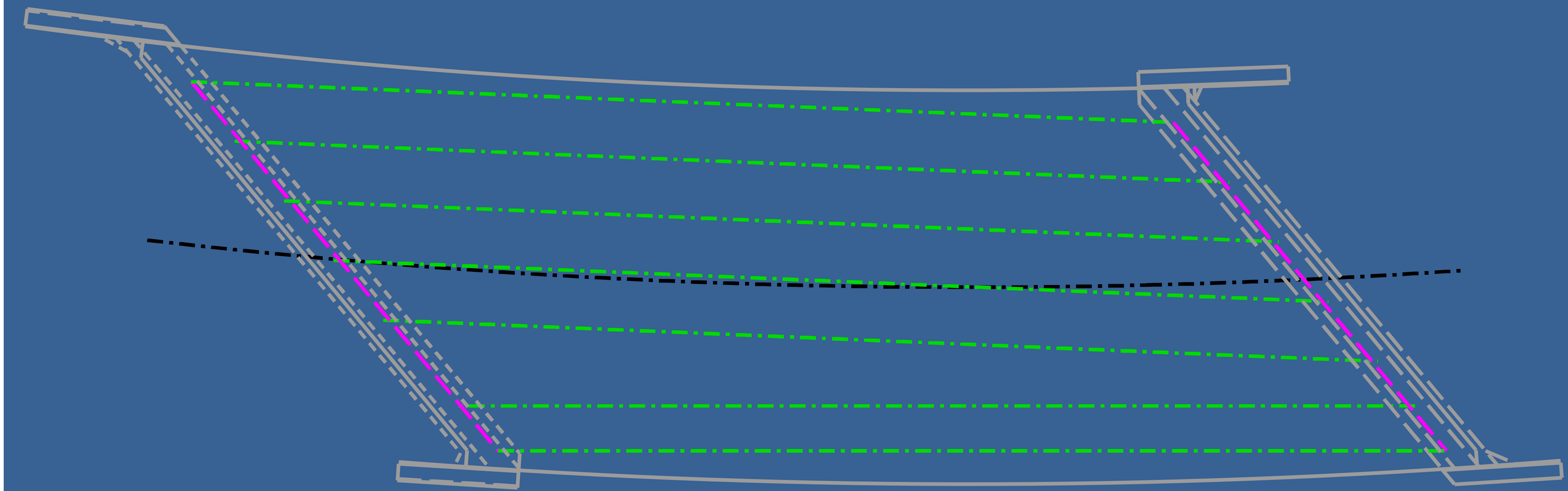
	NO CHANGE TO RELEASE CAMBER ESTIMATION	CHANGE RELEASE CAMBER ESTIMATION
Girder Age at Erection	MnDOT Time-Dependent Multipliers	Improved Time-Dependent Multipliers
0-2 months	1.25	1.65
2-6 months	1.40	1.85
6-12 months	1.50	2.00
12+ months	1.55	2.05

MnDOT Single-Value Multiplier: 1.35 ← NO OTHER CHANGES

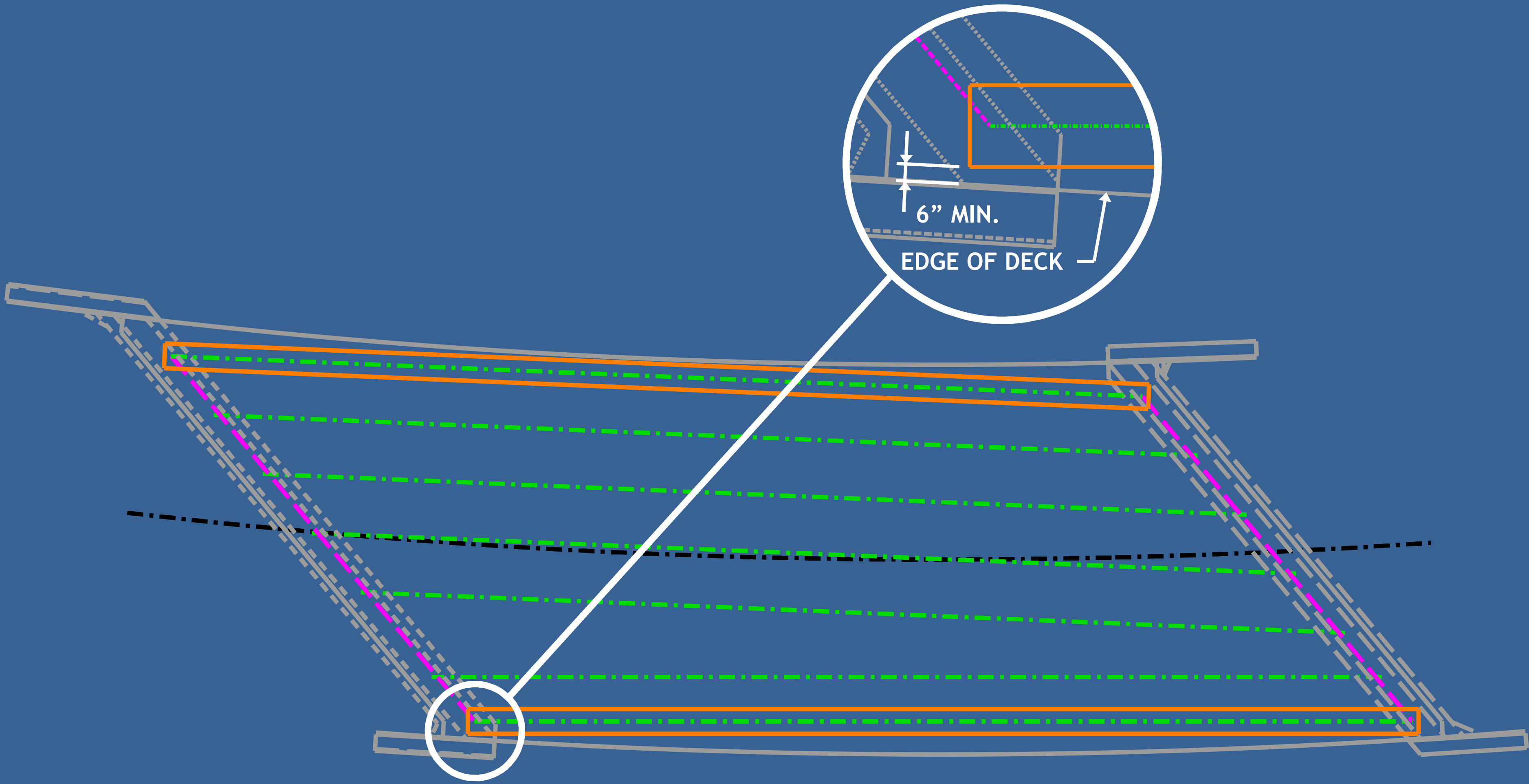
Improved Single-Value Multiplier: 1.80

- MnDOT is currently in the process of deciding which multipliers will be used

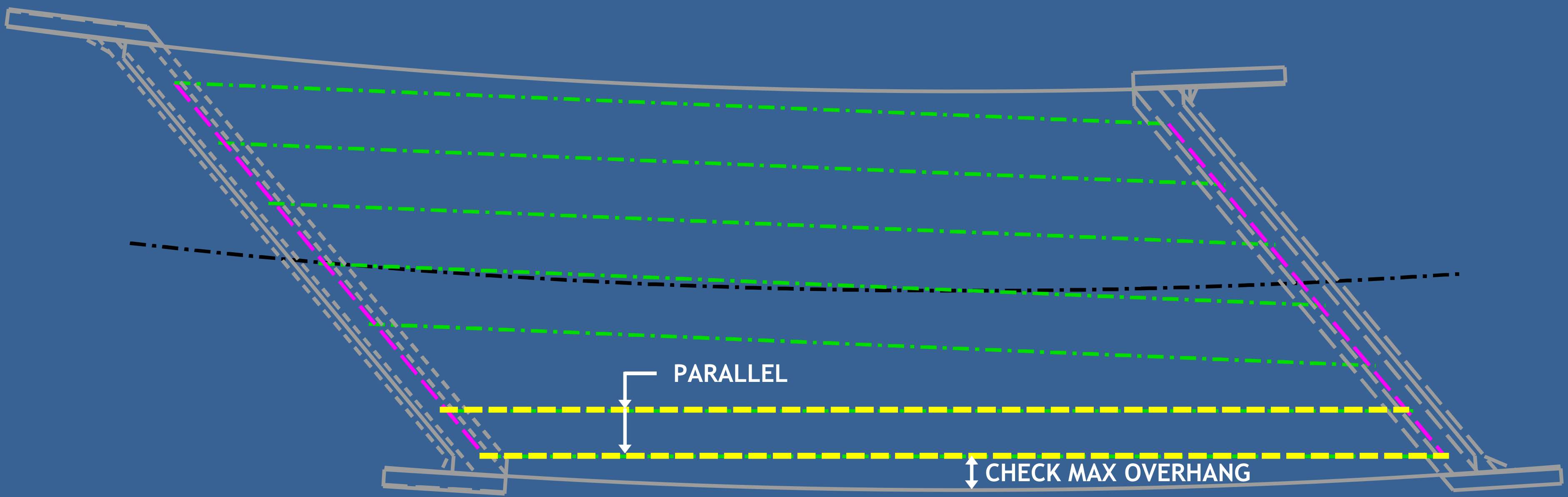
Curved Bridge Design



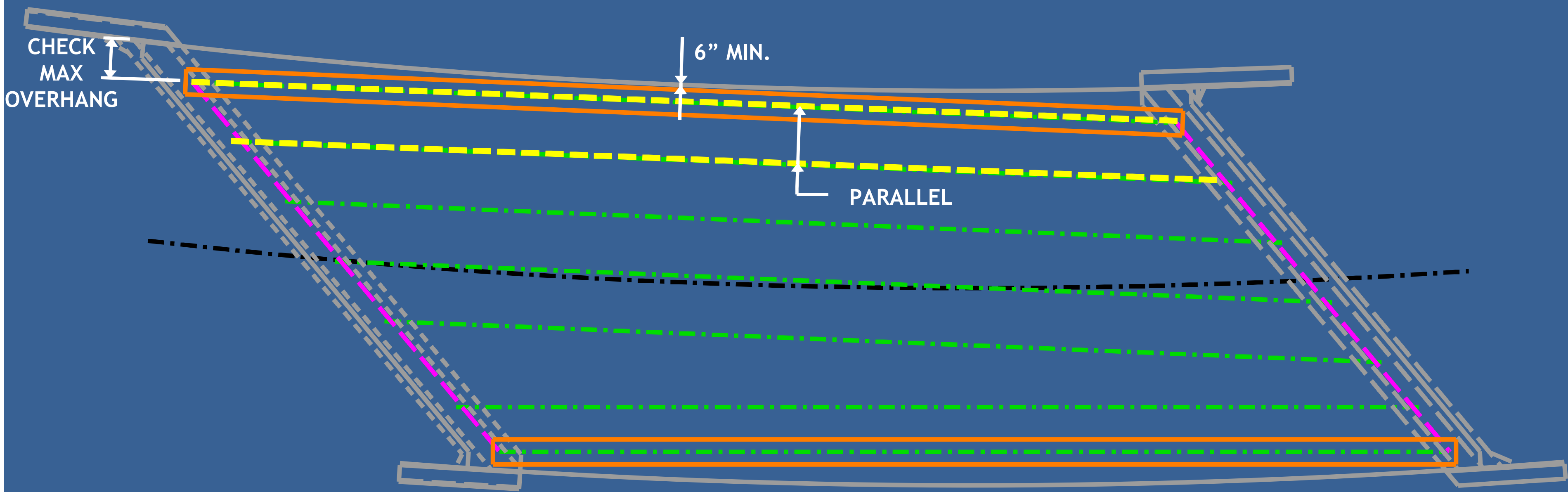
Curved Bridge Design – Layout Considerations



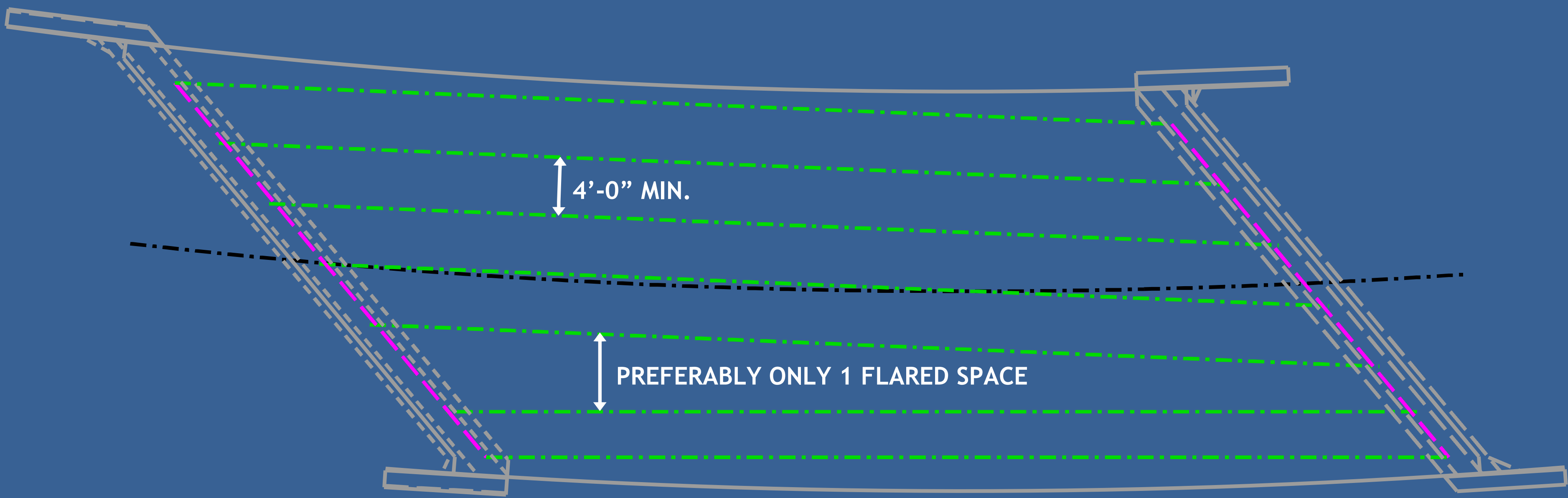
Curved Bridge Design – Layout Considerations



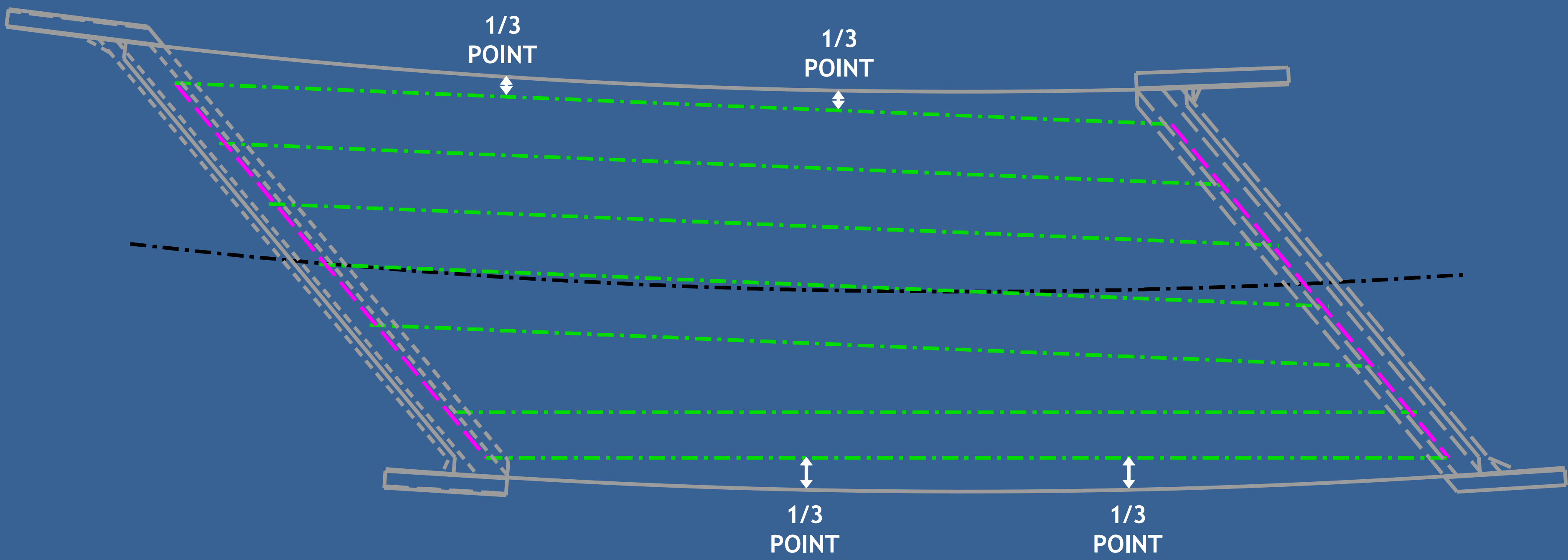
Curved Bridge Design – Layout Considerations



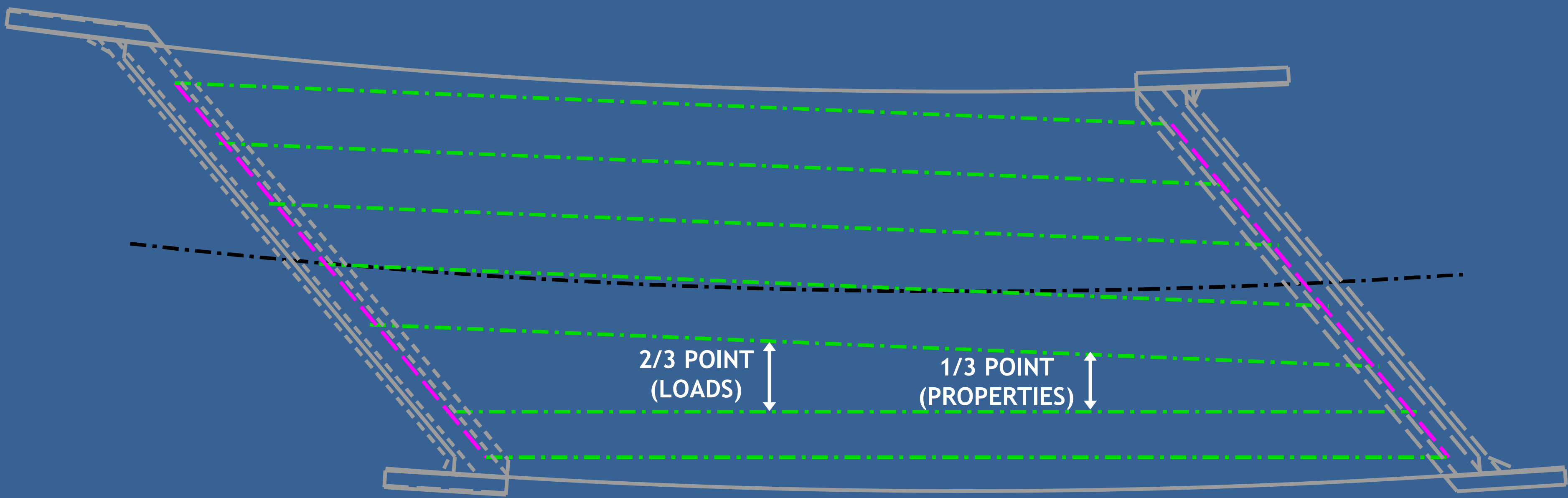
Curved Bridge Design – Layout Considerations



Curved Bridge Design – Design Considerations



Curved Bridge Design – Design Considerations



Curved Bridge Fascia Design – Design Considerations

- Stool
  - Should take into account horizontal curve
  - For straight bridges, typically use stool thickness of 2.5” for initial load calculations and 1.5” for properties.
  - For curved bridges, consider using stool thickness of something larger than 2.5” for initial load calculations to account for horizontal curve and increased stool heights. Use 1.5” for properties.

Summary

- Inverted Tees
- MW-Shapes
- Archiving M-Shapes
- Camber Study
- Curved Bridges

Questions and Discussion

Inverted Tees

MW-Shapes

M-Shapes

Camber Study

Curved Bridges