New York State Department of Transportation

Modeling and Verification of a High Skew Bridge in BrD 3D FEM

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August 12, 2025

MEET YOUR PRESENTERS

Julianne M. Fuda, P.E.

- Rensselaer Polytechnic Institute – BS in Civil Engineering, 2009
- NYS PE License – 2013
- Working at NYSDOT for 10 years
- Director of Structures Design Bureau

Kelsey Roman, P.E.

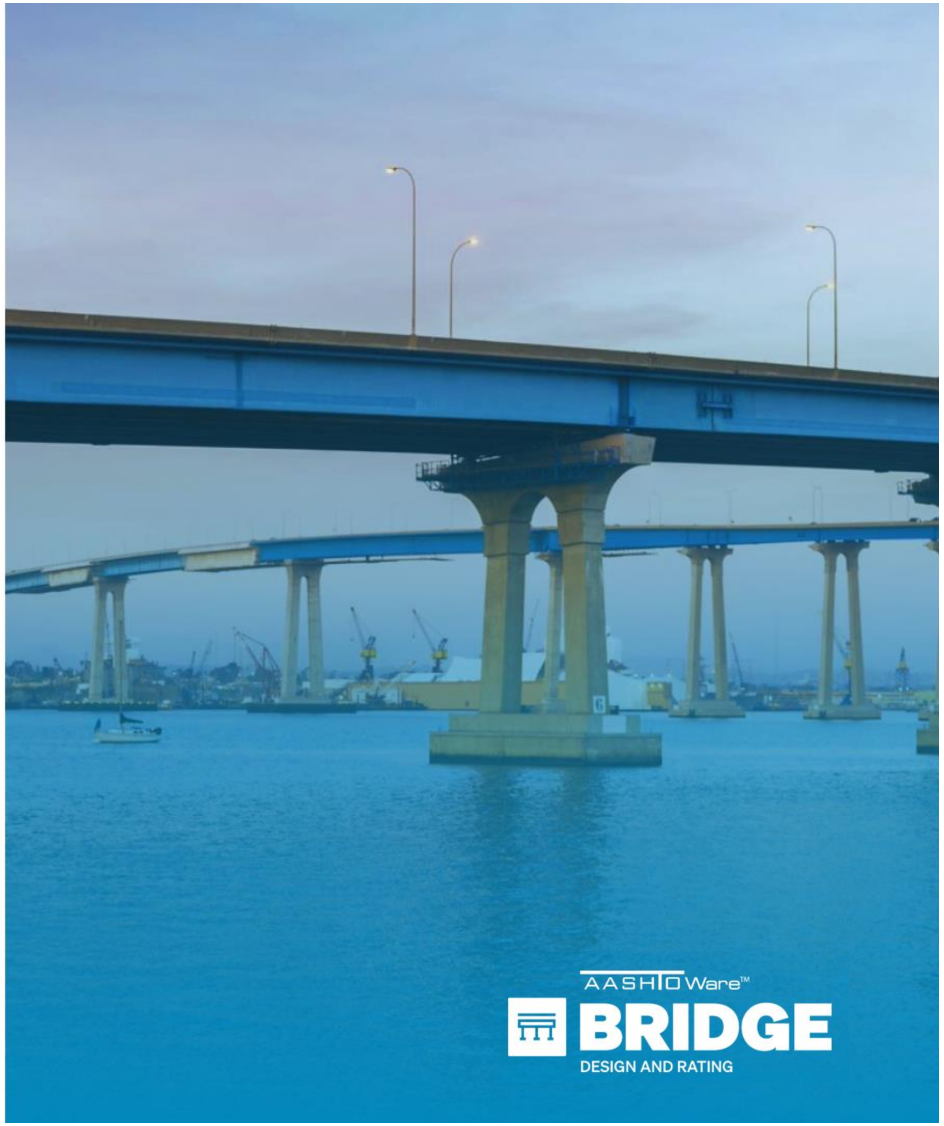
- Ohio State University – BS in Civil Engineering, 2017
- NYS PE License – 2022
- Working at NYSDOT for 8 years
- Squad Leader for a Structures Design Bureau squad

FUN FACT: NYSDOT just got a new mascot!

He may be hiding throughout this presentation…

AGENDA

- NYSDOT's Life Cycle of a BrDR Model
- BrDR Analysis Capabilities
- Route 378 over Route 32 Background
- Atypical BrDR Inputs
- Running a 3D FEM Analysis
- Interpreting the 3D FEM Results
- Rating Results & Rehabilitation Scope
- Lessons Learned



Life Cycle of a BrDR Model

Life Cycle of a BrDR Model at NYSDOT

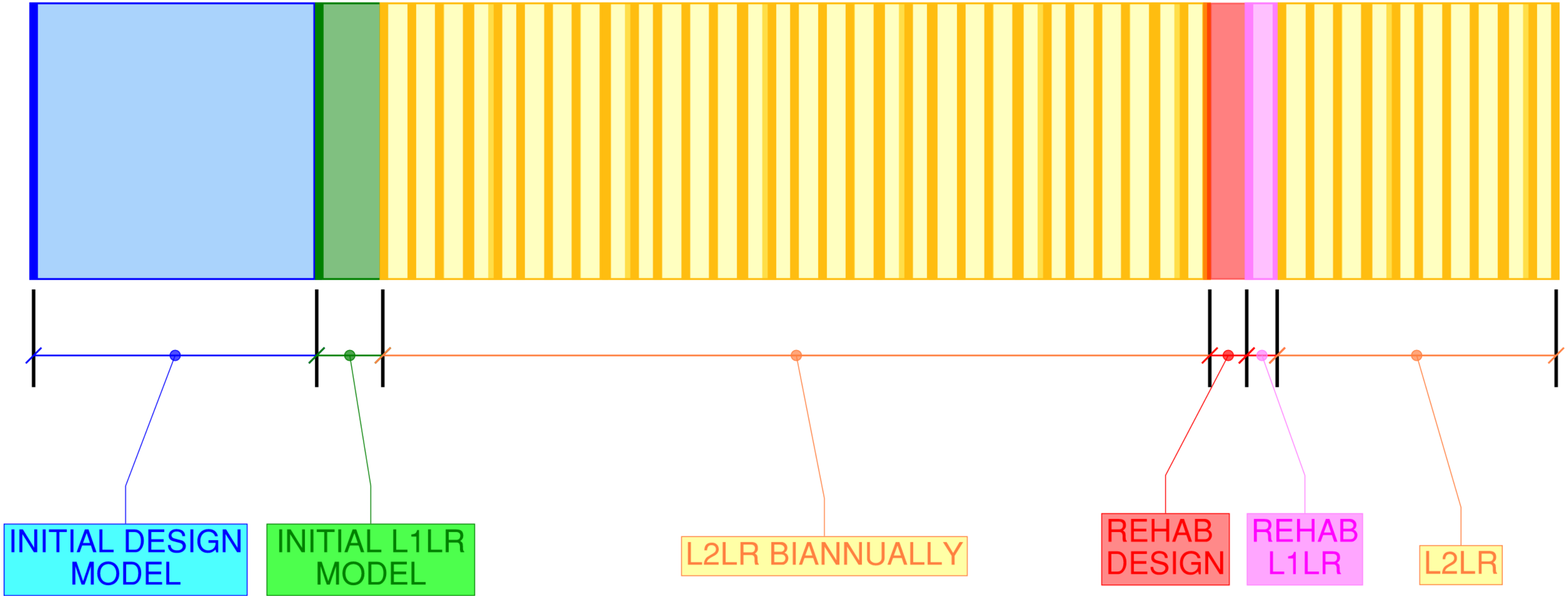
Design staff create model for bridge replacement

Load Rating staff use the model during bridge’s service life

Design staff update the model for a bridge rehabilitation

Load Rating staff use the model during bridge’s remaining service life

Life Cycle of a BrDR Model

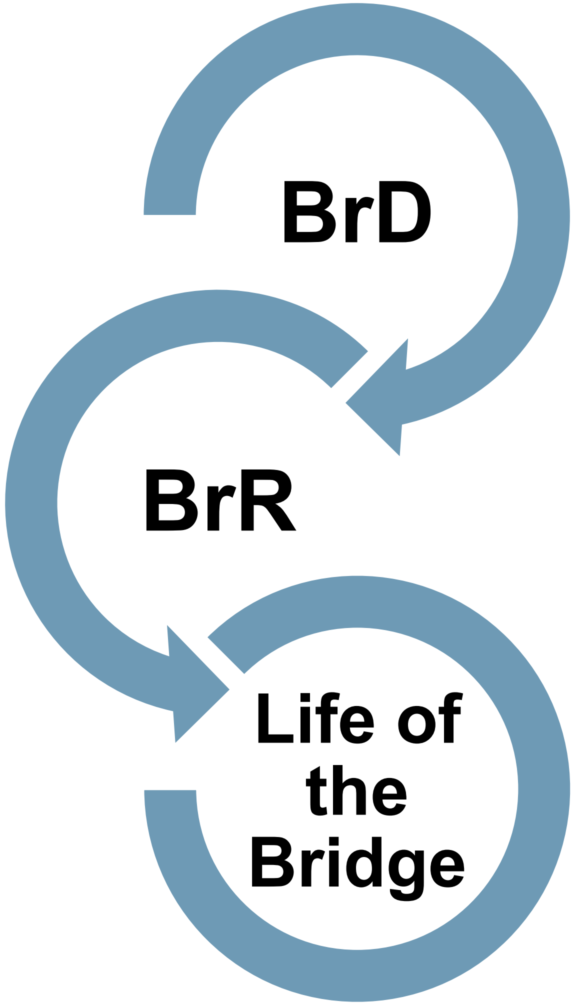


- Level 1 Load Rating (L1LR) vs. Level 2 Load Rating (L2LR)
- Updates to model during service life for:
  - Additional load (wearing surfaces, bridge railing/barrier)
  - Change in capacity (section loss)

Life Cycle of a BrDR Model at NYSDOT

Benefits:

- Keep BrDR models up to date for current design standards
- Cleans up the file periodically to improve rating accuracy
- Closer review with a “finer tooth comb” than the inspection/Level 2 process allows
- Time savings, models are not started from scratch
- Helps with overall efficiency, especially during emergencies
- Acts as an additional layer of QC, as shown by this case study



BrDR Analysis Capabilities

BrDR Analysis Capabilities

AASHTOWARE BRIDGE DESIGN

CURRENT FEATURES

BRIDGE CONFIGURATIONS AND CAPABILITIES

SUPERSTRUCTURES

- Reinforced concrete tee beams, slabs, I-beams, and multi-cell box beams
- Reinforced concrete box culverts
- Prestressed concrete box, I, tee, and U-beams (precast, pretensioned, continuity for live load, harped strands, and de-bonded strands)
- Steel rolled beams (including cover plates)
- Steel built-up plate I-girders
- Steel welded plate I-girders (including hybrid)
- Simple spans, continuous spans, hinges (steel and reinforced concrete)
- Parallel and flared girder configurations
- Parallel, tapered, parabolic, and circular webs
- Transverse and longitudinal stiffened steel girders
- Frame structure simplified definition
- Girder-line and 3D-FEM analyses
- 3-D analysis of steel and concrete multi-girder superstructures
- 3-D analysis of curved steel multi-girder superstructures
- U.S. customary and S.I. units

- Understand software capabilities
- AASHTOWare is constantly expanding
- BrDR User Group and enhancements
- Analysis capabilities in last 10-15 years
  - ➢ Curved Girders
  - ➢ Trusses
  - ➢ High Skews
  - ➢ Complex Framing
- Re-evaluate software, don't write off BrD!

BrDR Analysis Capabilities

Unratable Structure, Span, or Framing Plan? → Create Model Anyway! → Run Analysis when Capability Arrives

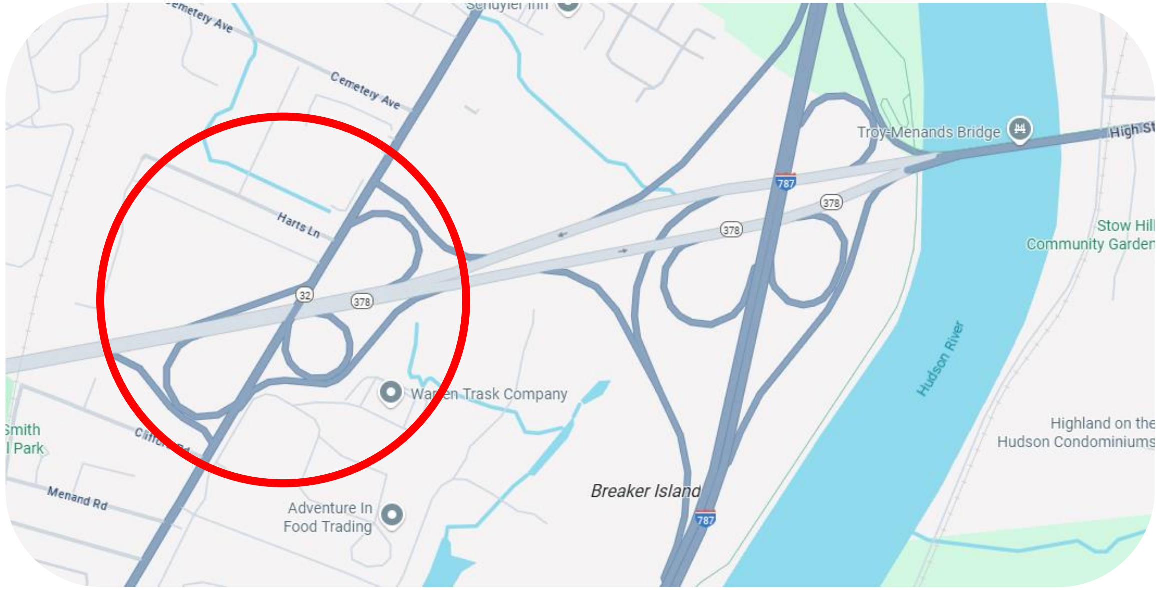
Example

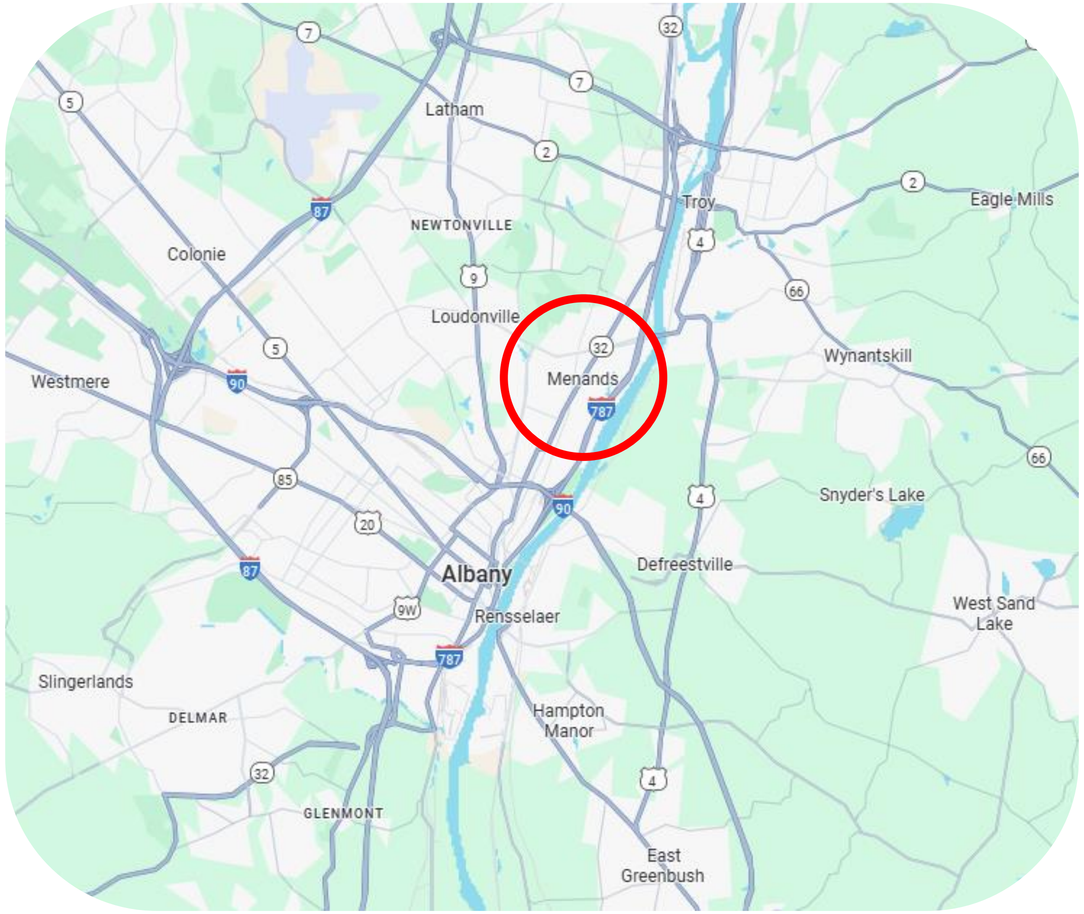
- Line Girder is go-to analysis method
- New software capability for 3D FEM
  - Opportunity for refined analysis
  - Check appropriateness of analysis assumptions
- Line girder results can be unconservative as shown in case study

Bridge Configurations and Capabilities		AASHTO LRFD Design Review	AASHTO LRFR, LFR, ASR Rating
Superstructures[4]	Reinforced concrete tee beams, slabs, I-beams, and multi-cell box beams	X	X
	[5]Reinforced concrete box culverts	X	X
	Prestressed concrete box, I, tee, and U-beams (precast, pretensioned, continuity for live load, harped strands, and de-bonded strands)	X	X
	Steel rolled beams (including cover plates)	X	X
	Steel built-up plate I-girders	X	X
	Steel welded plate I-girders (including hybrid)	X	X
	Steel trusses and floor systems		X
	Timber beams and decks (AASHTO engine available in Version 7.3.1)		X
	Corrugated metal decks		X
	Simple spans, continuous spans, hinges (steel and reinforced concrete)	X	X
	Parallel and flared girder configurations	X	X
	Parallel, tapered, parabolic, and circular webs	X	X
	Transverse and longitudinal stiffened	X	X
	Frame structure simplified definition	X	X
Girder-line and 3D-FEM[1]	3-D analysis of steel and concrete multi-girder superstructures	X	X
	[6]3-D analysis of curved steel multi-girder superstructures	X	X
Substructures	Bridge piers including wall, hammerhead and multi-column pier bents	X	
	Single drilled shaft for substructure	X	
Load Rating Features	Girder-floor beam-stringer configurations		X
	Truss-floor beam-stringer and floor-truss configurations		X
	Timber and corrugated metal decks		X
	Gusset-plate connections[2] and splice connections[3]		X
	[5]Metal Culverts (pipe, pipe arch, structural plate pipe and boxes)		LFR/LRFR

Route 378 over Route 32 Background

Route 378 over Route 32 Background: Village of Menands





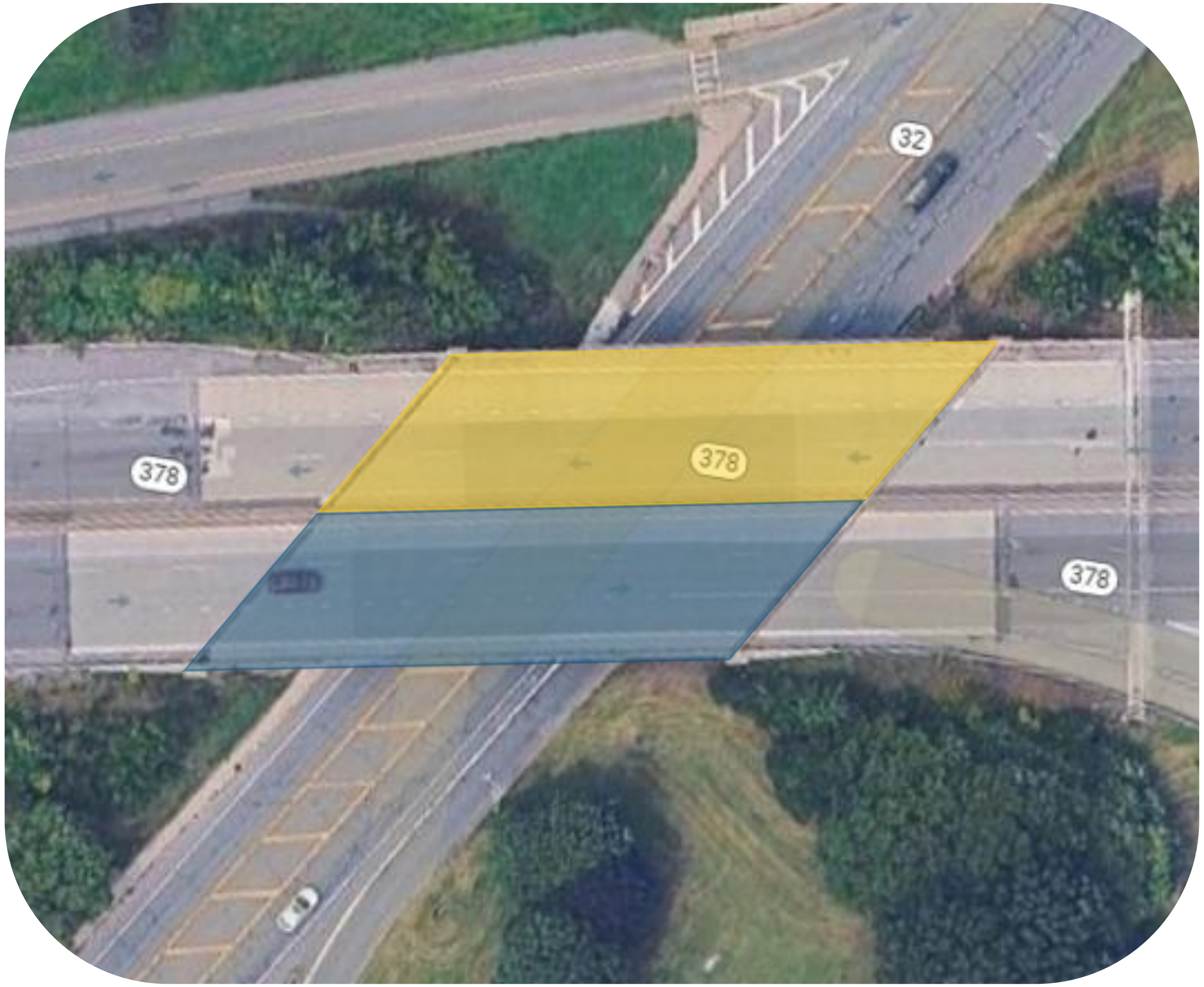
Route 378 over Route 32 Background: Bridge Layout and Geometry

- 42°10’22” skew
- 155’-0” simple span
- 91’-0” overall width

Route 378 over Route 32 Background: Bridge Layout and Geometry

WB/EB

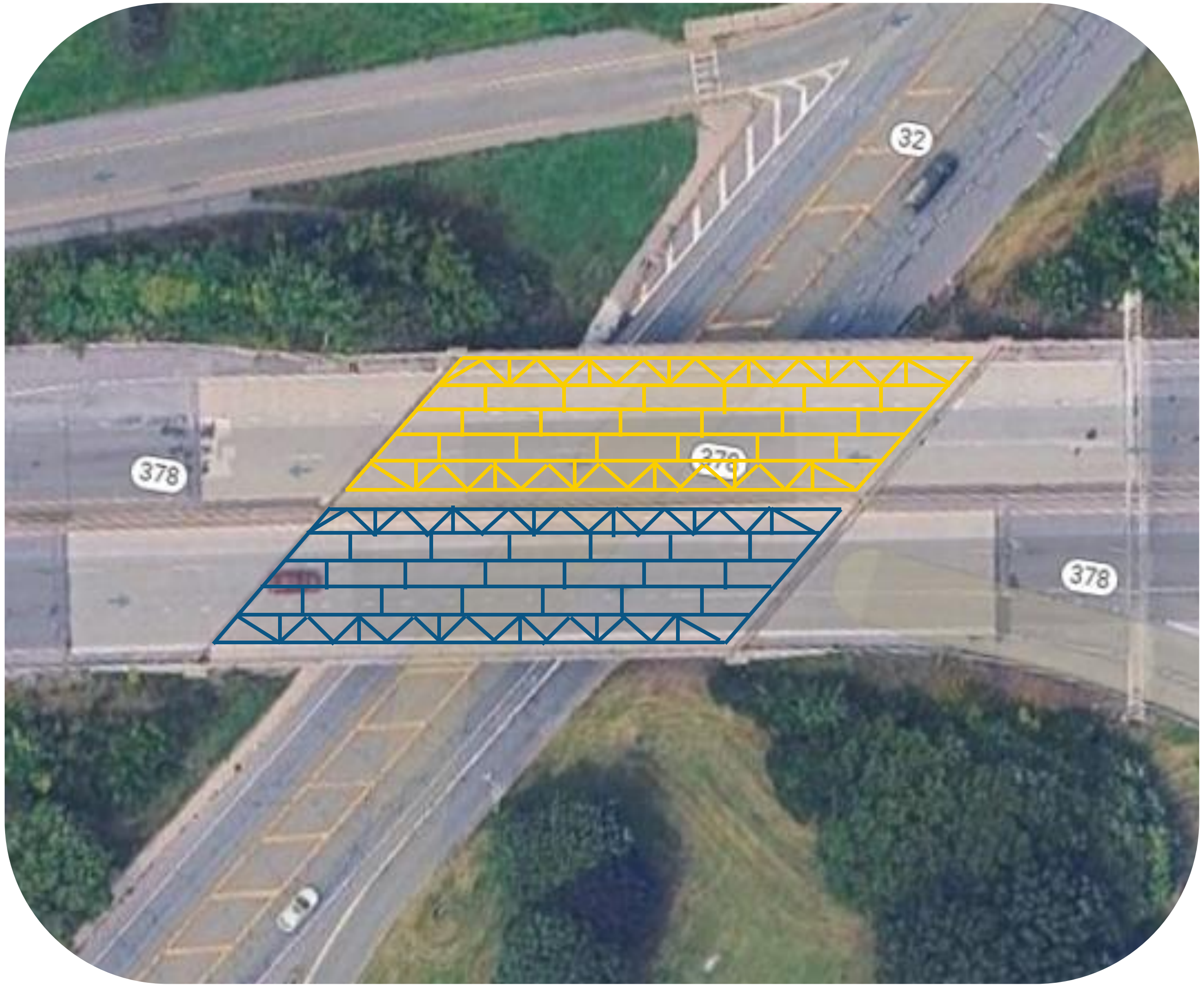
- 42°10’22” skew
- 155’-0” simple span
- 91’-0” overall width
- Two decks with longitudinal expansion joint
- Steel rail with brush curbs at fascias and median



Route 378 over Route 32 Background: Bridge Layout and Geometry

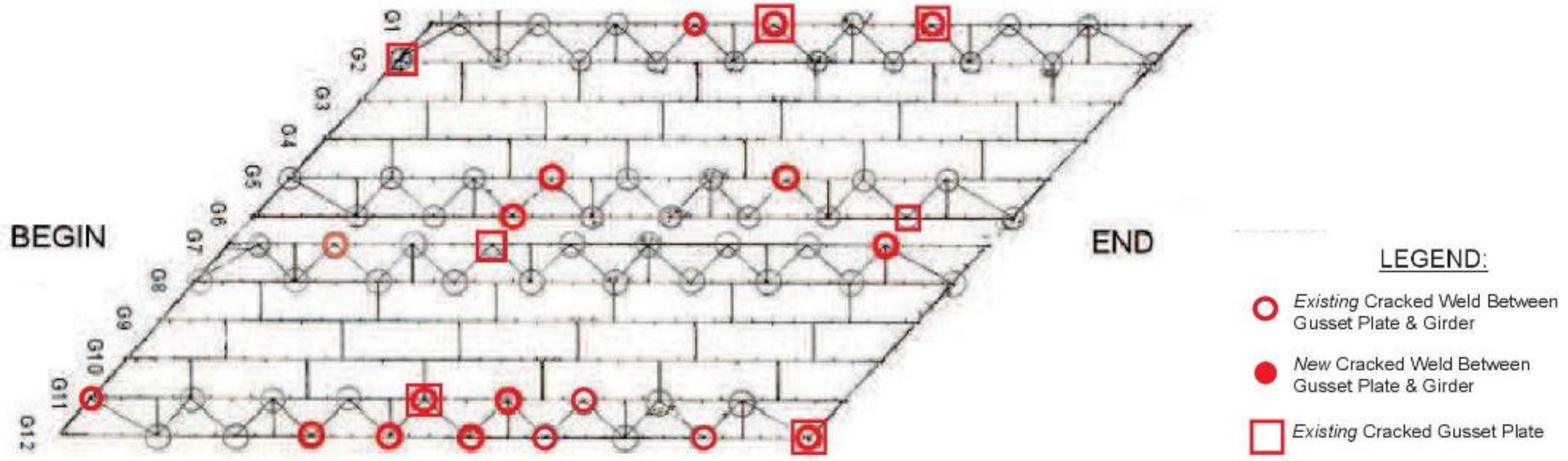
WB/EB

- 42°10’22” skew
- 155’-0” simple span
- 91’-0” overall width
- Two decks with longitudinal expansion joint
- Steel rail with brush curbs at fascias and median
- Steel multi-girder (plate girder)
- Bottom laterals in fascia bays
- Conventional spread footer abutments with U-walls hold both superstructures



Route 378 over Route 32 Background: Bottom Lateral Bracing

A Yellow Flag was issued due to cracks in gusset plates and gusset plate welds for bottom flange lateral bracing.



Route 378 over Route 32 Background: Bottom Lateral Bracing

Route 378 over Route 32 Background: Section Loss

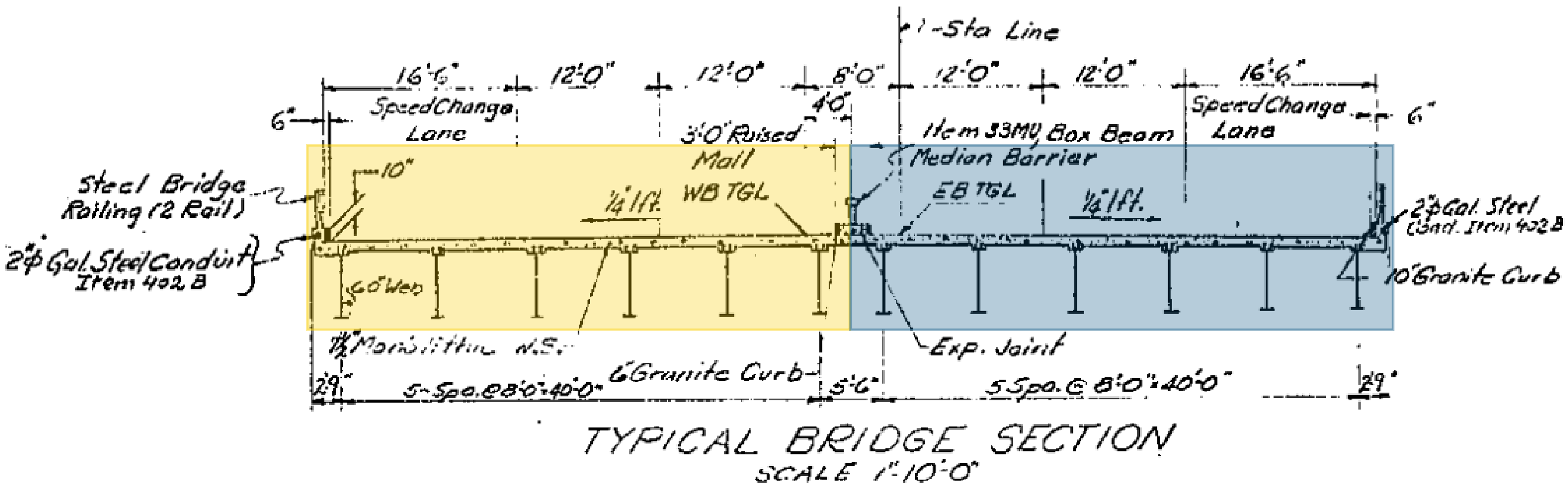
Not part of the Yellow Flag, but web perforations were included in scope of repair work to be completed.

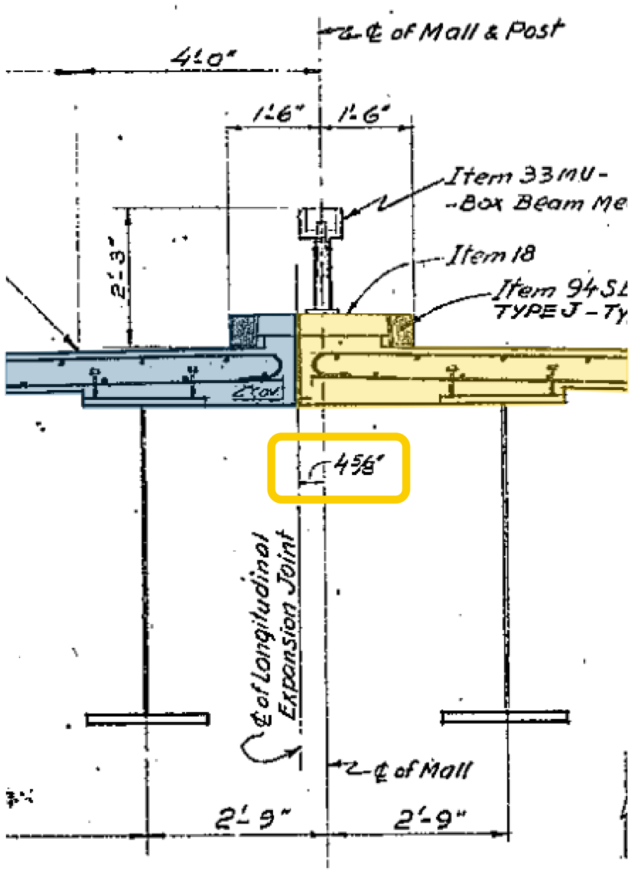
Atypical BrDR Inputs

Atypical BrDR Inputs: Longitudinal Expansion Joint

WB/EB

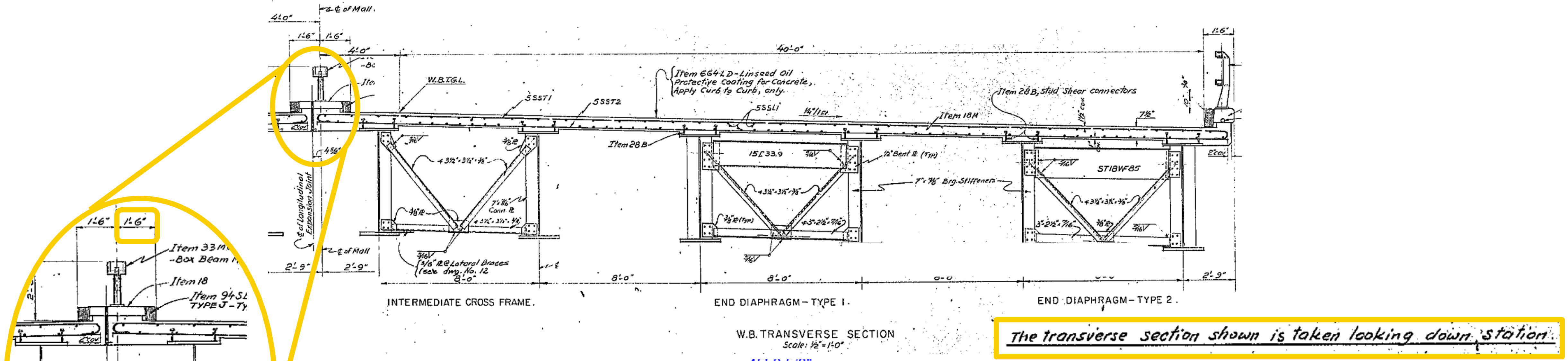
Longitudinal expansion joint between decks is offset 4⅝” from center (two superstructure models).

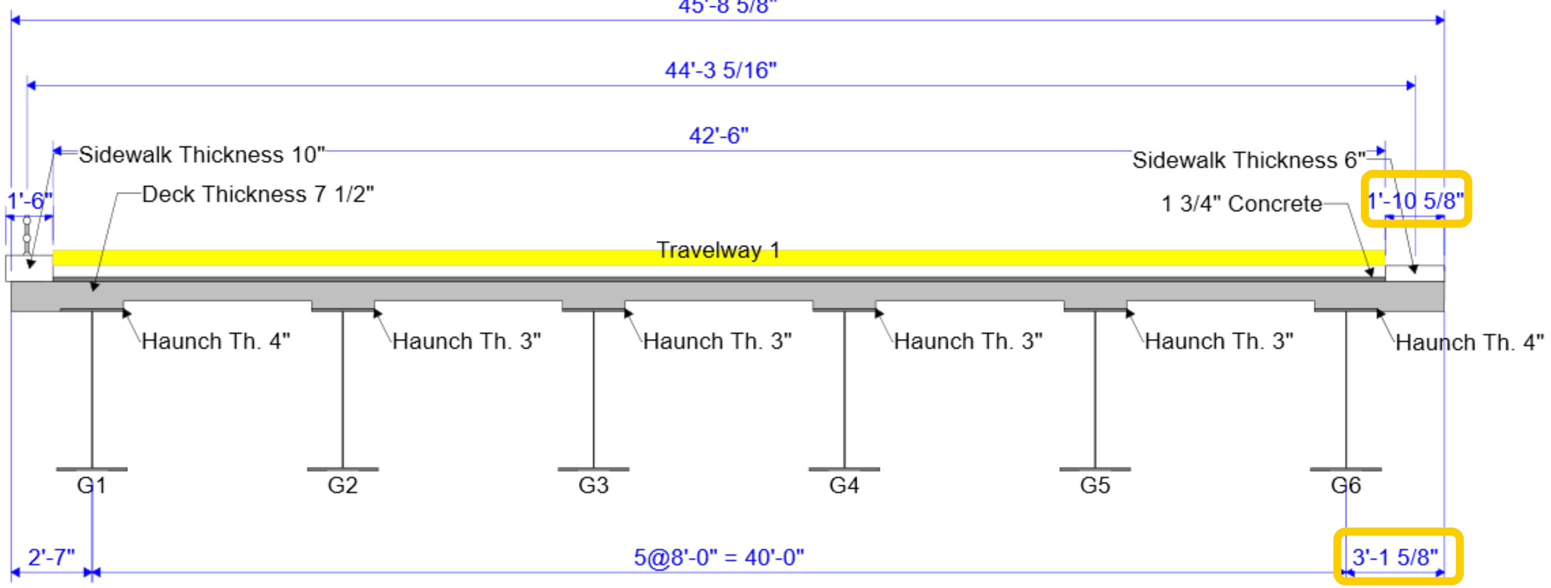




Atypical BrDR Inputs: Longitudinal Expansion Joint

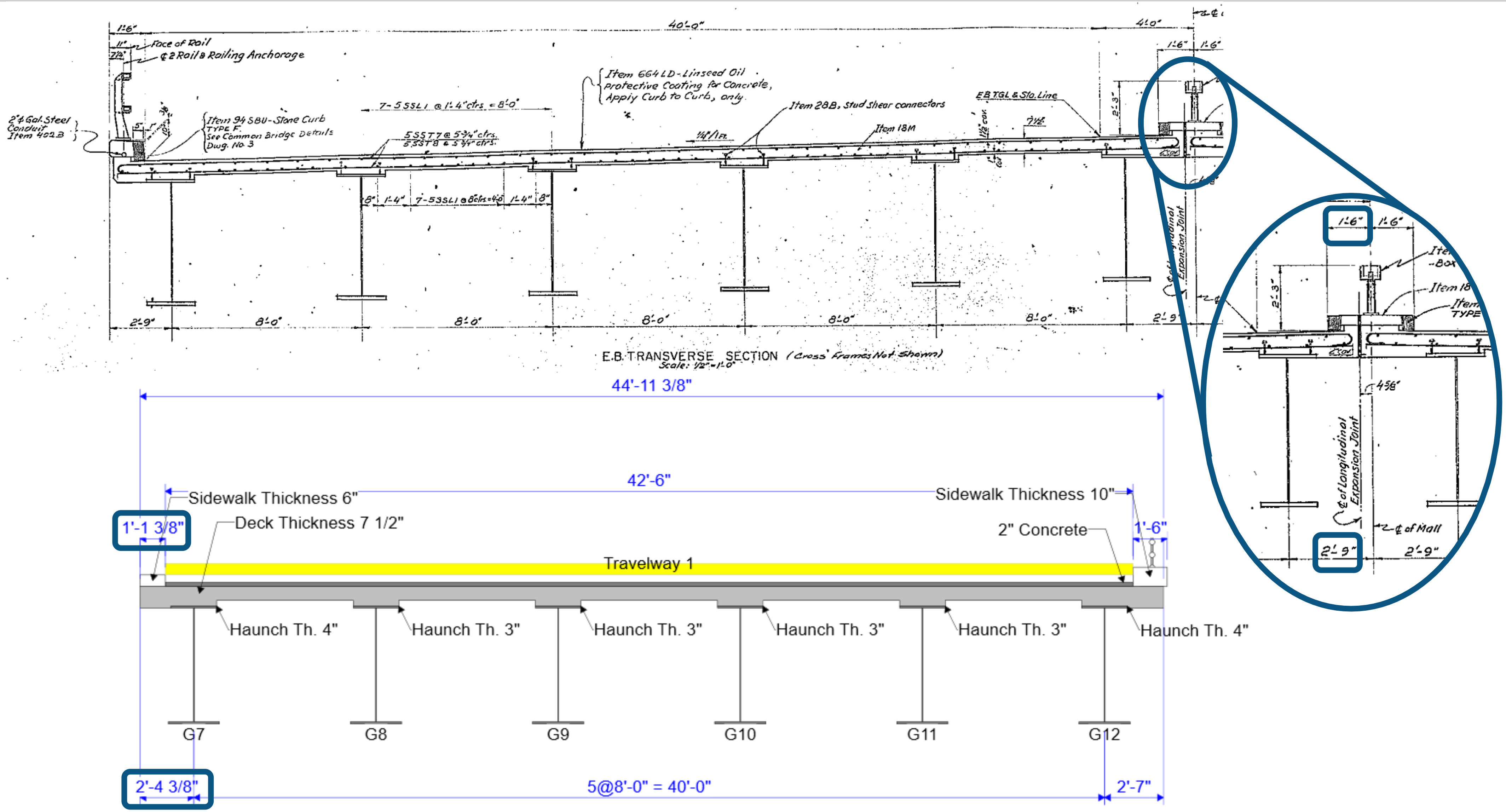
WB/EB





Atypical BrDR Inputs: Longitudinal Expansion Joint

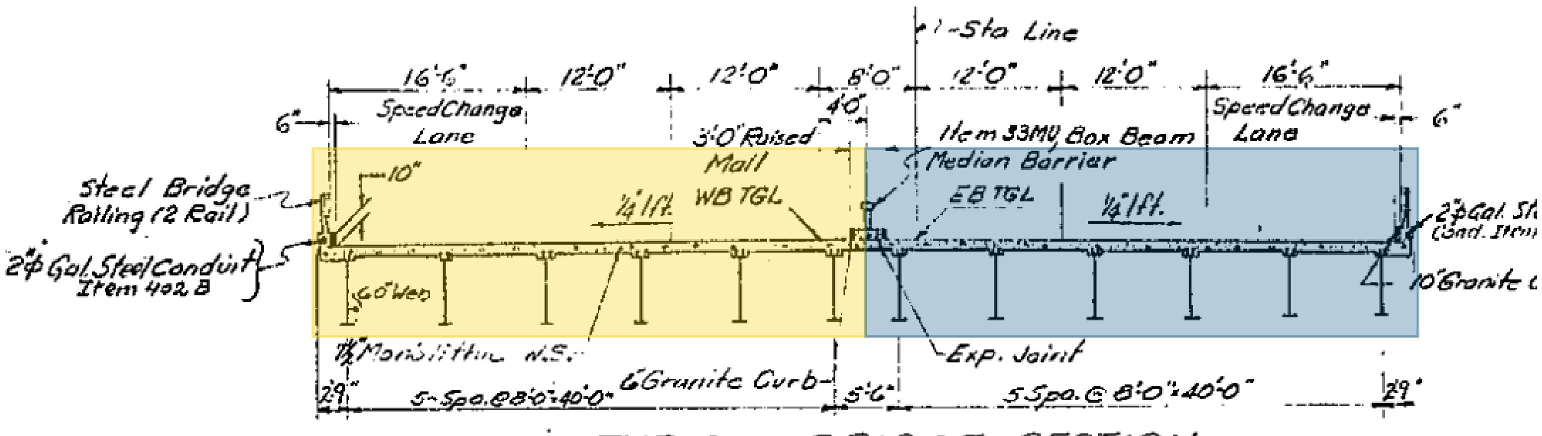
WB/EB

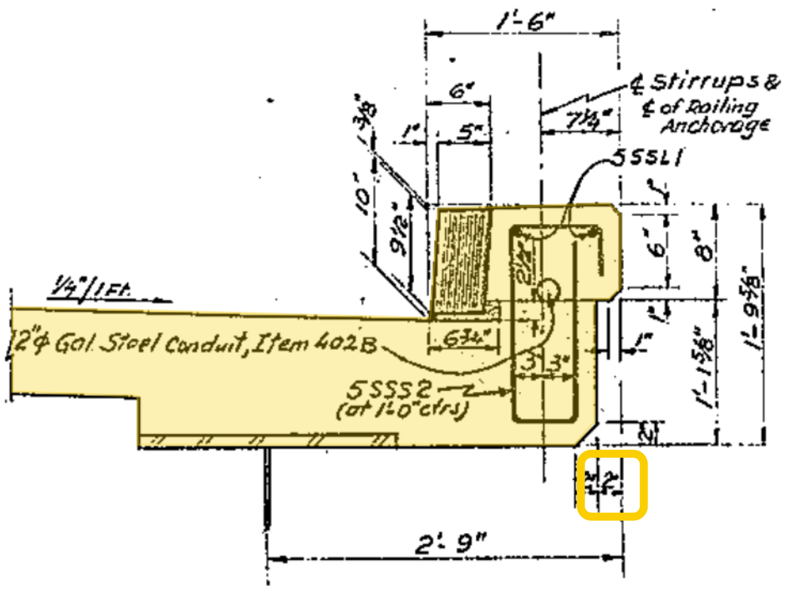


Atypical BrDR Inputs: Brush Curb Overhang

WB/EB

Brush curbs overhang the deck fascia by 2” on both sides.





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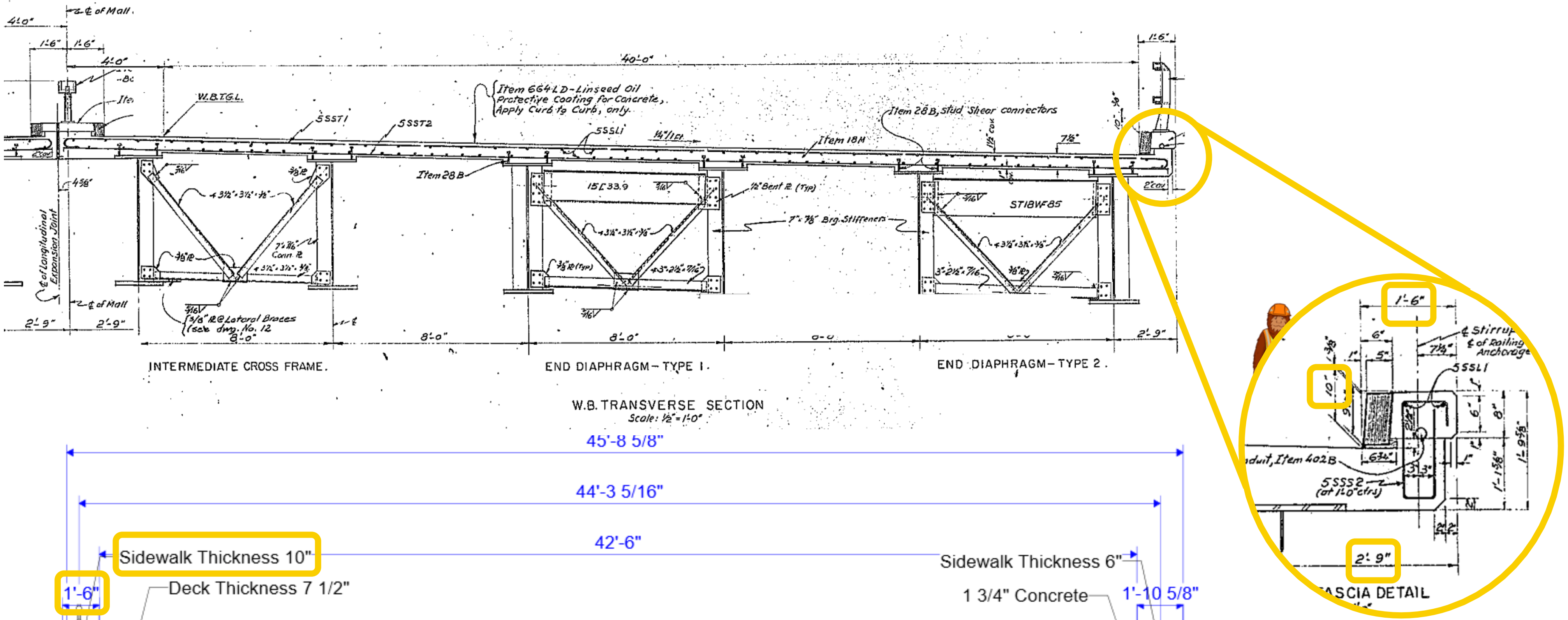

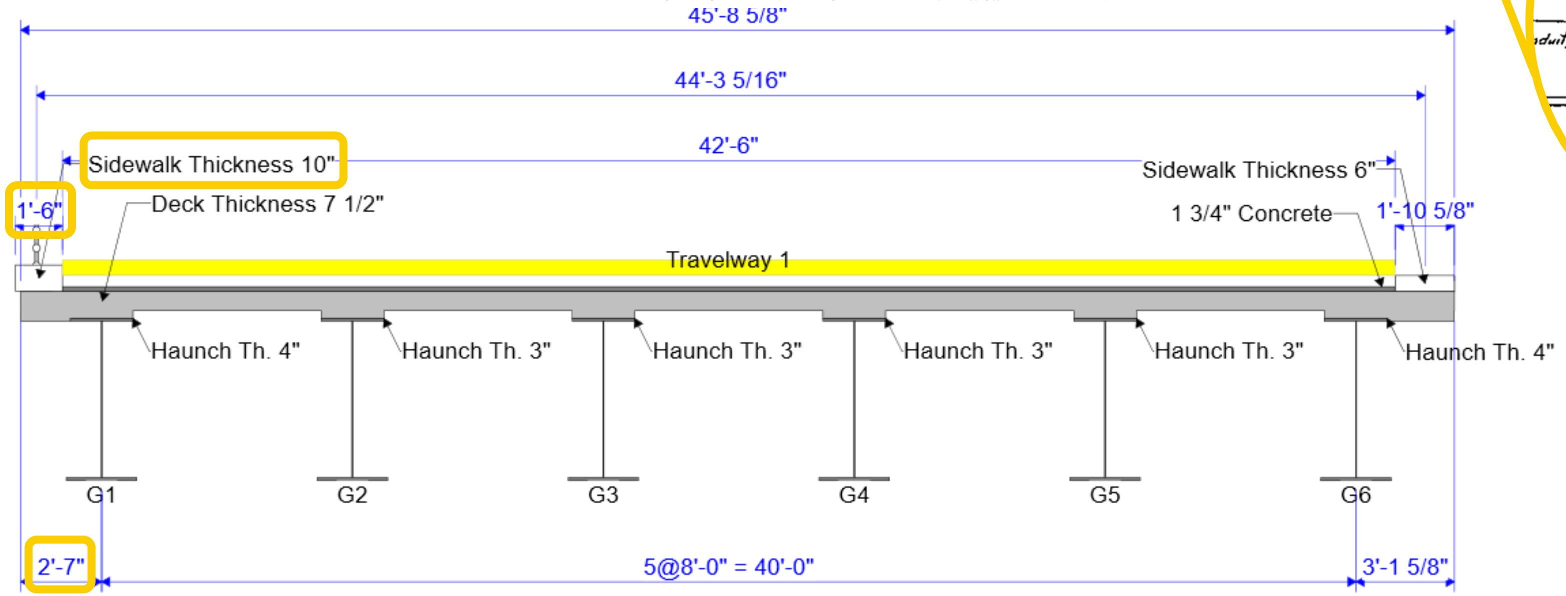

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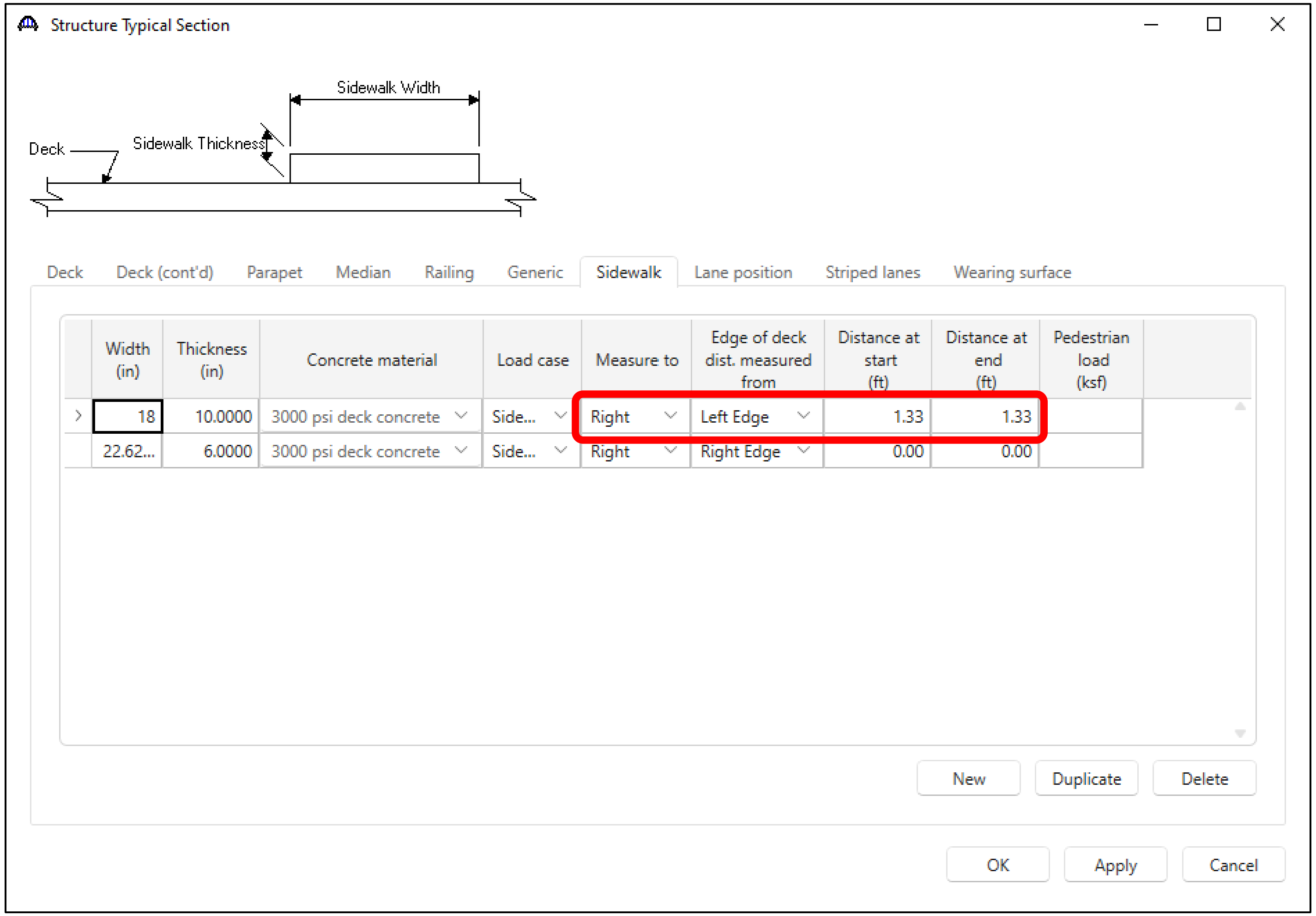
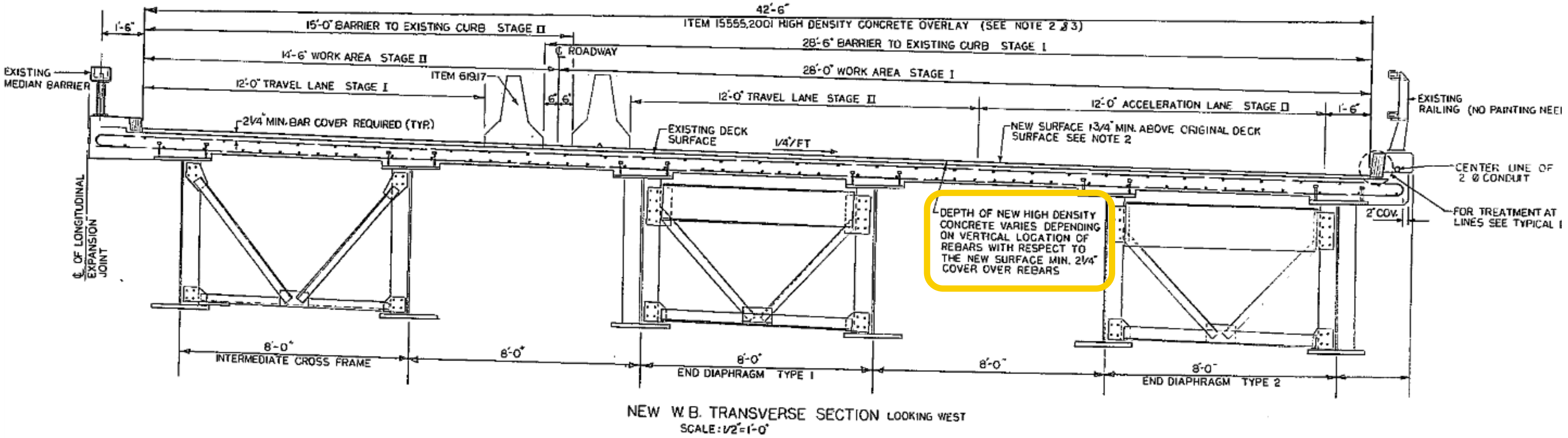
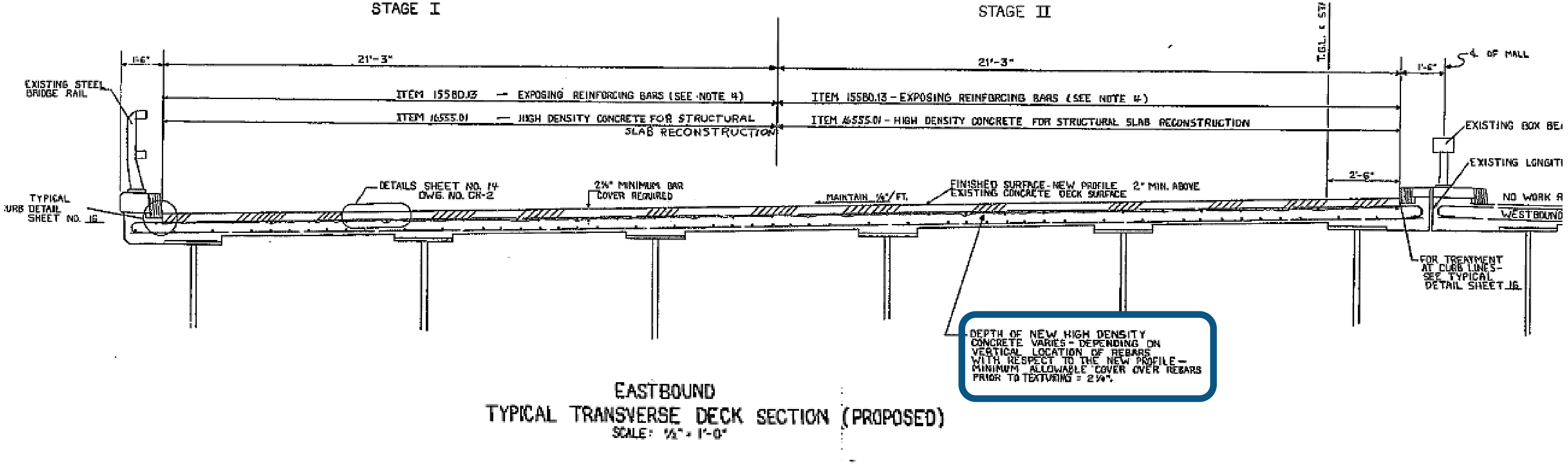


Atypical BrDR Inputs: Concrete Overlay

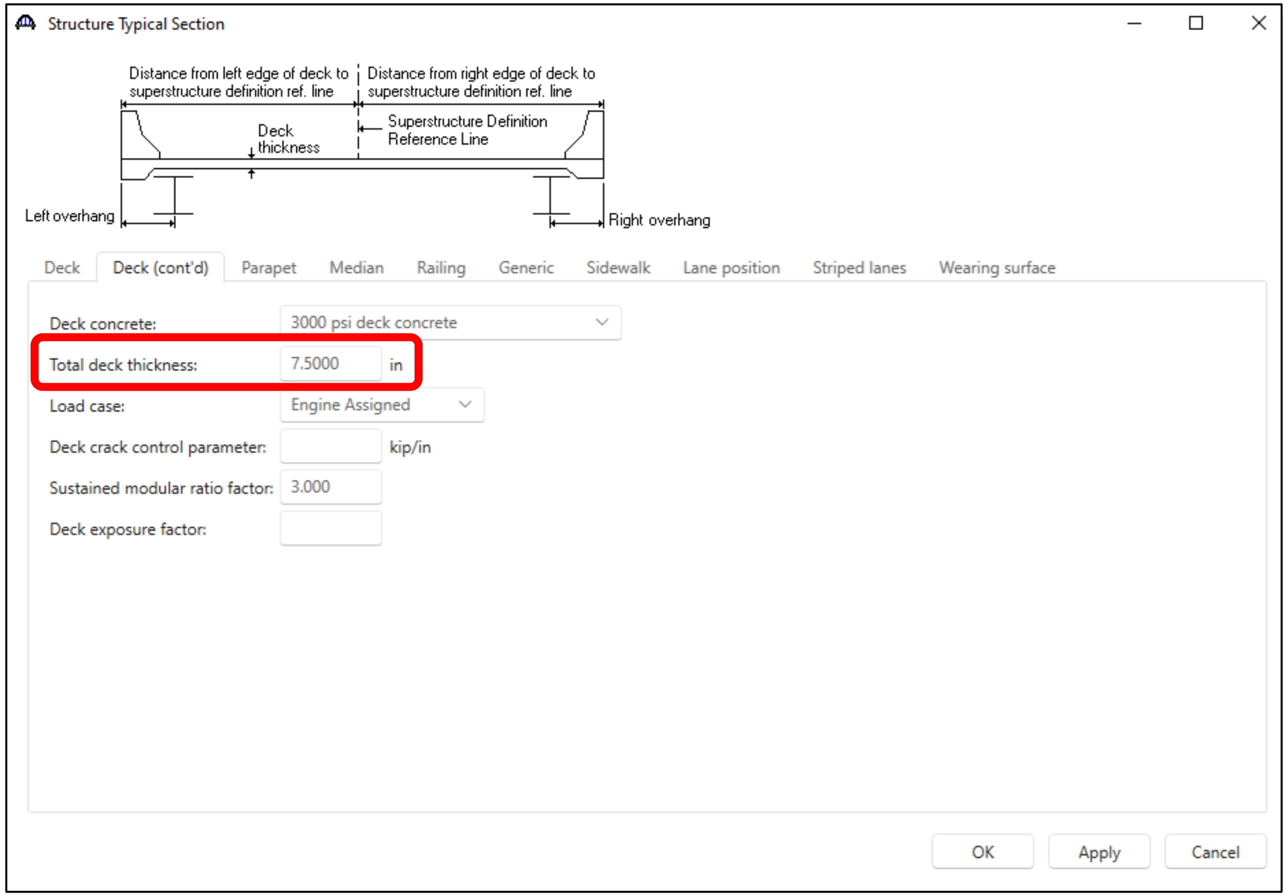
WB/EB

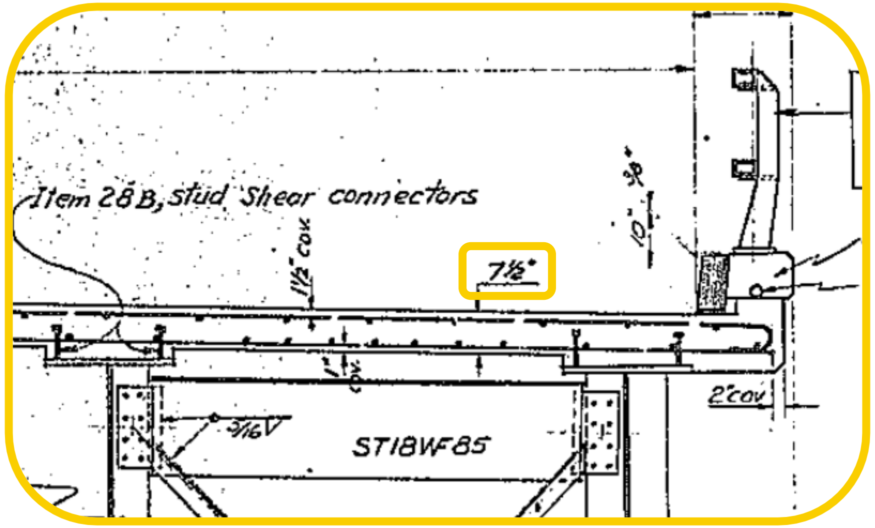


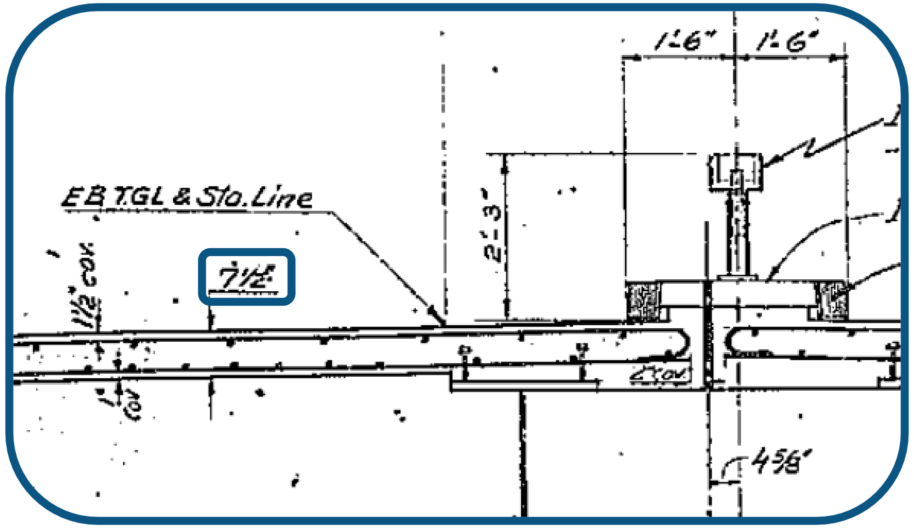


Atypical BrDR Inputs: Concrete Overlay

WB/EB







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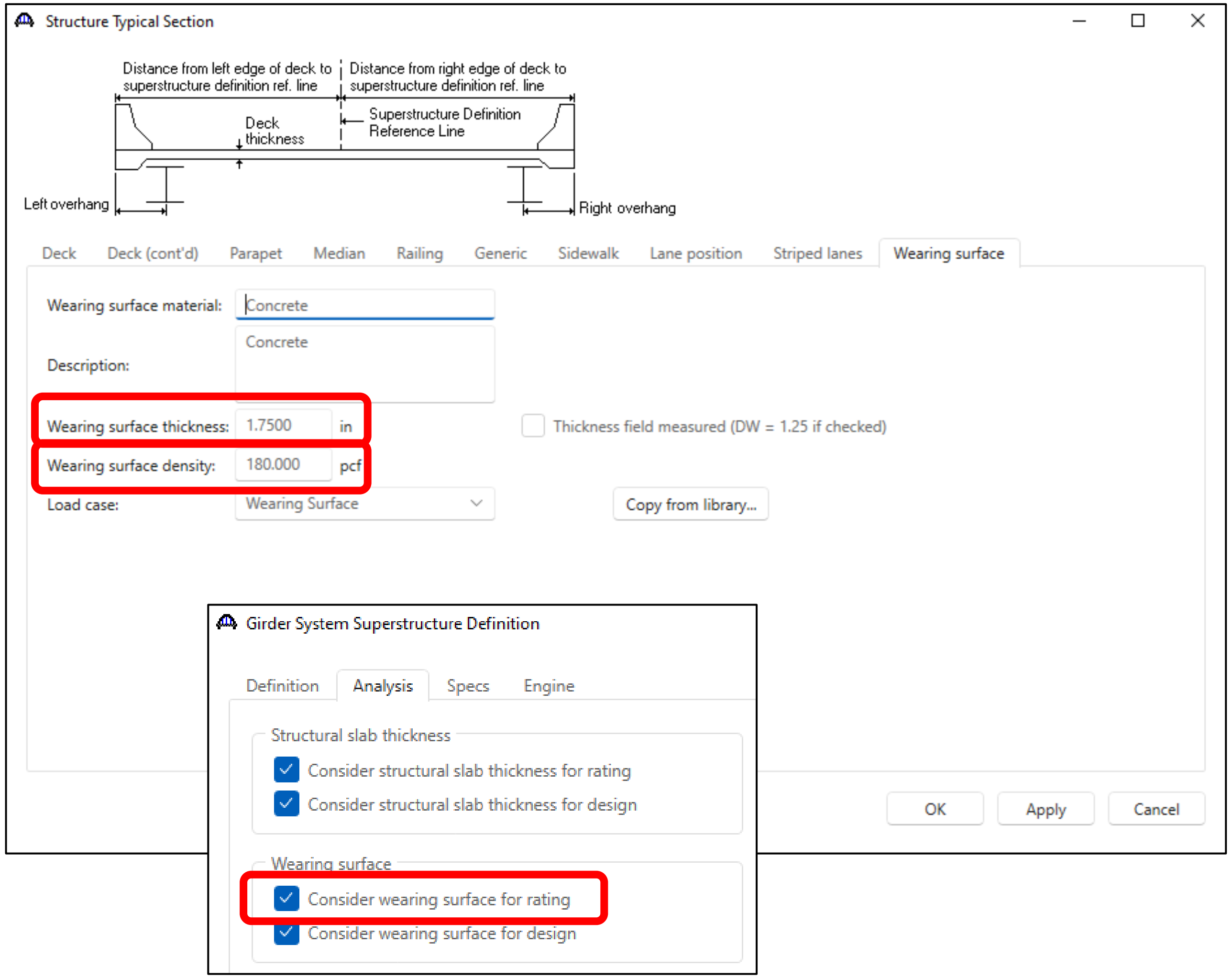
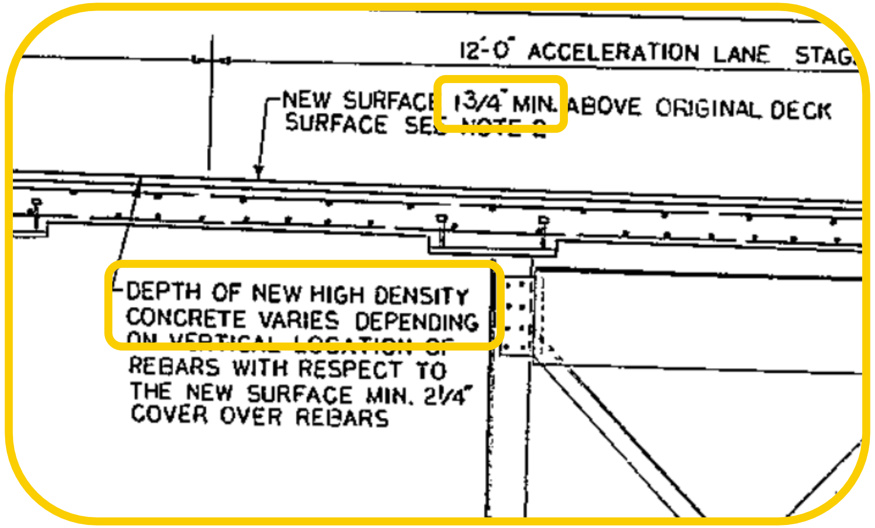
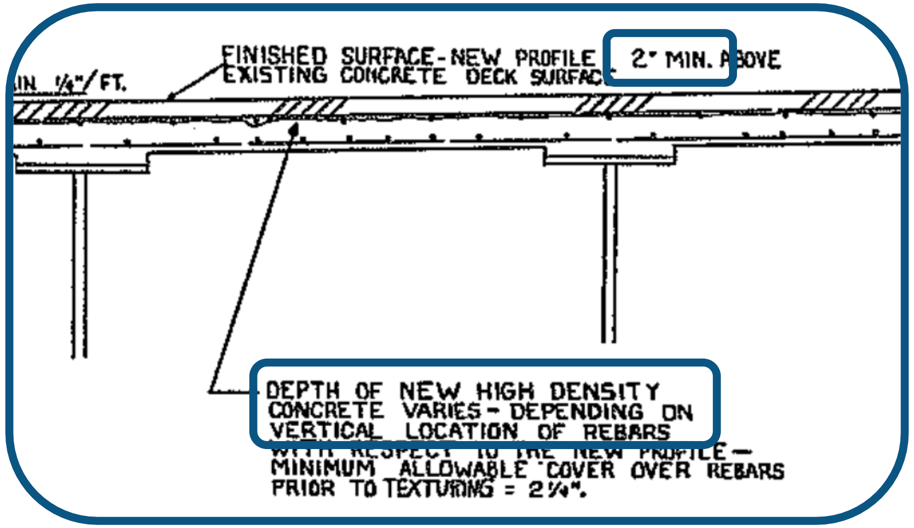
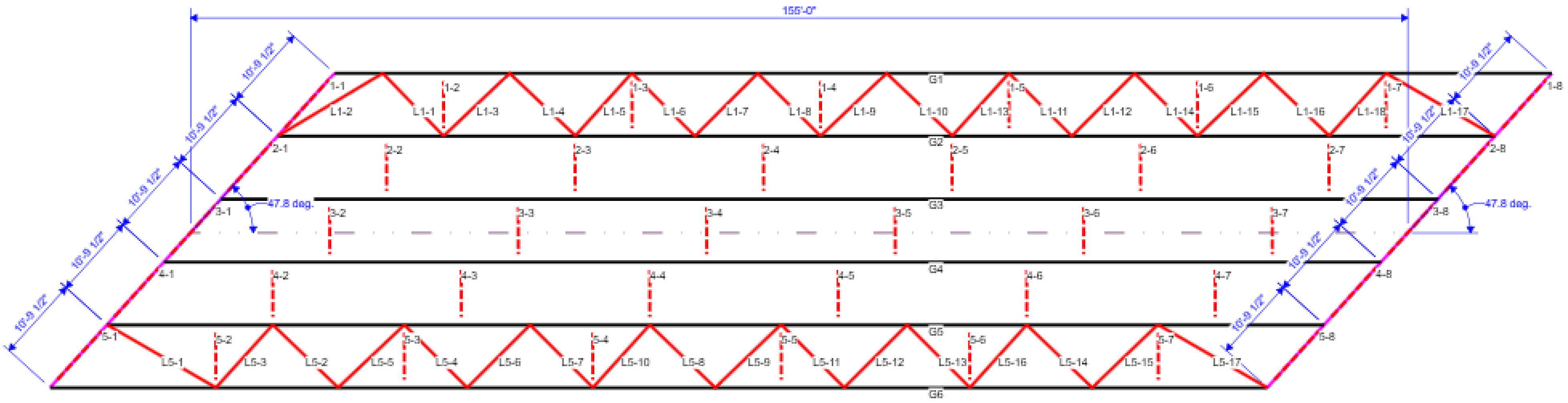




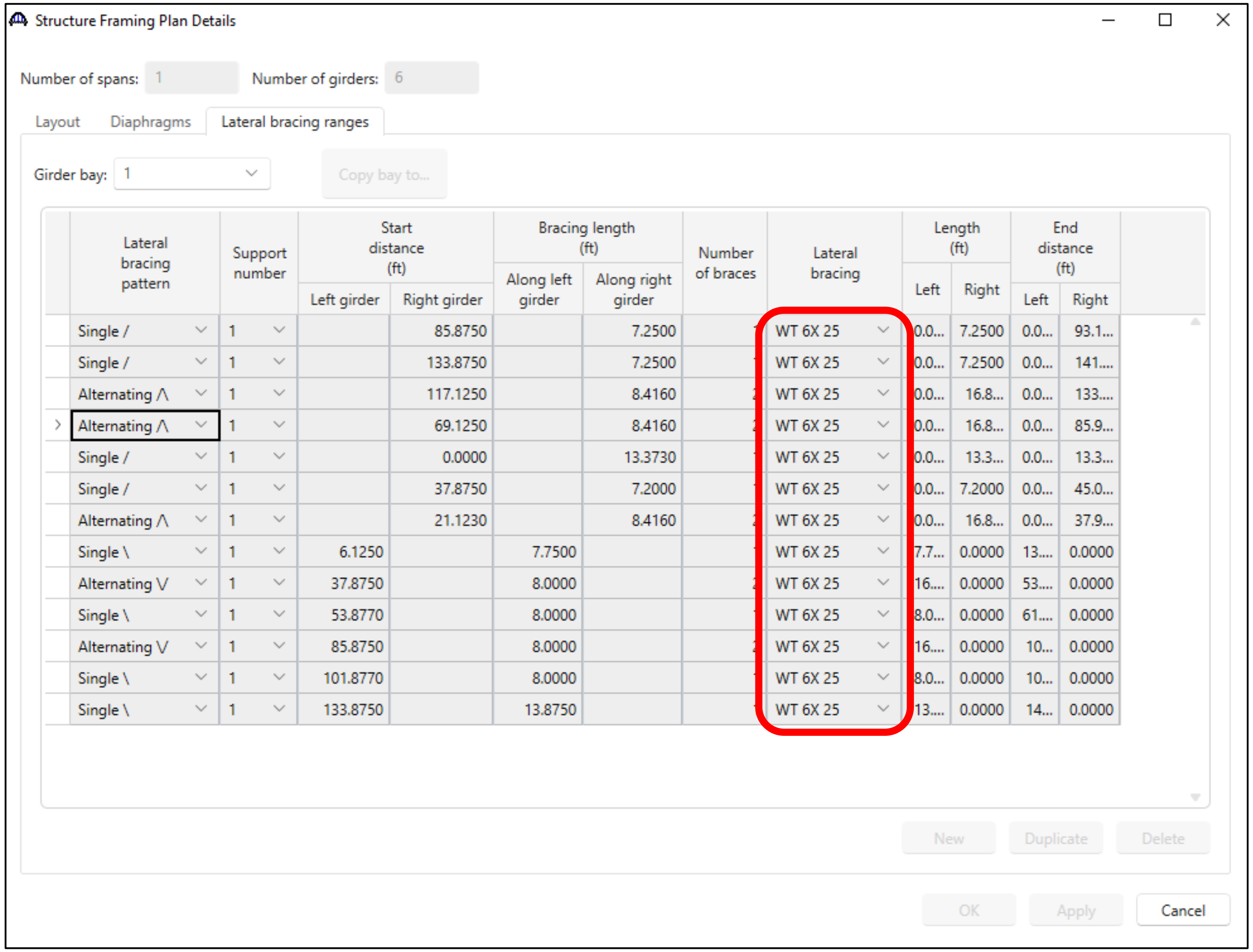


Atypical BrDR Inputs: Bottom Lateral Bracing

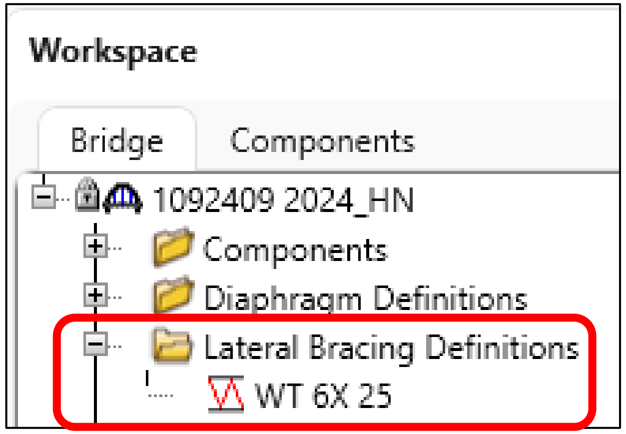
Opted to model bottom lateral supports as designed, as repairs to these welds were already included in the scope of work.



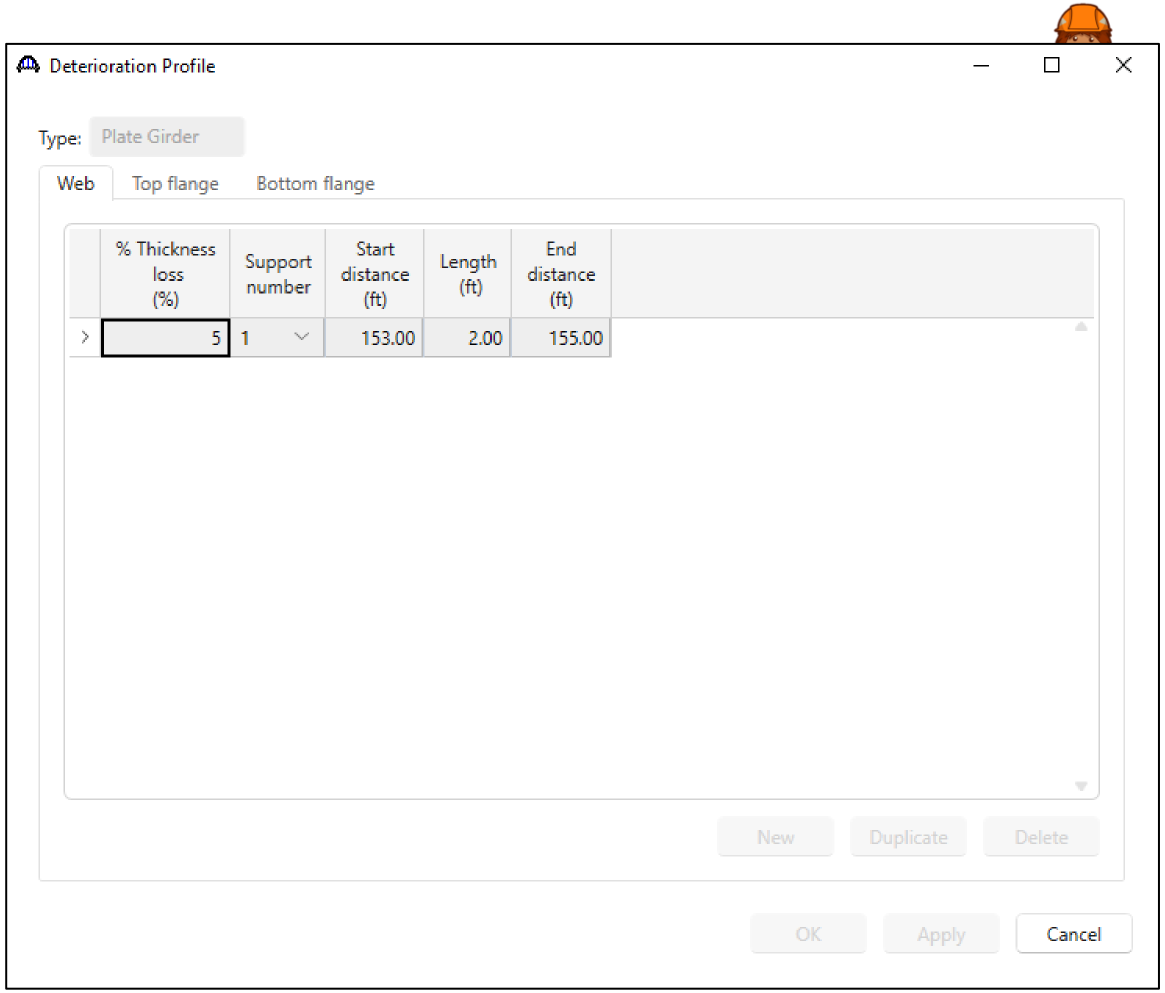
Atypical BrDR Inputs: Bottom Lateral Bracing



Lateral bracing pattern	Support number	Start distance (ft) Left girder	Start distance (ft) Right girder	Bracing length (ft) Along left girder	Bracing length (ft) Along right girder	Number of braces	Lateral bracing	Length (ft) Left	Length (ft) Right	End distance (ft) Left	End distance (ft) Right
Single /	1		85.8750		7.2500		WT 6X 25	0.0...	7.2500	0.0...	93.1...
Single /	1		133.8750		7.2500		WT 6X 25	0.0...	7.2500	0.0...	141....
Alternating /\	1		117.1250		8.4160		WT 6X 25	0.0...	16.8...	0.0...	133....
Alternating /\	1		69.1250		8.4160		WT 6X 25	0.0...	16.8...	0.0...	85.9...
Single /	1		0.0000		13.3730		WT 6X 25	0.0...	13.3...	0.0...	13.3...
Single /	1		37.8750		7.2000		WT 6X 25	0.0...	7.2000	0.0...	45.0...
Alternating /\	1		21.1230		8.4160		WT 6X 25	0.0...	16.8...	0.0...	37.9...
Single \	1	6.1250		7.7500			WT 6X 25	7.7...	0.0000	13....	0.0000
Alternating \/	1	37.8750		8.0000			WT 6X 25	16....	0.0000	53....	0.0000
Single \	1	53.8770		8.0000			WT 6X 25	8.0...	0.0000	61....	0.0000
Alternating \/	1	85.8750		8.0000			WT 6X 25	16....	0.0000	10....	0.0000
Single \	1	101.8770		8.0000			WT 6X 25	8.0...	0.0000	10....	0.0000
Single \	1	133.8750		13.8750			WT 6X 25	13....	0.0000	14....	0.0000



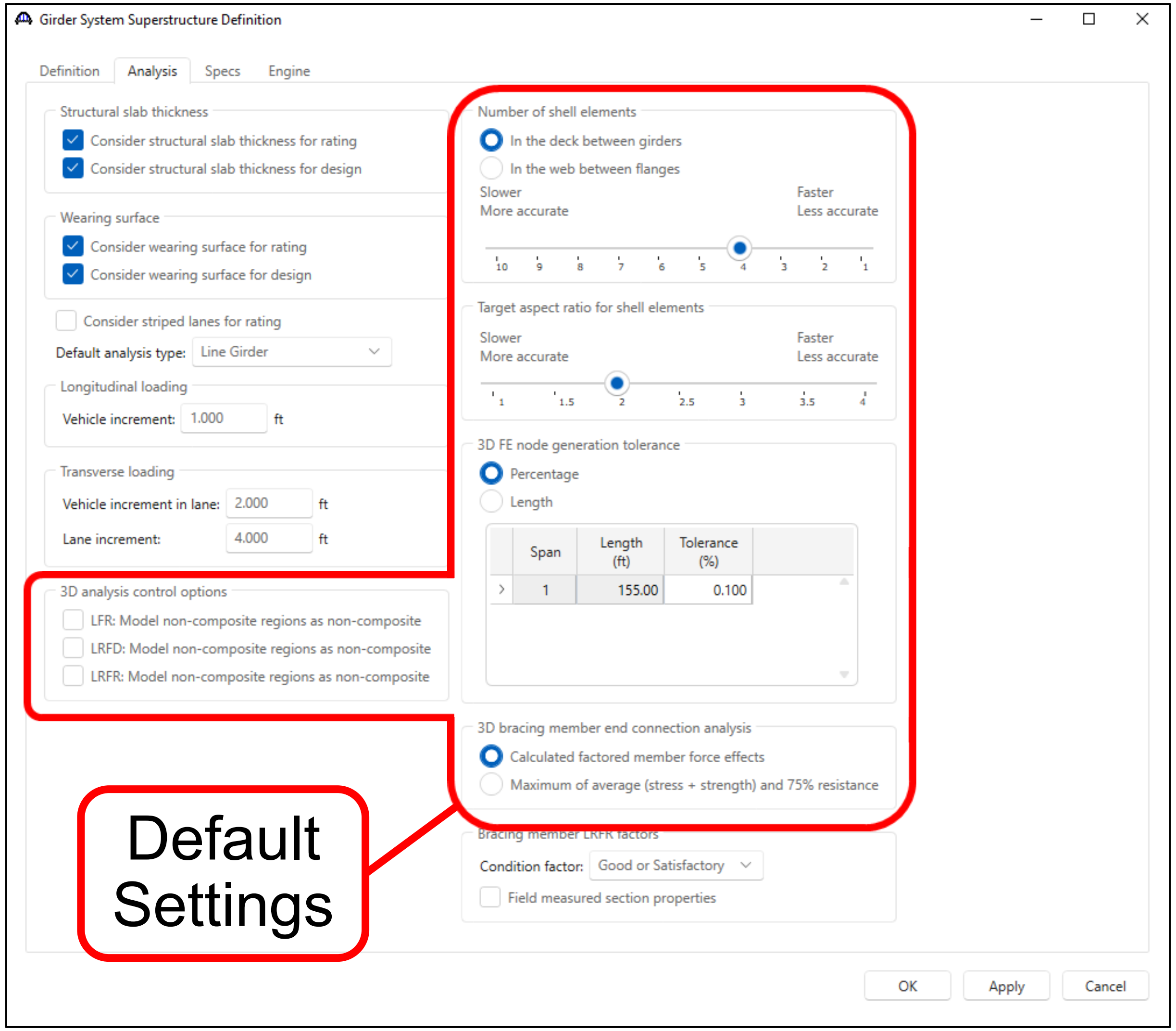
Atypical BrDR Inputs: Section Loss

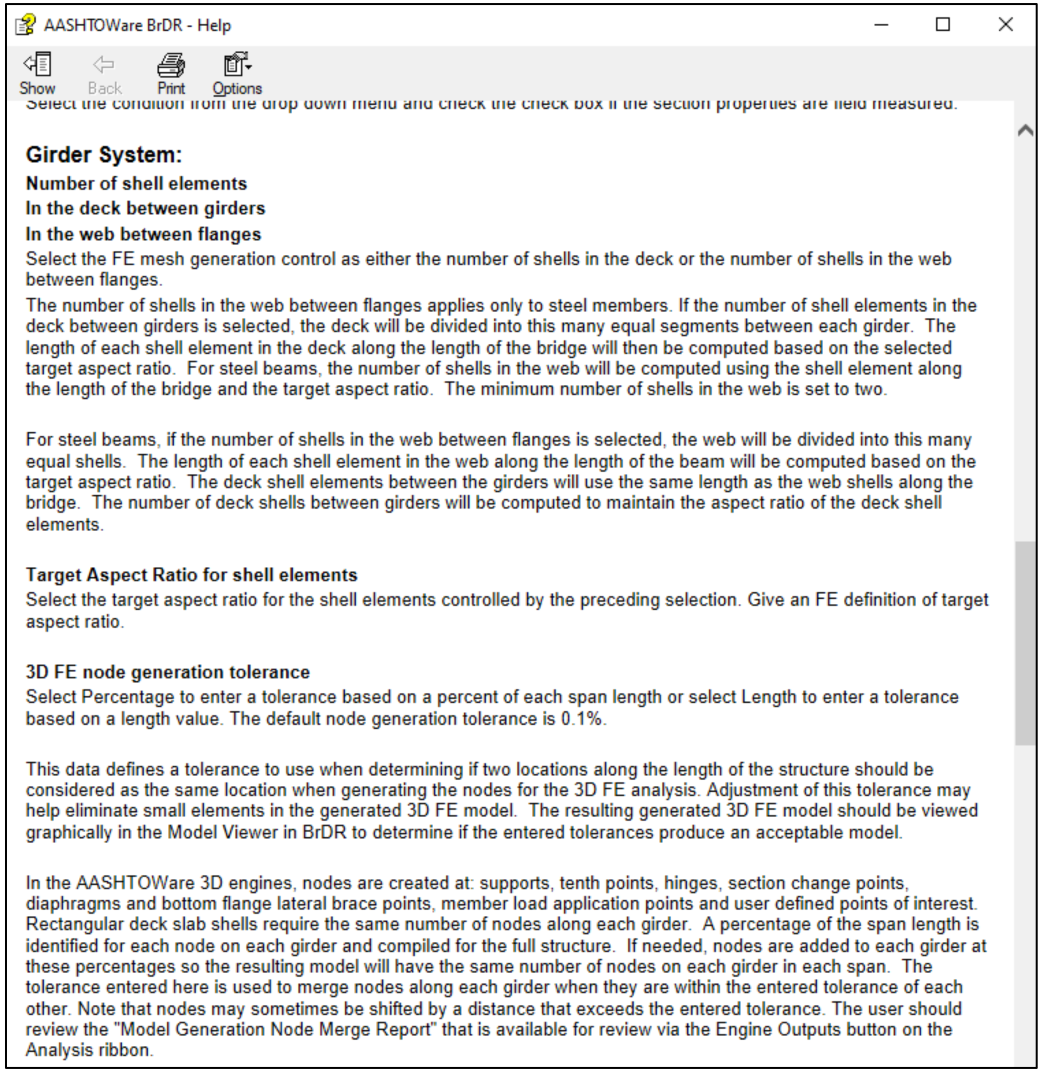


Used separate hand calculation for perforations in bearing area.

Running a 3D FEM Analysis

Running a 3D FEM Analysis: Analysis Settings




AASHTOWare BrDR - Help

Show Back Print Options

Select the condition from the drop down menu and check the check box if the section properties are field measured.

Girder System:

Number of shell elements

In the deck between girders

In the web between flanges

Select the FE mesh generation control as either the number of shells in the deck or the number of shells in the web between flanges.

The number of shells in the web between flanges applies only to steel members. If the number of shell elements in the deck between girders is selected, the deck will be divided into this many equal segments between each girder. The length of each shell element in the deck along the length of the bridge will then be computed based on the selected target aspect ratio. For steel beams, the number of shells in the web will be computed using the shell element along the length of the bridge and the target aspect ratio. The minimum number of shells in the web is set to two.

For steel beams, if the number of shells in the web between flanges is selected, the web will be divided into this many equal shells. The length of each shell element in the web along the length of the beam will be computed based on the target aspect ratio. The deck shell elements between the girders will use the same length as the web shells along the bridge. The number of deck shells between girders will be computed to maintain the aspect ratio of the deck shell elements.

Target Aspect Ratio for shell elements

Select the target aspect ratio for the shell elements controlled by the preceding selection. Give an FE definition of target aspect ratio.

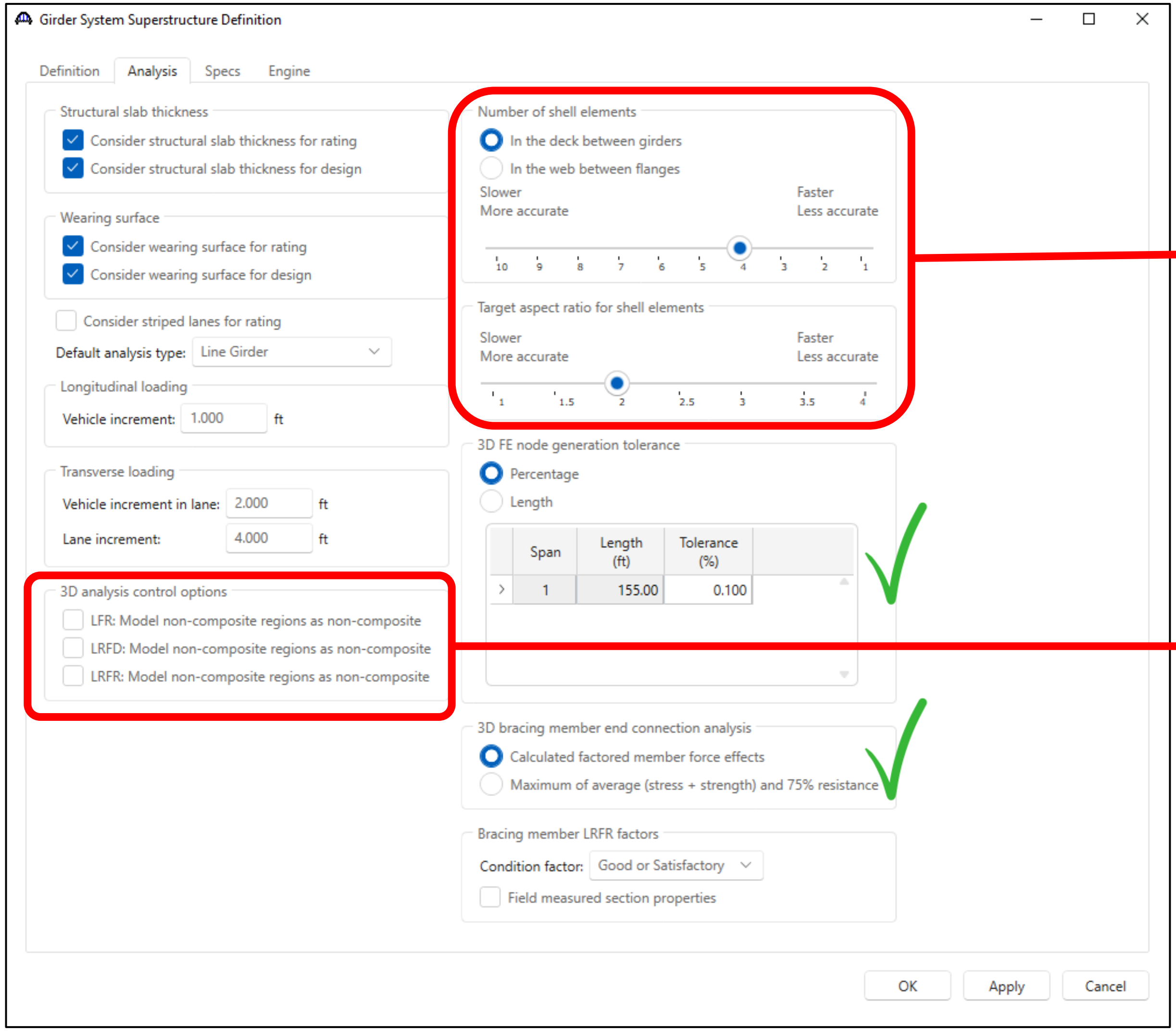
3D FE node generation tolerance

Select Percentage to enter a tolerance based on a percent of each span length or select Length to enter a tolerance based on a length value. The default node generation tolerance is 0.1%.

This data defines a tolerance to use when determining if two locations along the length of the structure should be considered as the same location when generating the nodes for the 3D FE analysis. Adjustment of this tolerance may help eliminate small elements in the generated 3D FE model. The resulting generated 3D FE model should be viewed graphically in the Model Viewer in BrDR to determine if the entered tolerances produce an acceptable model.

In the AASHTOWare 3D engines, nodes are created at: supports, tenth points, hinges, section change points, diaphragms and bottom flange lateral brace points, member load application points and user defined points of interest. Rectangular deck slab shells require the same number of nodes along each girder. A percentage of the span length is identified for each node on each girder and compiled for the full structure. If needed, nodes are added to each girder at these percentages so the resulting model will have the same number of nodes on each girder in each span. The tolerance entered here is used to merge nodes along each girder when they are within the entered tolerance of each other. Note that nodes may sometimes be shifted by a distance that exceeds the entered tolerance. The user should review the "Model Generation Node Merge Report" that is available for review via the Engine Outputs button on the Analysis ribbon.

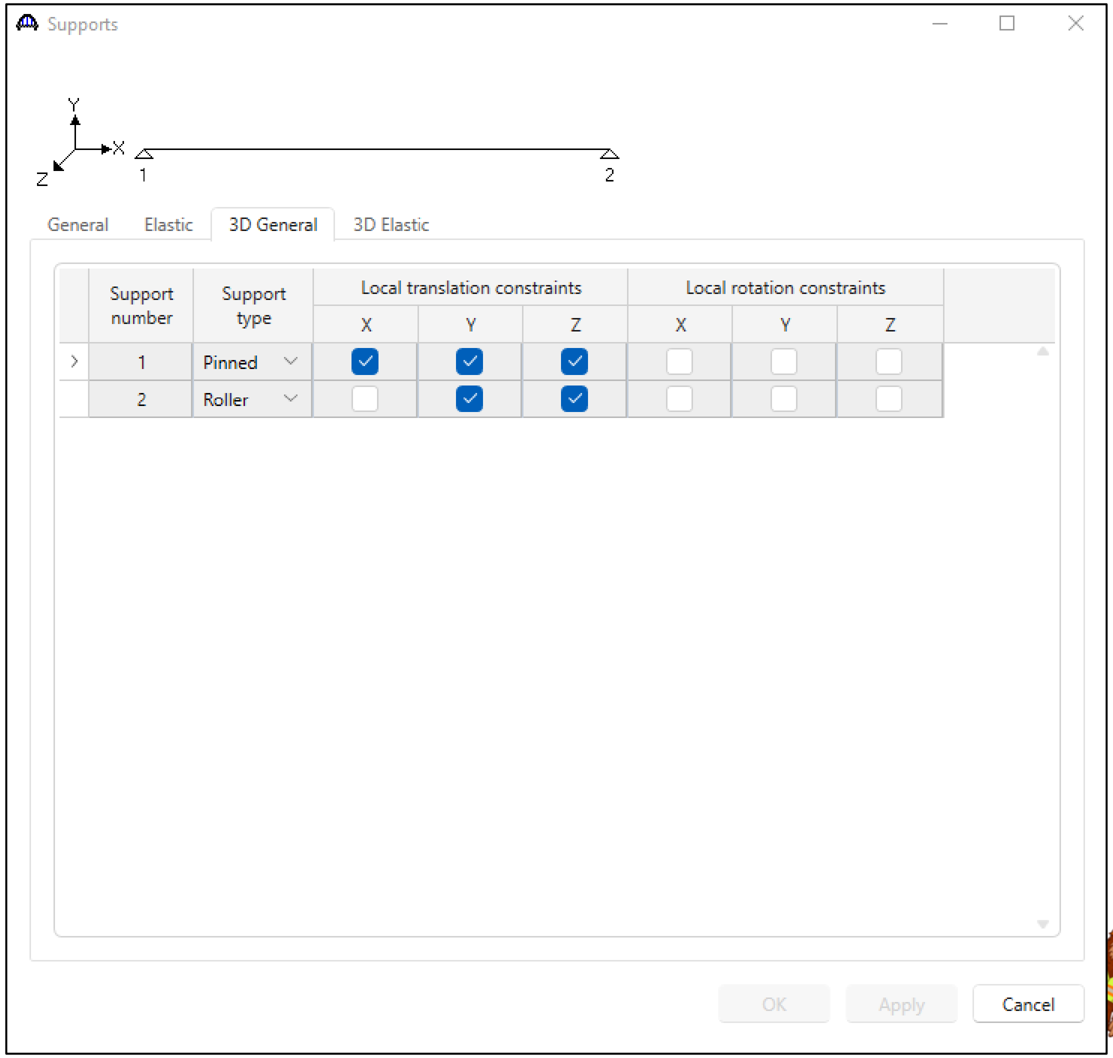
Running a 3D FEM Analysis: Analysis Settings



Adjust speed for more/less accurate results. Recommend starting with less accuracy for design.

Check on boxes as needed.

Running a 3D FEM Analysis: Supports



AASHTOWare BrDR - Help

Show Back Print Options

Support Constraints - Beam: 3D General

The 3D General tab of the Support Constraints - Beam window allows you to define 3D general support constraints. You must select a constraint on the Support Constraints - Beam: 3D General tab in order to be able to input a spring constant on the Support Constraints - Beam: 3D Elastic tab. Enter the required information and click another tab or the **OK** button.

Engine Related Help

Support Number
Displays each of the beam support numbers.

Support Type
Select the support type as either pinned, roller, fixed, free, or other. Check marks will automatically appear in the appropriate boxes for translation and rotation constraints to correspond with the selected support type.

Translation Constraints

X
Check the box if the support is constrained from moving in the X (longitudinal) direction. The appropriate support type will automatically change to correspond with the checked translation and rotation constraints.

Y
Check the box if the support is constrained from moving in the Y (vertical) direction. The appropriate support type will automatically change to correspond with the checked translation and rotation constraints.

Z
Check the box if the support is constrained from moving in the Z direction. The appropriate support type will automatically change to correspond with the checked translation and rotation constraints.

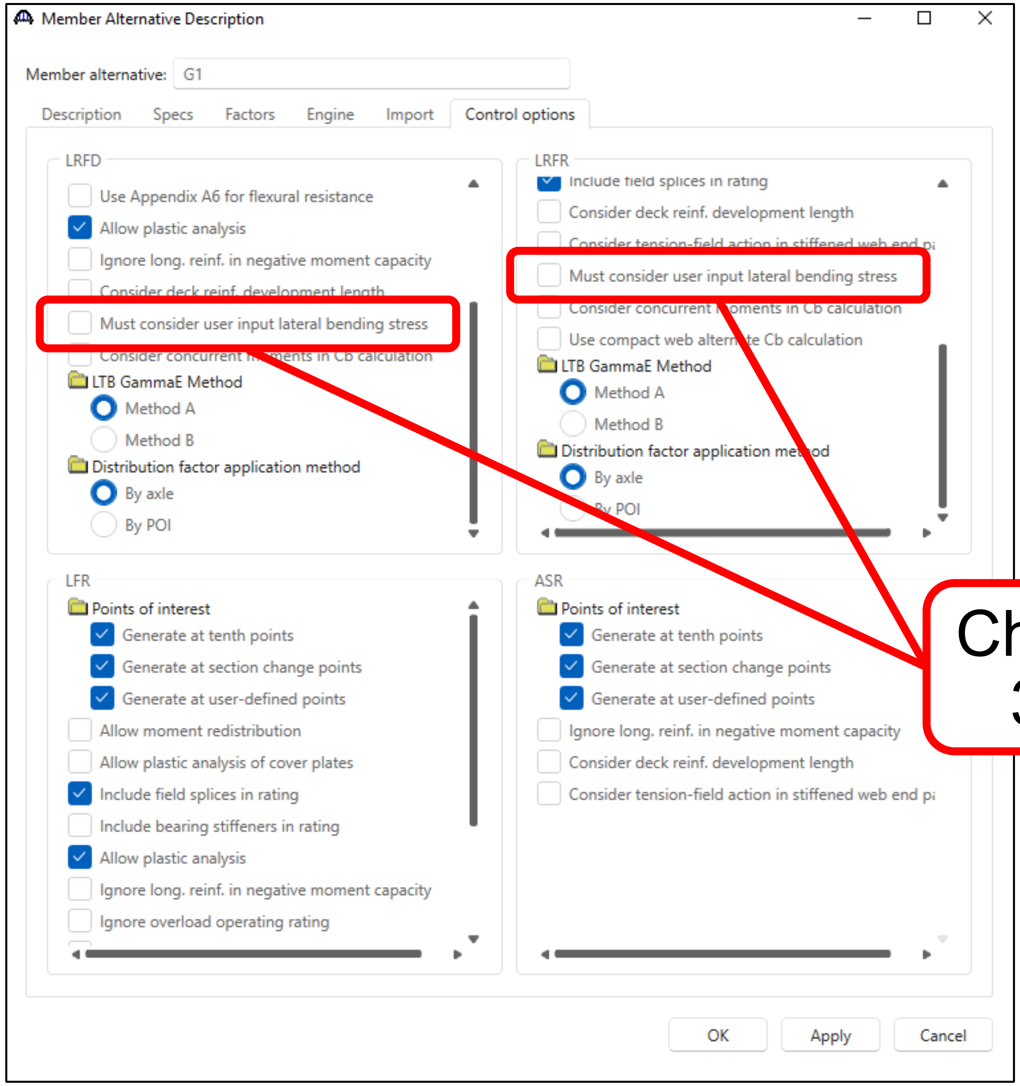
Rotation Constraints

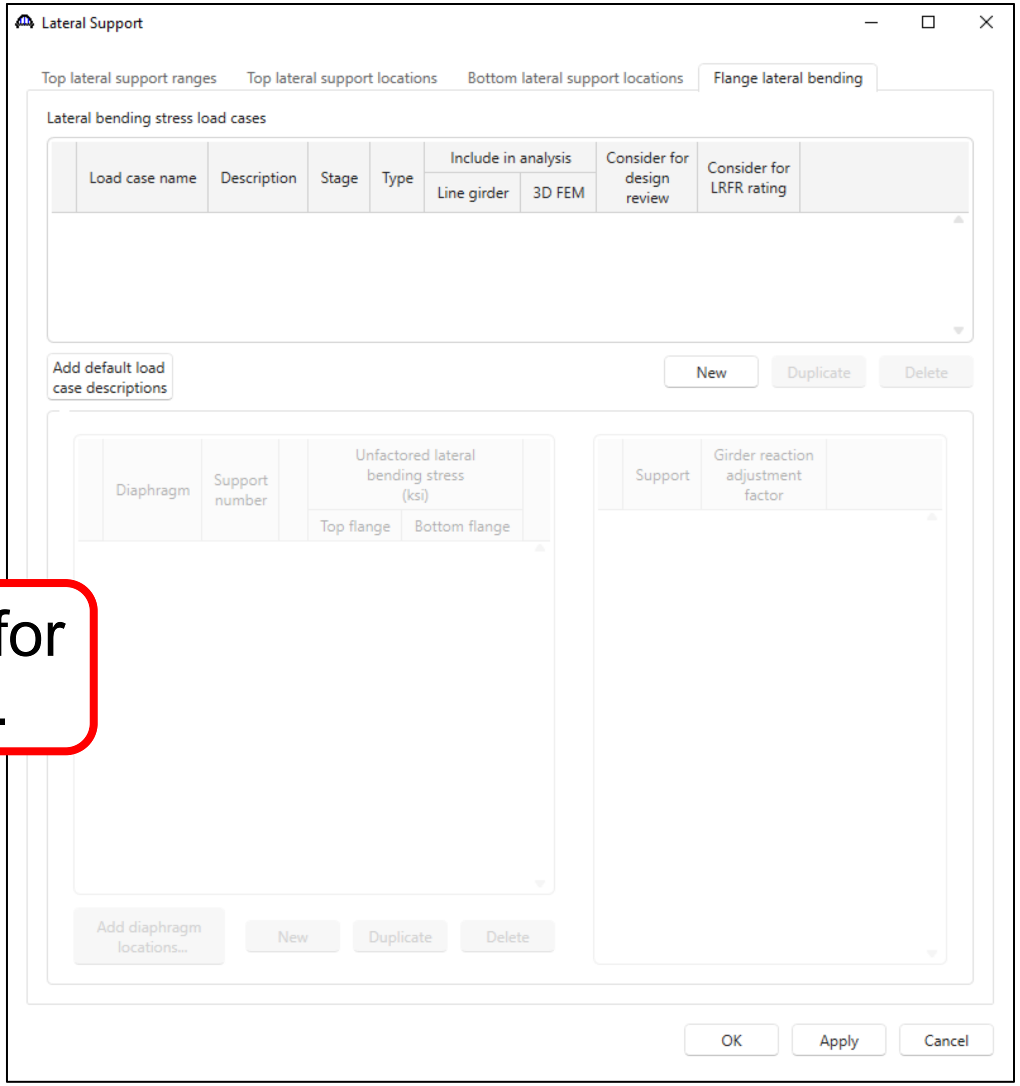
X
Check the box if the support is constrained from rotating about the X axis. The appropriate support type will automatically change to correspond with the checked translation and rotation constraints.

Y
Check the box if the support is constrained from rotating about the Y axis. The appropriate support type will automatically change to correspond with the checked translation and rotation constraints.

Z
Check the box if the support is constrained from rotating about the Z axis. The appropriate support type will automatically change to correspond with the checked translation and rotation constraints.

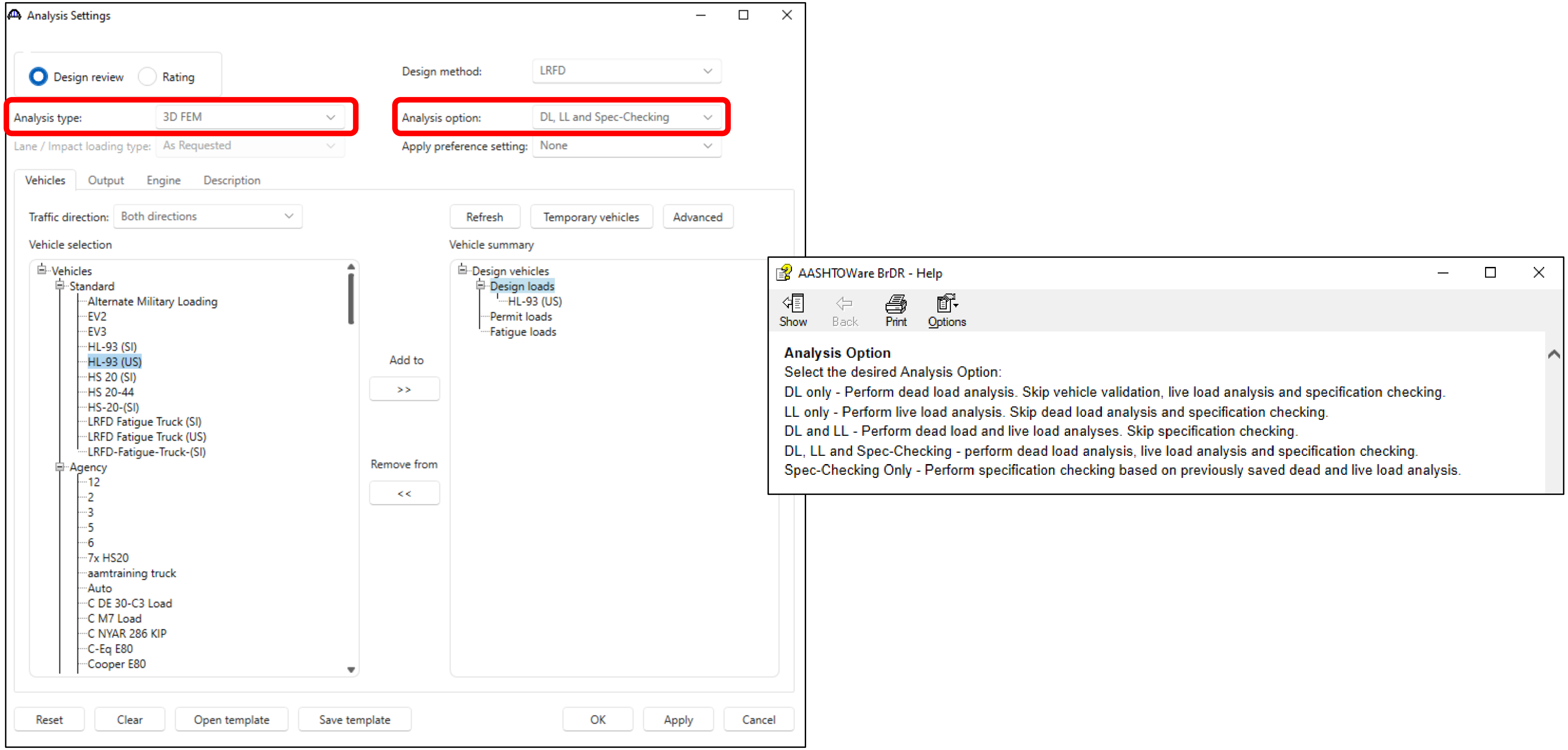
Running a 3D FEM Analysis: Lateral Bending





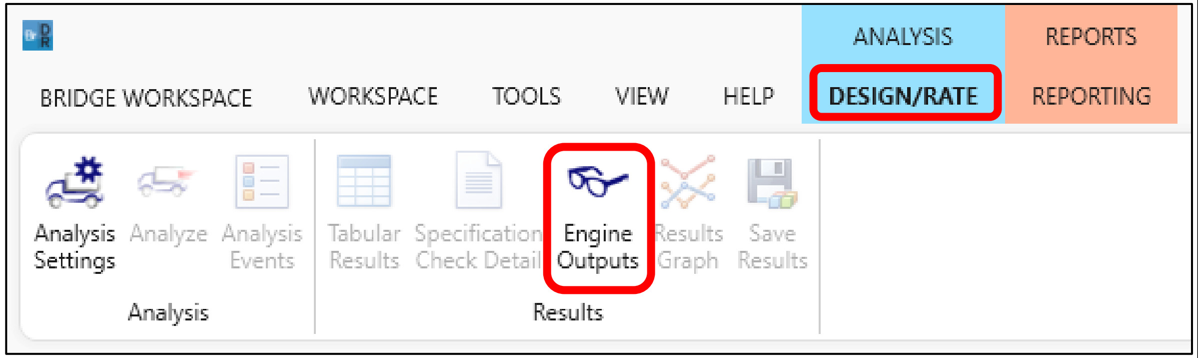
Check off for 3D FEM.

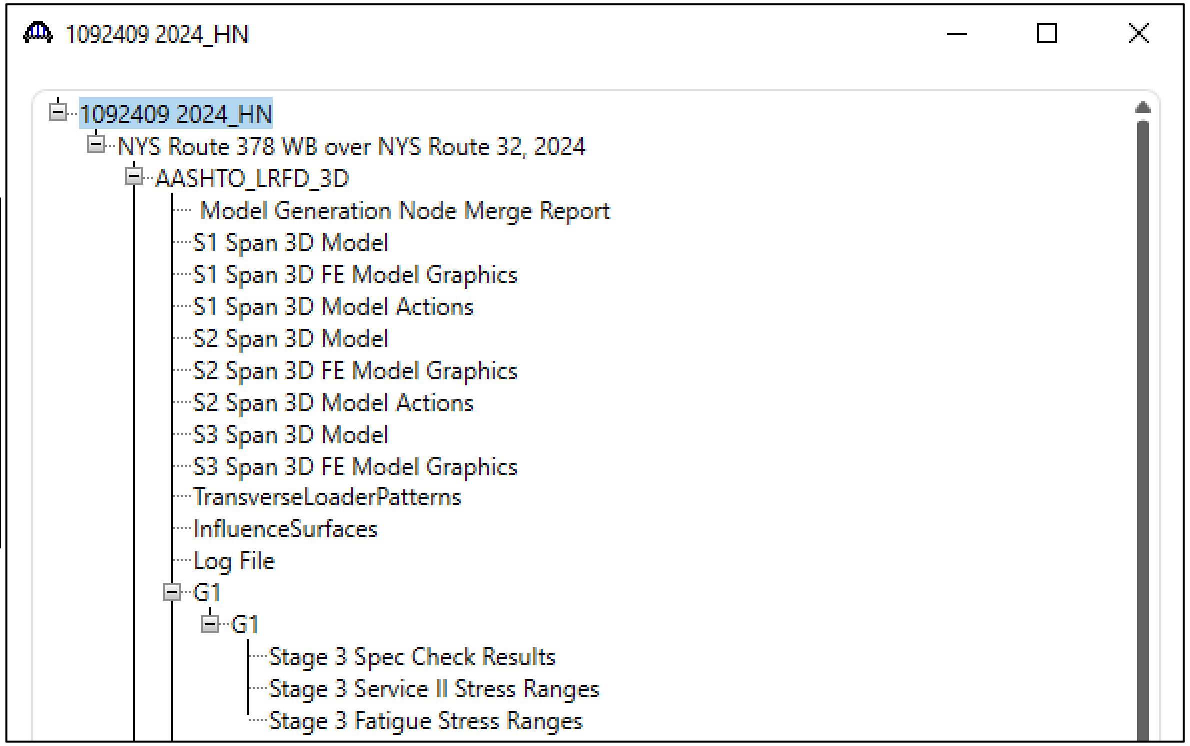
Running a 3D FEM Analysis: Running the Analysis



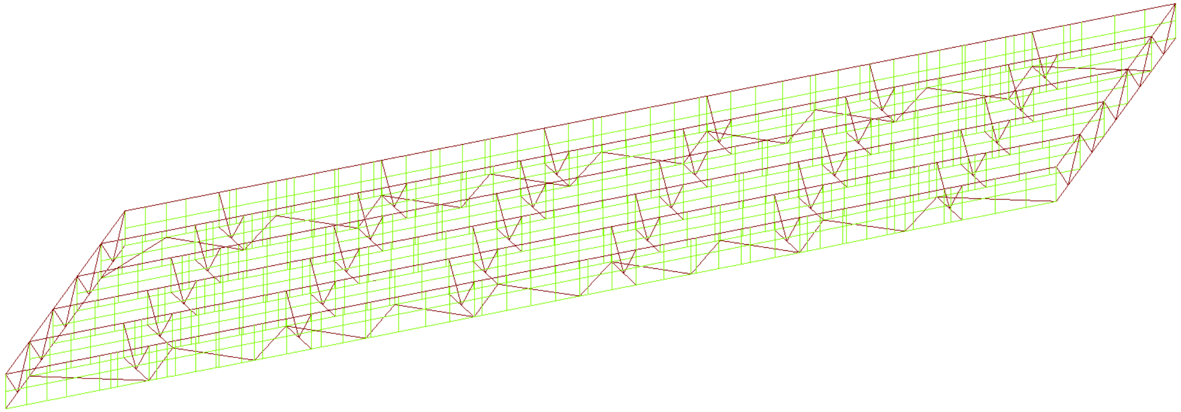
Interpreting the Results

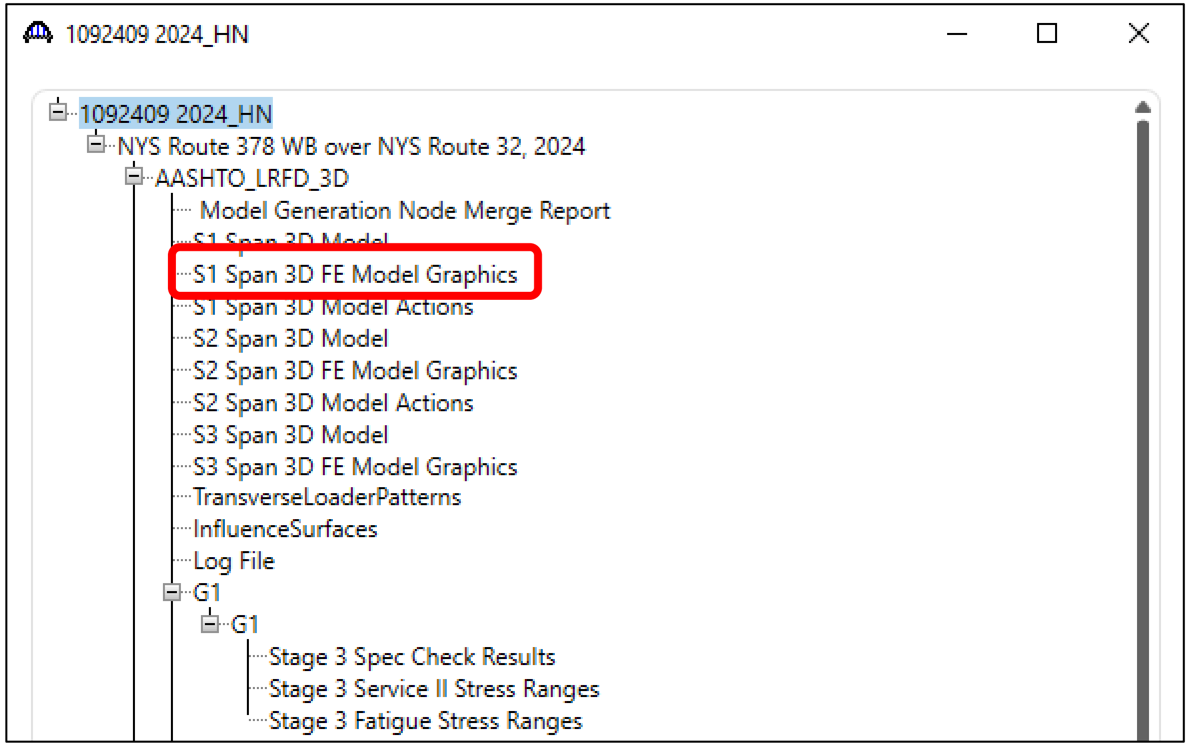
Interpreting the Results: FE Model Graphics



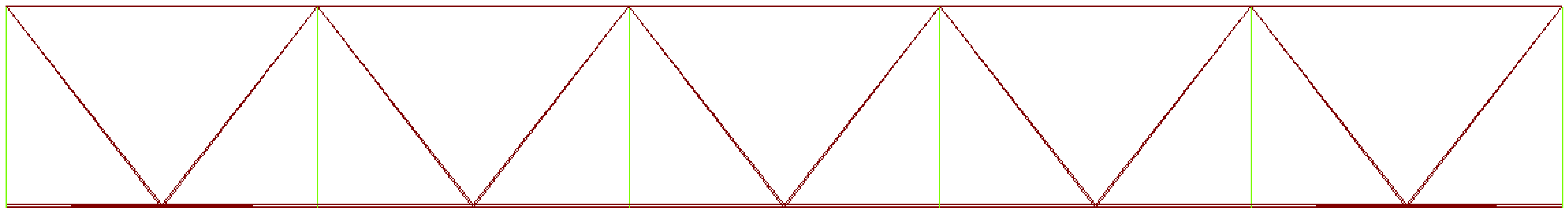


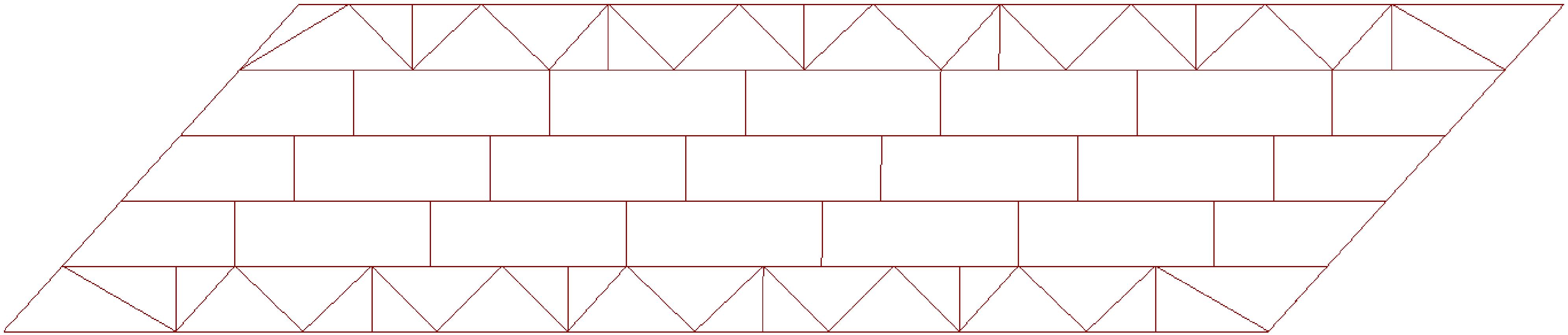
Interpreting the Results: FE Model Graphics



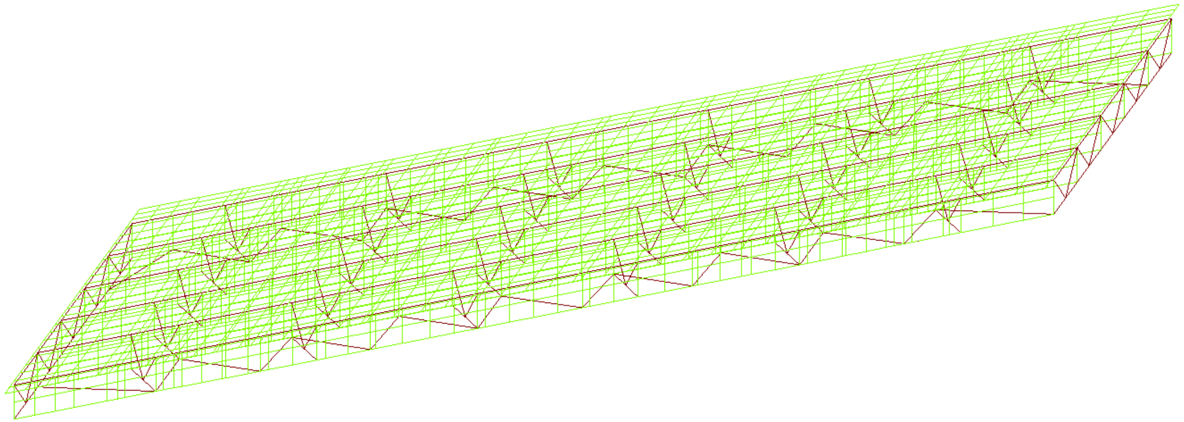


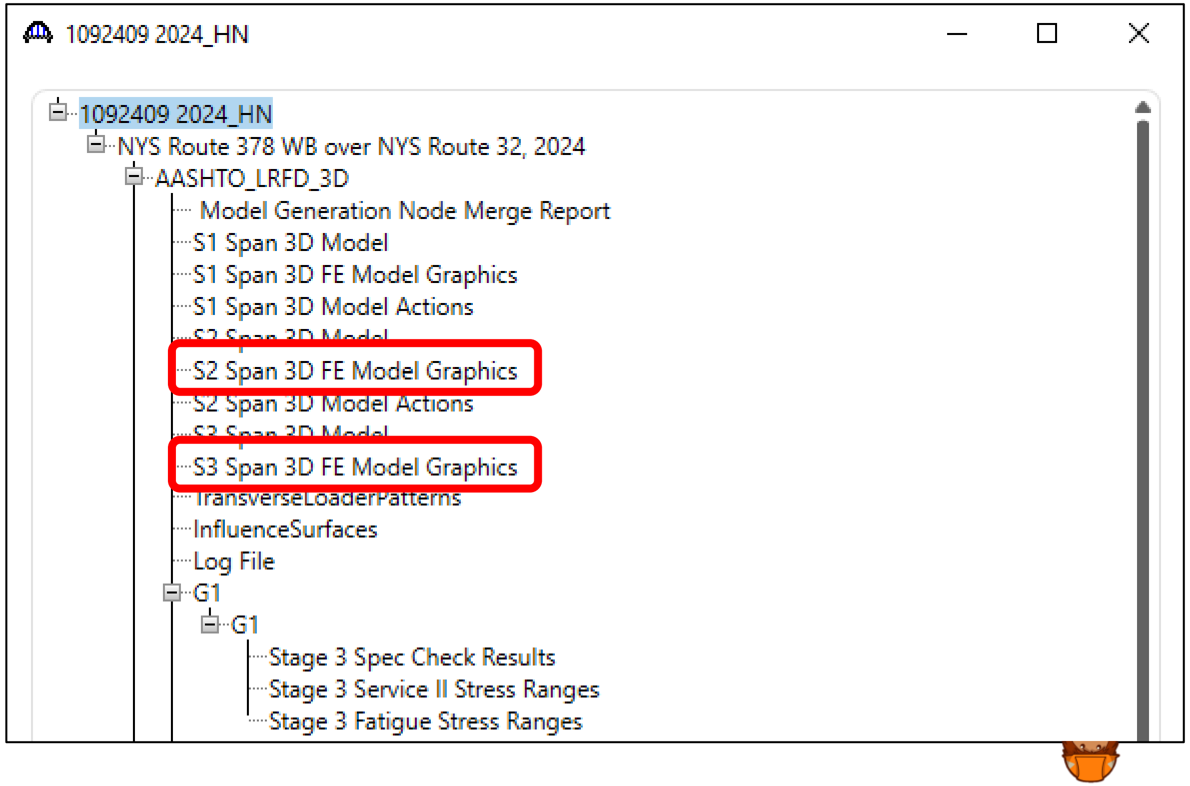
Interpreting the Results: FE Model Graphics



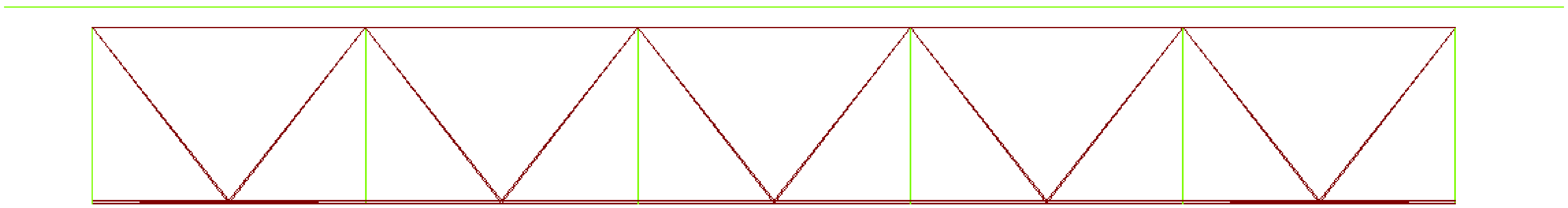


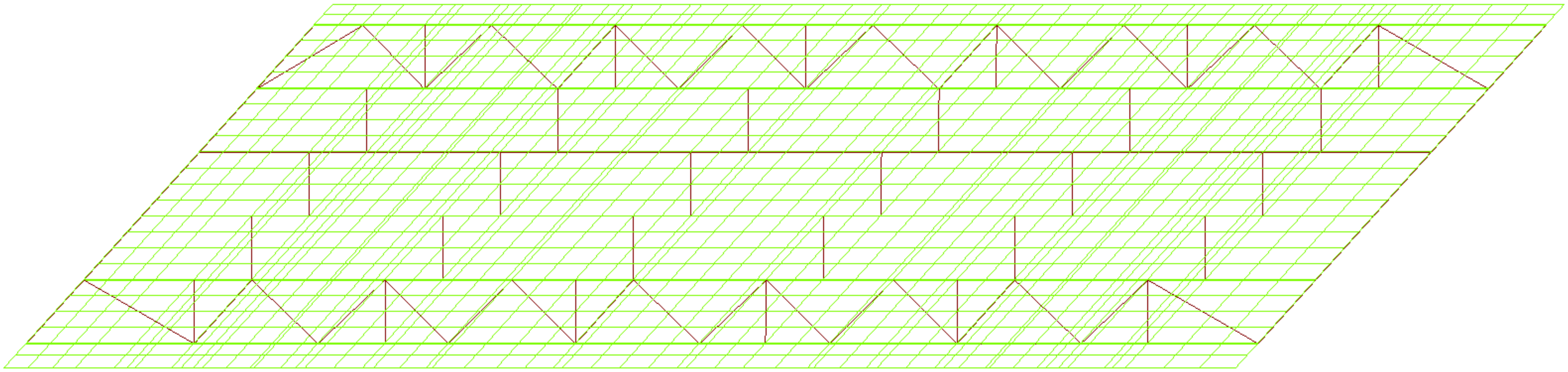
Interpreting the Results: FE Model Graphics



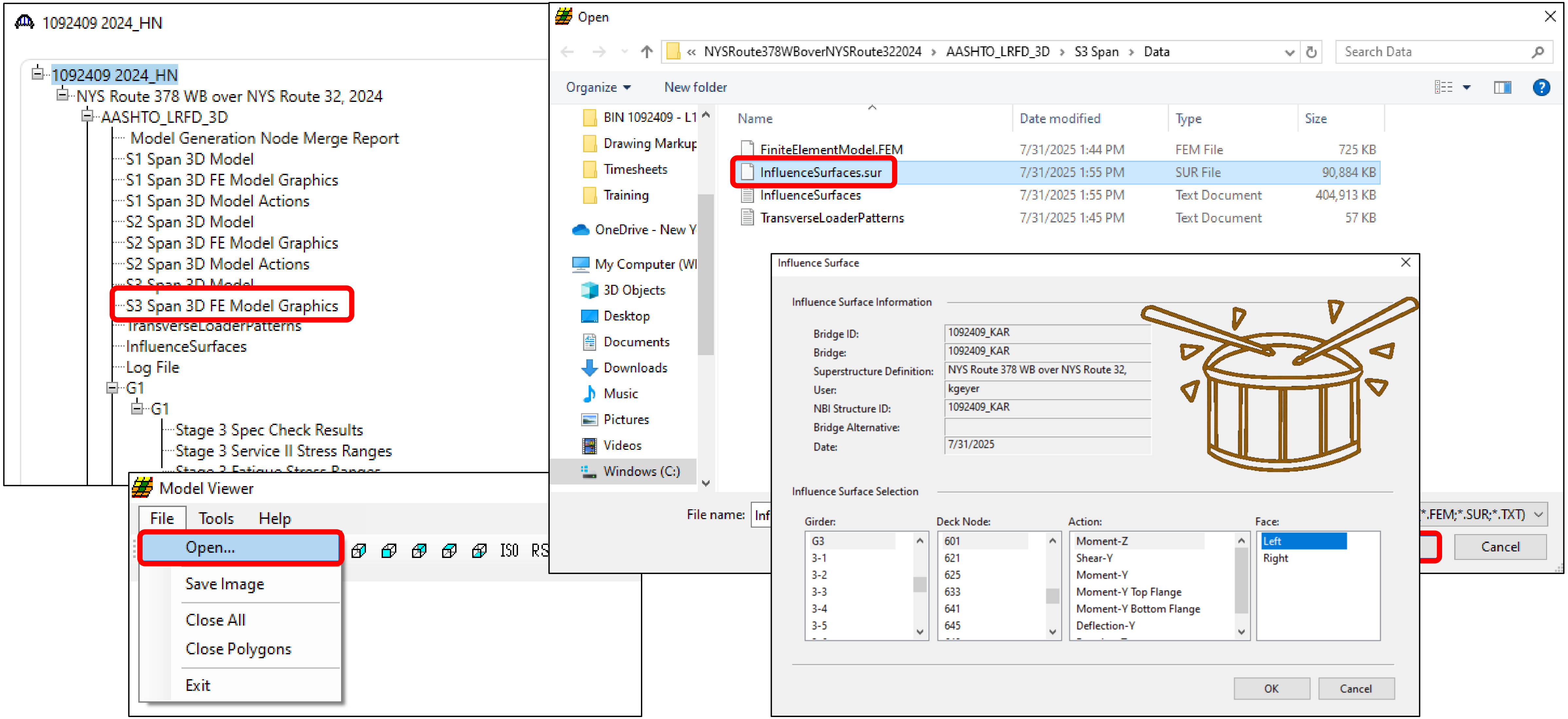


Interpreting the Results: FE Model Graphics

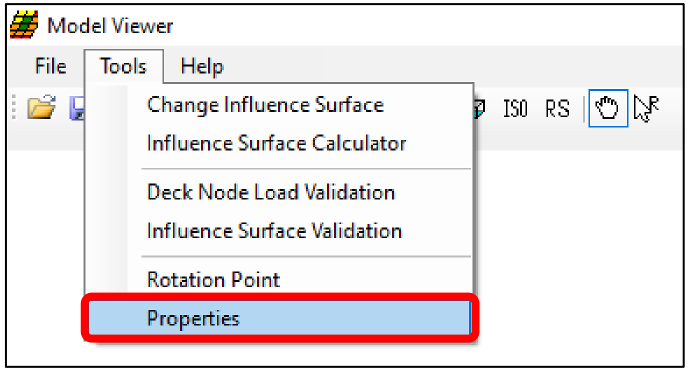


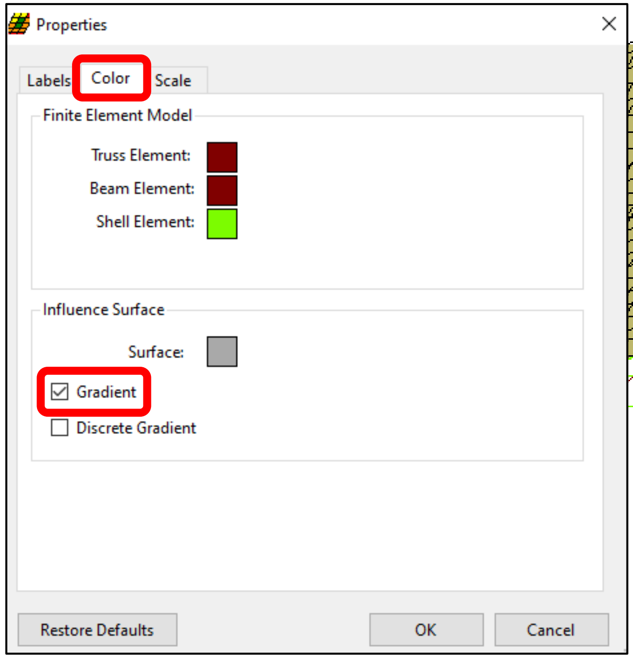


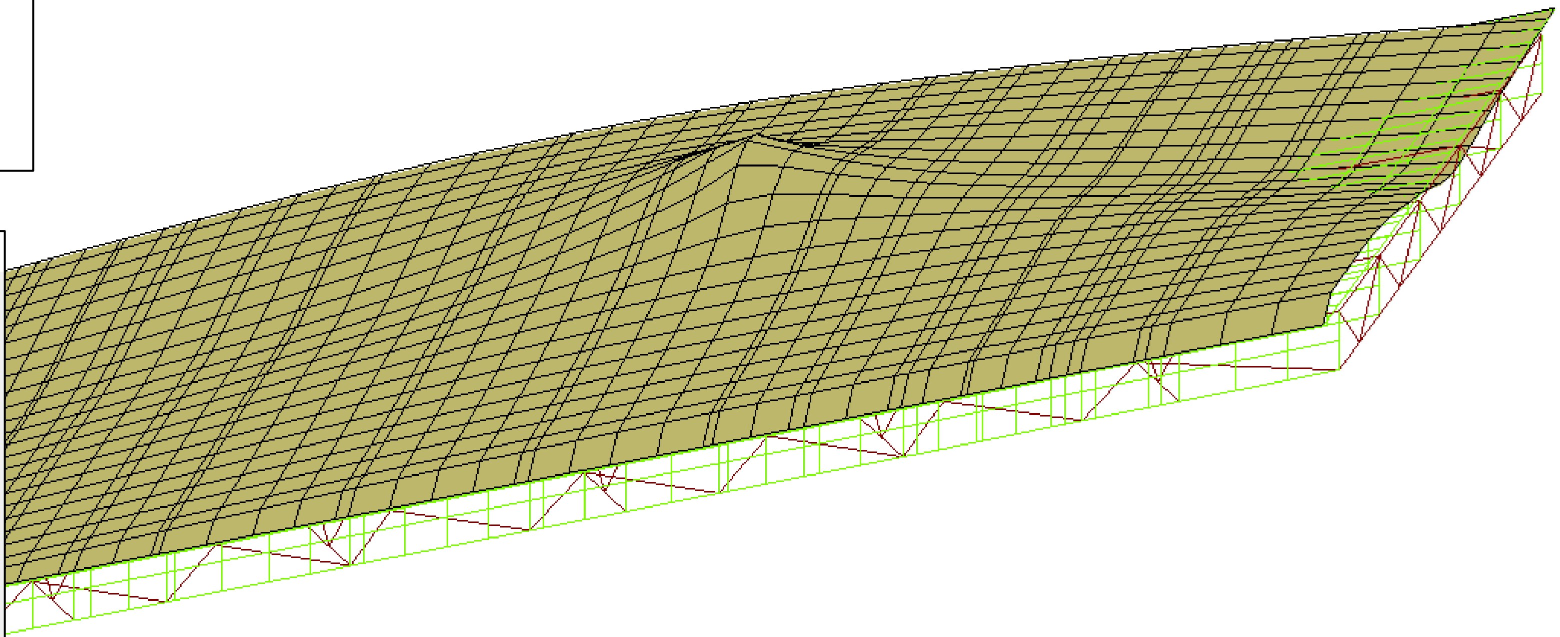
Interpreting the Results: Influence Surfaces



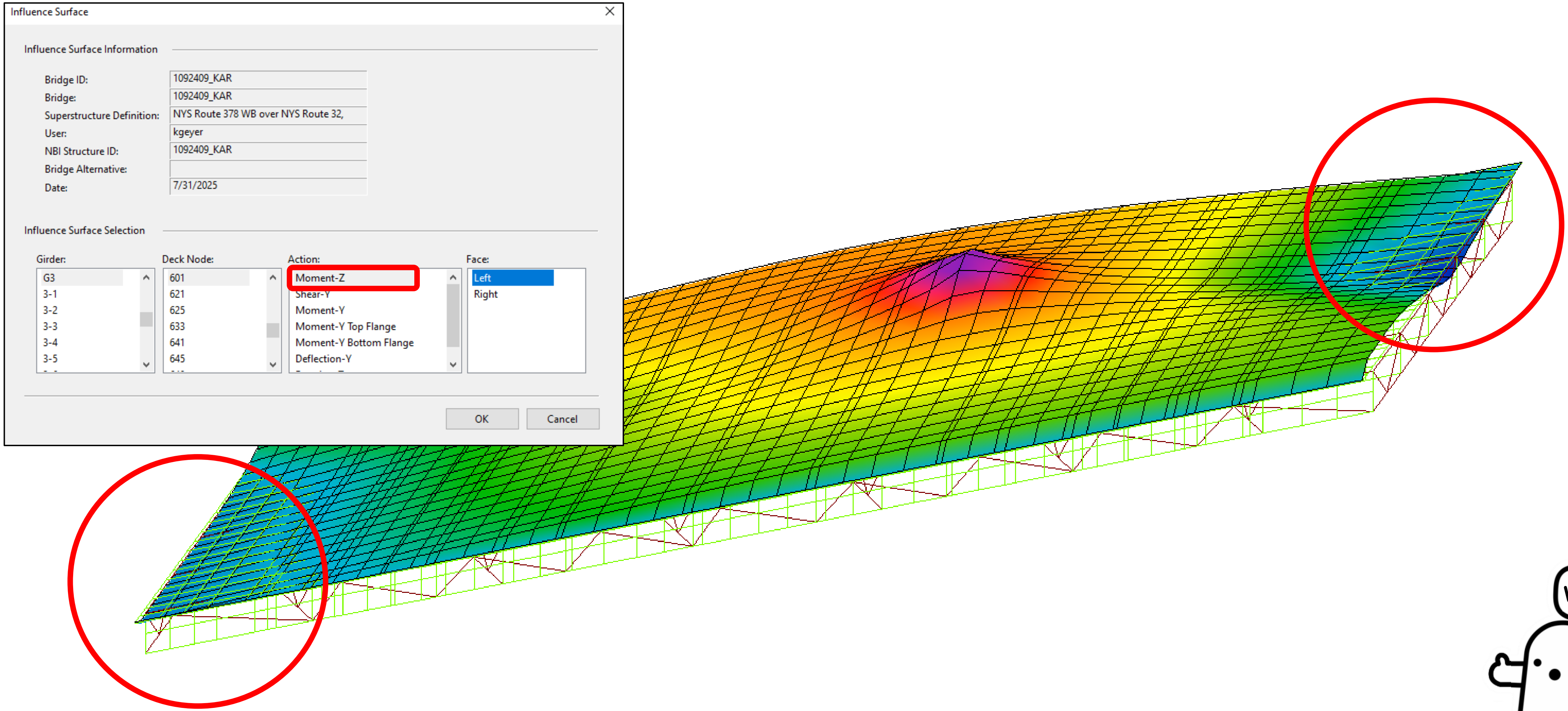
Interpreting the Results: Influence Surfaces

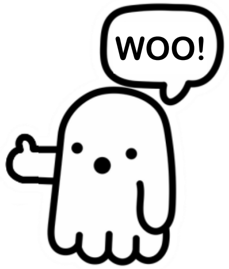






Interpreting the Results: Influence Surfaces





Interpreting the Results: Sanity Check

Design and Performance of Highly Skewed Deck Girder Bridges

Pinar Okumus, Ph. D.
Mauricio Diaz Arancibia
University at Buffalo, the State University of New York

Michael G. Oliva, Ph. D.
University of Wisconsin, Madison

WisDOT ID no. 0092-16-05

May 2018

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WHRP

WISCONSIN HIGHWAY RESEARCH PROGRAM

WISCONSIN DOT
PUTTING RESEARCH TO WORK

Problems Associated with Skew

A literature review, interviews with Wisconsin regional bridge maintenance engineers, a survey to New York State bridge maintenance engineers and field inspections revealed the following related to high skew:

- Skew bridge geometries can affect girder live load distribution due to modified load paths. Due to the skewed geometry, the shortest path to supports becomes the region joining obtuse corners of a span. Higher shear forces are seen near obtuse corners, while reduced shear forces are found near acute corners, possibly leading to uplift. In addition, girder moments are reduced with increasing skews. Torsion and negative moments at bridge ends also develop in skewed geometries.

Final Rating Results and Rehabilitation Scope

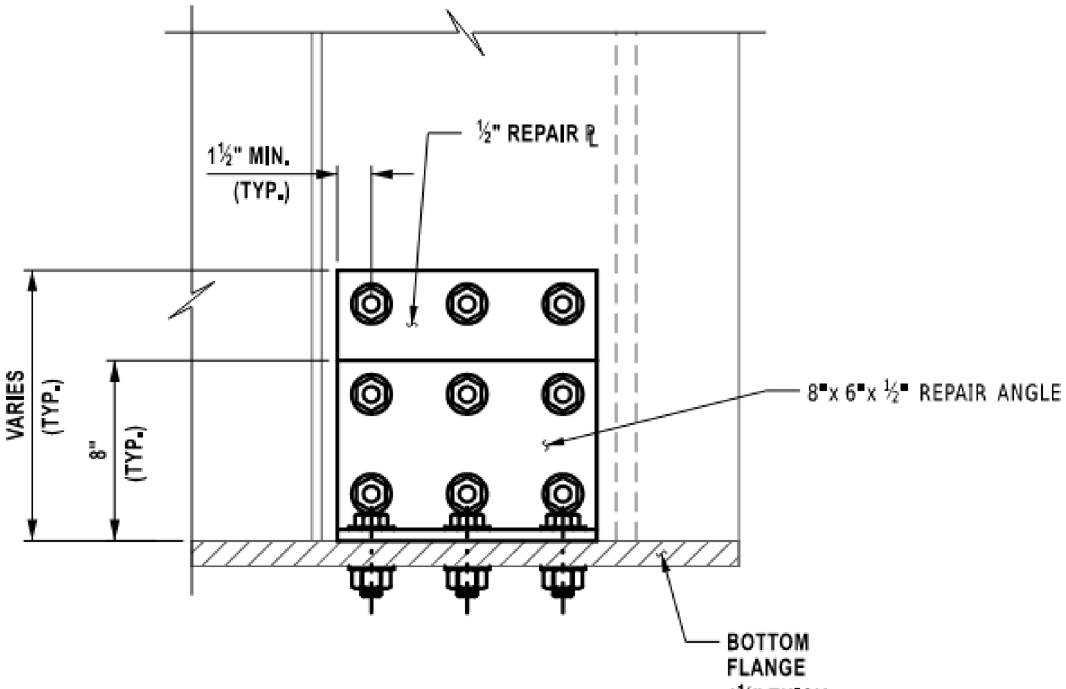
Final Rating Results and Rehabilitation Scope: LFR and LRFR Ratings

HS20 — LOAD FACTOR RATING SUMMARY TABLE			
Rating Type	HS Equivalent	Tonnage	Controlling Member
INVENTORY	HS 40.55	73.00 Tons*	G12 @ 150.0 ft, Shear – Steel
OPERATING	HS 67.77	122.00 Tons*	G12 @ 150.0 ft, Shear – Steel

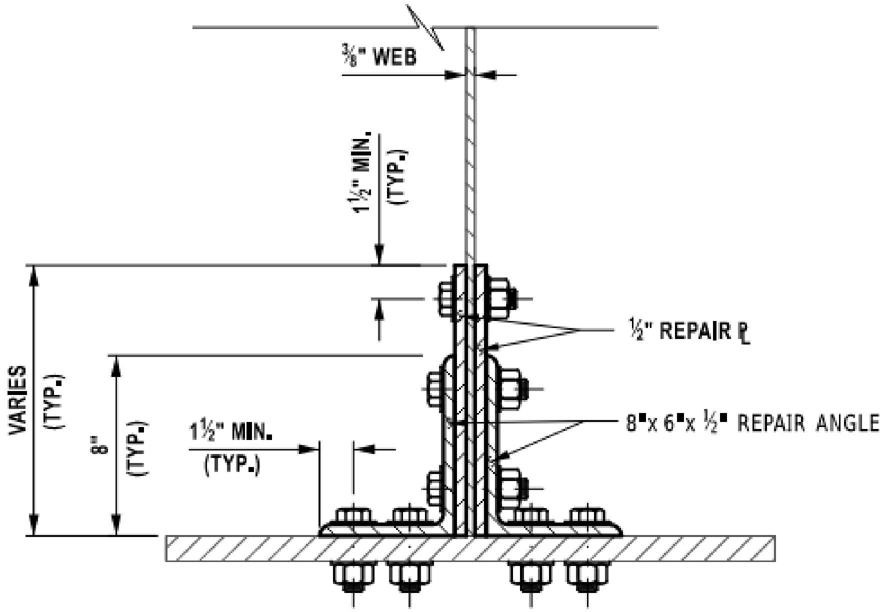
HL93 — LOAD AND RESISTANCE FACTOR RATING SUMMARY TABLE			
Rating Type	Truck	Rating	Controlling Member
INVENTORY	HL-93	0.971	G11 @ 130.00 ft, Strength I- Steel Flex. Stress
OPERATING	HL-93	1.259	G11 @ 130.00 ft, Strength I- Steel Flex. Stress

Final Rating Results and Rehabilitation Scope: Angle Retrofit

Typical repair type at locations with web perforations.



SECTION A-A
SCALE: 1" = 1'



SECTION B-B
SCALE: 1" = 1'

Lessons Learned

Lessons Learned

1092409 2024

Year b

Interior Girders G8-G11 control in Flexure at Midspan.

RATING L1 (TONS): HS20 **, **; H20 **, **
RATING L2 (TONS): HS20 60, 101; H20 33, 56 (2019)
RATING L2 (TONS): HS20 60, 101; H20 33, 56 (2020)
RATING L2 (TONS): HS20 60, 101; H20 33, 56 (2021)
RATING L2 (TONS): HS20 60, 101; H20 33, 56 (2022)
RATING L2 (TONS): HS20 60, 101; H20 33, 56 (2023)
RATING L2 (TONS): HS20 60, 101; H20 33, 56 (2024)

LEVEL 2 LOAD RATING LRFR:
HL-93: Inv. RF = 1.14, Opr. RF = 1.47 (2023)
HL-93: Inv. RF = 1.14, Opr. RF = 1.47 (2024)

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Rating Type	HS Equivalent	Tonnage	Controlling Member
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HL93 — LOAD AND RESISTANCE FACTOR RATING SUMMARY TABLE

Rating Type	Truck	Rating	Controlling Member
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- Level 2 Ratings were consistent, but unconservative using Line Girder.
- Difference in rating results would not have been found if the rating model wasn’t used to start with for design project, using a BrDR model life cycle approach
- Re-evaluate software capabilities, verify analysis methodology is appropriate
- NYSDOT is changing design standards for high skew structures, rating standards are being evaluated

QUESTIONS

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Department of Transportation