2D Grillage Analysis of Curved Steel Box Girders

Presented by

Tim Link, PE

DAVID EVANS AND ASSOCIATES INC.

Introduction

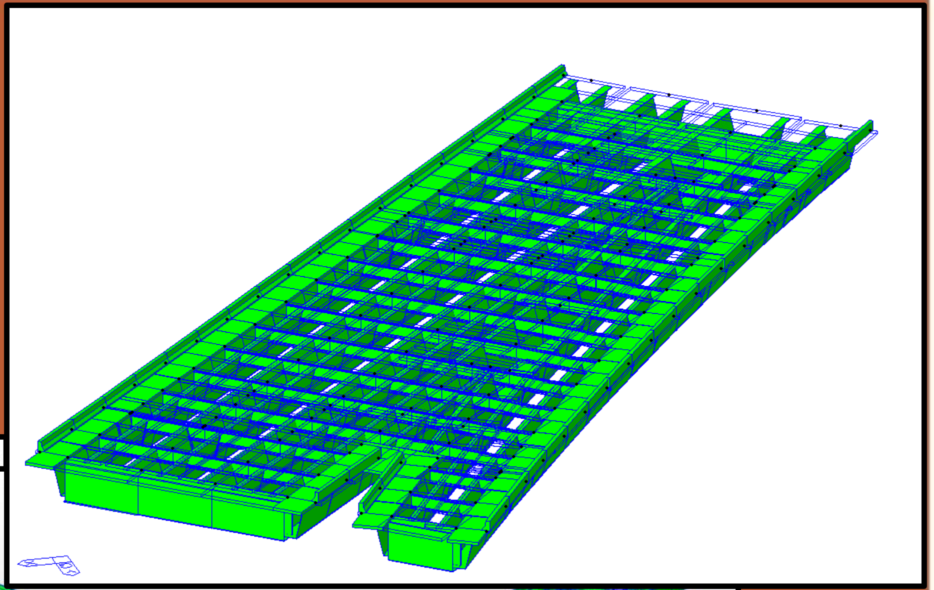
Presentation Highlights:

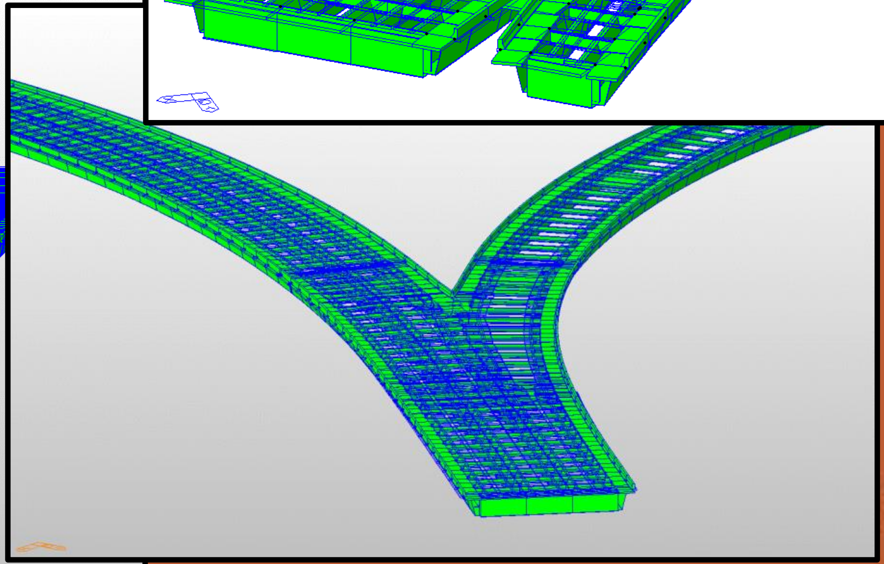
- Use of 2D grillage models as a refined analysis method when AASHTO LLDF can't be used
- Use of Midas MCT Command Shell tool to automate the creation of large complicated bridge models
- Use of Excel workbooks w/ macros to streamline and simplify data input
  - Functioned as the central tool
    Export/import data from Cad files
  - Export data into Midas (create MCT files)
  - Import girder force effects from Midas and compute rating factors
- Ways to reduce analysis run time of complex Midas Civil Models

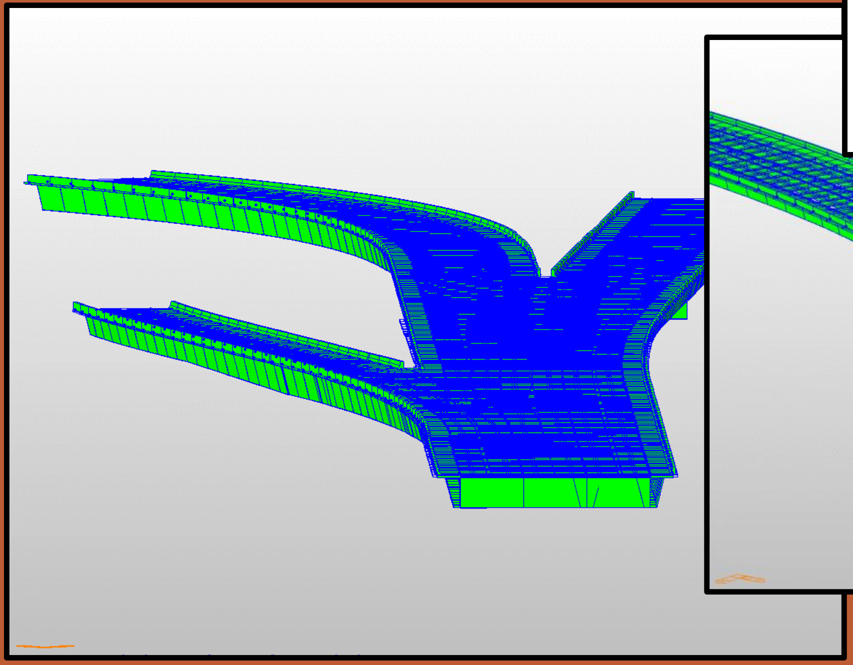
Introduction

Presentation Outline:

- Project Overview
- Load Rating Overview
- Fremont Bridge Overview
- Midas Modeling
- Conclusion
- Q&A







Project Overview

- The work I'm presenting was part of two separate projects for ODOT
- Rated 26 steel box girder (SBG) bridges in Oregon
  - Included bridges with curved girders, large skews, splayed/flared girders, bifurcated/splitting girders, splitting decks, and even two railroad car bridges
  - The bridges were split into 3 groups
- Developed SBG load rating procedures and tools for ODOT
  - Will be included in the next version of the ODOT LRFR manual
- Involved a large project team
  - Project managers:
    - Lwin Hwee, PE, PMP
    - Joel B. Tubbs, PE, SE
    - Matthew D. Harland, PE, ENV SP
  - Special recognition to Eric Ferluga, PE
    - Significantly contributed to the development of the Excel workbooks and macros used to generate the MCT files

Load Rating Overview

Topics:

- General load rating process
- ODOT LRFR procedures
- SBG load rating process
- SBG live load distribution factors (LLDF)

OREGON D.O.T. BRIDGE SECTION

LRFR LOAD RATING SUMMARY REPORT (PAGE 1)

Latest Revision 10/5/2016

QUALITY CONTROL...

FIRM QC REVIEWER(S): Carly Clark, Rachel Bassil, Antonio Mititiero, Eric Ferluga, Joel Tubbs

ODOT QC CHECK BY:

BRIDGE DATA...

BRIDGE #: 08958B   NBI FEATURE: City Streets RR

BRIDGE NAME: Hwy 61 over City Strs & RR (E Fremont Bridge Appr)

HIGHWAY NAME: Stadium Freeway   HIGHWAY #: 061

REGION: 1   DIST: 2B   COUNTY: Multnomah   MILEPOST: 3.72

YEAR BUILT: 1973   DESIGN LOADING: HS20   OWNER: ODOT

SPAN DESCR: 2 levels of 1-15' Cant, 1-162', 1-194', 1-190', 1-142' St Box Gir

OTHER DESCR: (2 levels of 703' St Box Gir: Units "EW-3" & "WE-4")

LOAD RATING ENGINEER DATA...

RATING DATE: 6/30/17   FIRM: David Evans and Associates, Inc   LOAD RATER: Tim Link, Eric Ferluga   CALCULATION BOOK:

LATEST INSPECTION DATA...

INSP. DATE: 2/7/17   ADT: 122,400   ADTT: 8,568   YEAR of ADT (2 digits): 14   A.C. DEPTH, INCHES: 0.0

CONDITION RATINGS ----> DECK: 5   SUPERSTR.: 6   SUBSTR.: 7   IMPACT ASSESSMENT (Elem. 325): CS2

RATING DATA...

NBI STATUS ITEMS:

LRFR FACTORS: IMPACT 1+I: 1.20 γ_{DC} 1.25 γ_{DW} 1.50   Operational Status (Item 41): A

LRFR RATINGS FOR N.B.I. : INVENTORY (Item 66): Tons 27.0   OPERATING (Item 64): Tons 35.0   Bridge Posting Status (Item 70): 5

Temporary Status (Item 103):

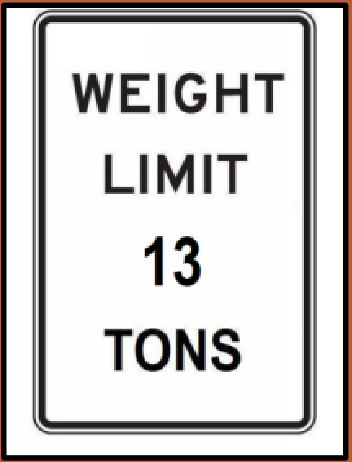
SECTIONS EVALUATED: 1207   COMMENTS:

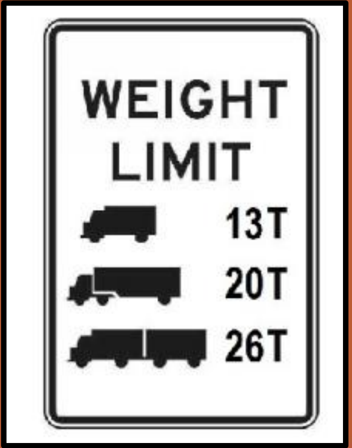
LOAD:	γ_L	R.F.	Limit State	Force Type	Φ	CONTROLLING... MEMBER	SPAN	LOCATION	R.F.	Limit State	Force Type	Φ	CONTROLLING... MEMBER	SPAN	LOCATION
		<--------1st rating control-------->							<--------2nd rating control-------->						
DESIGN & LEGAL VEHICLES															
HL93 (INVENTORY)	1.750	0.75	St1	-M	1.000	Tub A (L)	2 of 5	0.000L	0.89	St1	-M	1.000	Tub B (L)	2 of 5	0.000L
TYPE 3 (50K)	1.390	2.27	St1	-M	1.000	Tub A (L)	2 of 5	0.000L	2.38	St1	+M	0.900	Floorbeam	1 of 1	0.5L
TYPE 3S2 (80K)	1.390	1.71	St1	-M	1.000	Tub A (L)	2 of 5	0.000L	2.04	St1	-M	1.000	Tub B (L)	2 of 5	0.000L
TYPE 3-3 (80K)	1.390	1.80	St1	-M	1.000	Tub A (L)	2 of 5	0.000L	2.13	St1	-M	1.000	Tub B (L)	2 of 5	0.000L
TYPE 3-3 & LEGAL LANE	1.390	3.61	St1	-M	1.000	Tub D(L)	3 of 5	0.857L	3.78	St1	-M	1.000	Tub D(L)	3 of 5	0.157L

Load Rating Overview

General Load Rating Process

- Evaluates the bridge capacity (moment, shear, bearing, and service limits) to carry current vehicles (design, legal, permit)
  - Calculates a rating factor for each vehicle rather than a design ratio (capacity/demand)
- Accounts for the current bridge condition
- Used to identify the need for load posting or strengthening and make overweight-vehicle permit decisions
- Used in bridge management systems to prioritize bridge repairs and replacements



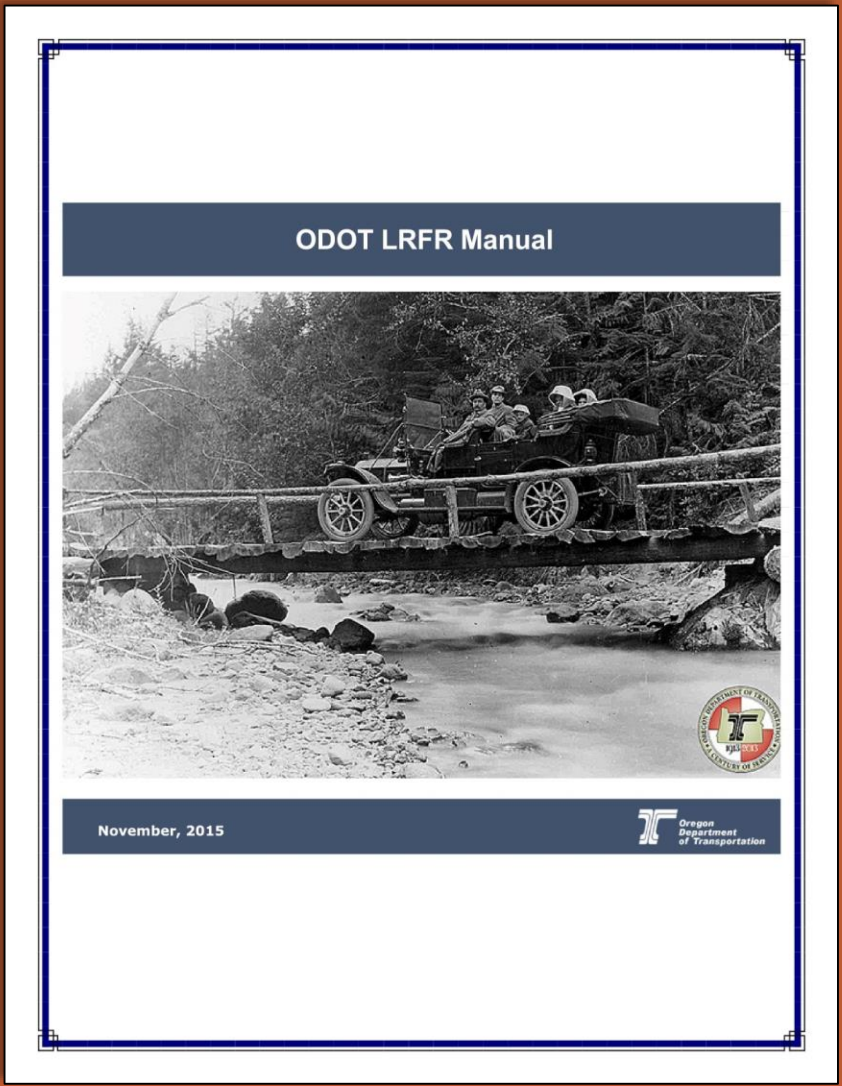


$$RF = \frac{\text{Available Load Capacity}}{\text{Load of Vehicle Considered}}$$

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_{P})(P)}{(\gamma_{L})(LL + IM)}$$

Load Rating Overview

ODOT LRFR Procedures

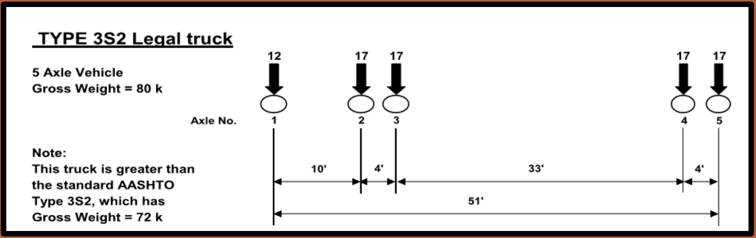


- ODOT LRFR Load Rating Manual outlines procedures for seven unique structure types, pin and hanger connections, and crossbeams
- Current manual version does not cover steel box girders
- BRASS is used as the primary analysis software
- Midas Civil is used for structure types not applicable to BRASS to determine load effects and Excel workbooks are used to calculate capacities and rating factors

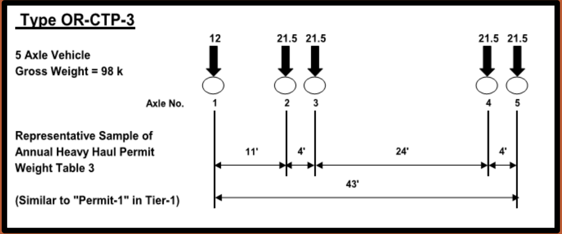
Load Rating Overview

ODOT LRFR Procedures

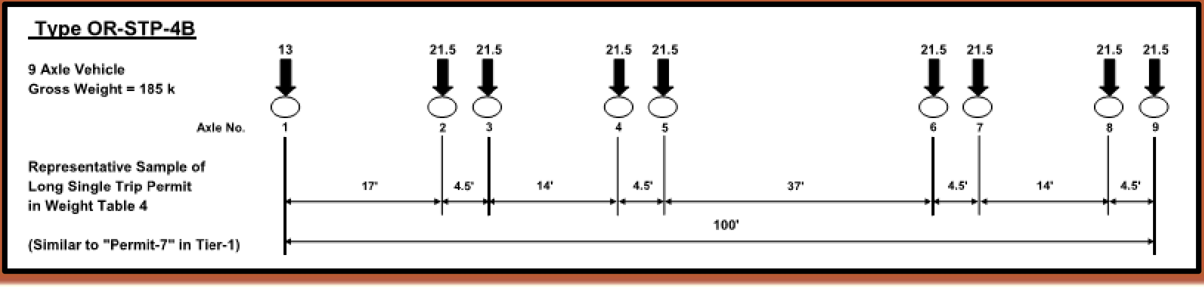
- Rating factors are computed for the design load, legal vehicles, and permit vehicles
    - •23-24 live load definitions
- Design Load
    - •HL-93
- ODOT Legal Trucks
    - •Used to base posting decisions
    - •type 3, type 3S2, type 3-3, legal lane and combinations
    - •ODOT type 3S2 is heavier than the vehicle in the MBE manual



- Specialized Hauling Vehicles (SHVs)
    - •SU4, SU5, SU6, and SU7
- ODOT Continuous Trip Permit (CTP) Trucks
    - •OR-CTP-2A, OR-CTP-2B, and OR-CTP-3



- ODOT Single Trip Permit (STP) Trucks
    - •OR-STP-3, OR-STP-4A, OR-STP-4B, OR-STP-4C, OR-STP-4D, OR-STP-4E, and OR-STP-5BW



Load Rating Overview

SBG Load Rating Process

Bridge Inspection Report and SI&A Sheet + Bridge Plans + Scope

↓

CAD + Mathcad Prelim File + Excel Workbooks

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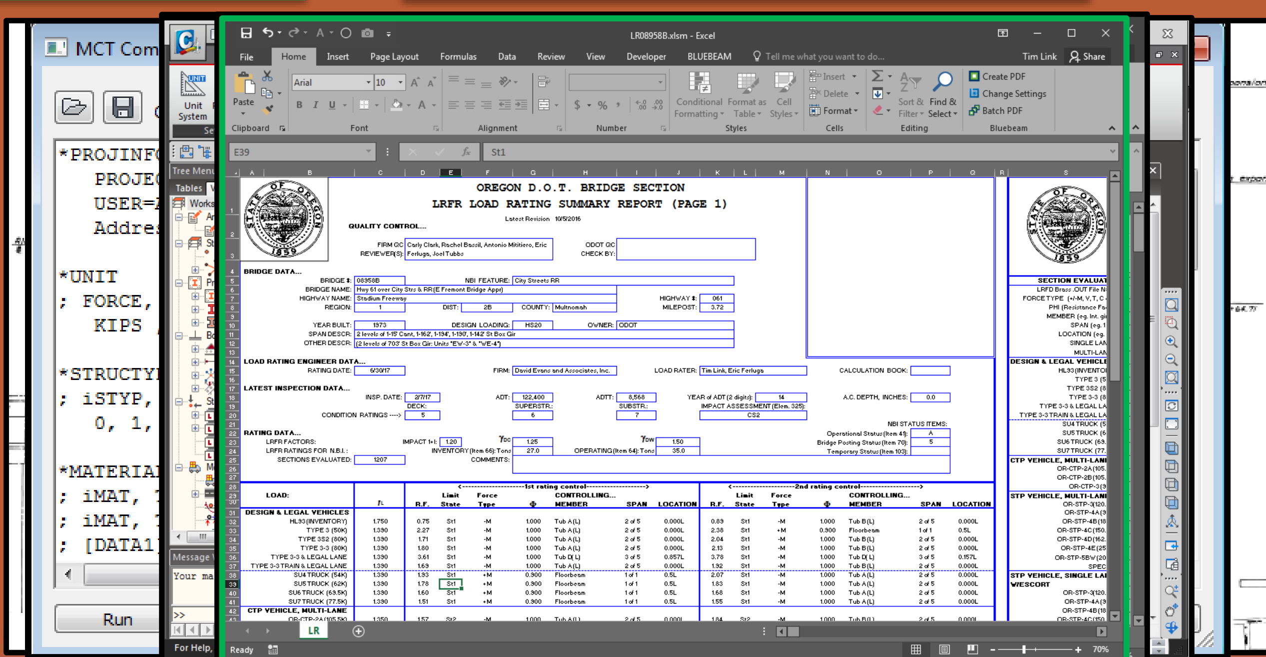
Midas Civil Model ← MCT Shell Files

↓

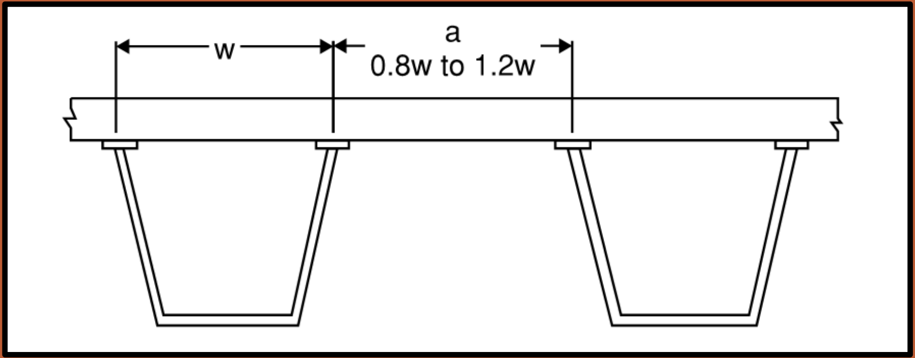
ODOT Load Rating Summary Worksheet ← Capacity and RF Worksheet (Template)



Load Rating Overview

SBG Live Load Distribution Factors – AASHTO LRFD

- Special restrictions per sections 4.6.2.2 and 6.11.2.3
  - Bridge shall not be curved
  - Bearing lines shall not be skewed
  - Bridge shall consist of two or more single-cell box sections
  - The distance c-t-c (w) of the top flanges of individual tub girders shall be the same
  - The inclination of the web shall not exceed 1 to 4 (horizontal to vertical) to a plane normal to the bottom flange
  - Must be within a/w ratio limits
  - Deck overhang cannot exceed 60% of the average “a” distance nor 6ft
  - Deck width must be constant*
  - Beams have approximately the same stiffness

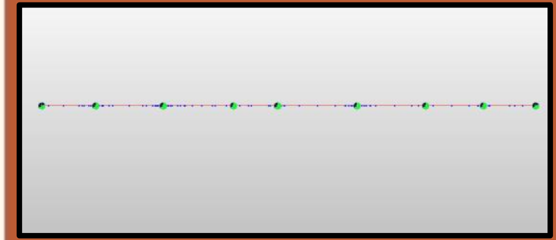


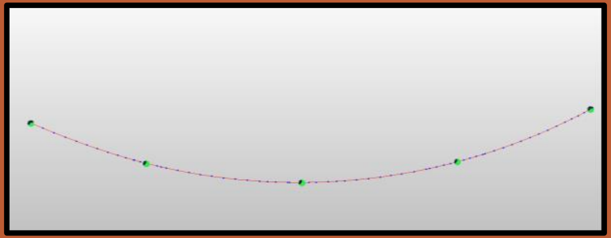
Load Rating Overview

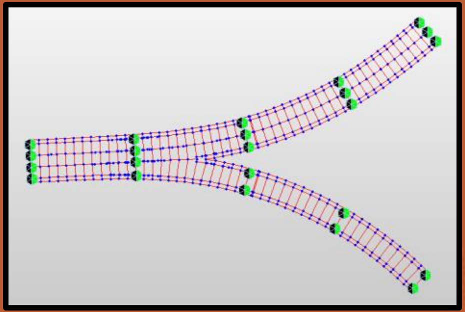
SBG Live Load Distribution Factors – Project Application

- The 26 SBG bridges in the project were split into 3 groups

Group	Criteria	Model Description	Live Load Application
A	-slight to no curvature -parallel girders -up to approx. 10° skew	-single straight girder line models -span length = arc length for slight curvature	-AASHTO LLDF -Lever Rule when AASHTO LLDF girder spacing limit was exceed
B	-curved bridges -parallel girders -slight variable skews (11° max)	-single curved girder line models -model captured torsional effects due to the curvature	-Lever Rule
C	-highly complex -curved girders -splayed/flared girders -bifurcated/splitting girders -skews greater than approx. 10°	-2D grillage models	-Multiple lanes defined within the 2D grillage model


Group A


Group B


Group C

Fremont Bridge Overview

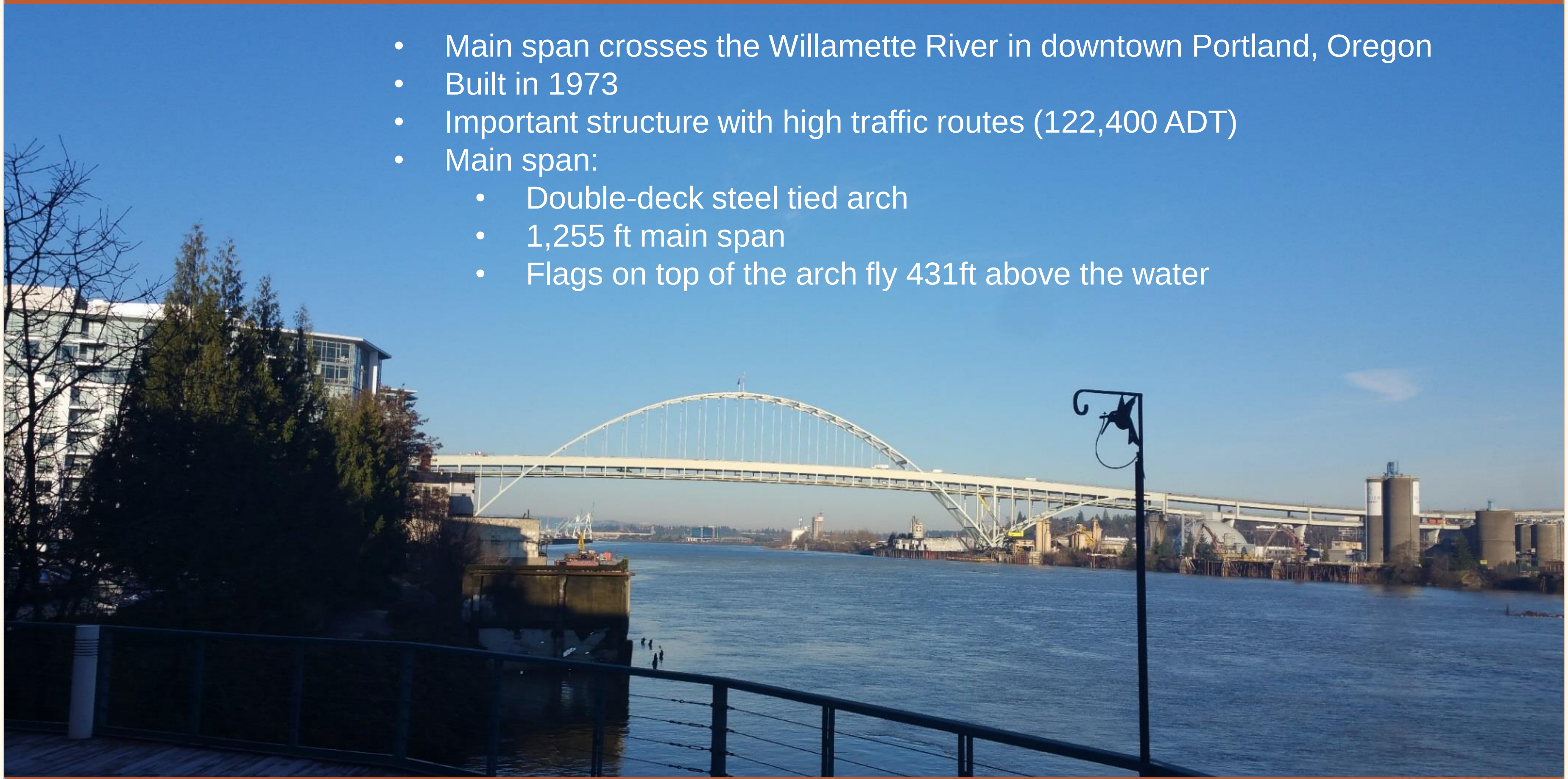
Topics:

- General Bridge Information
- Primary East Approach Ramps – focus of this presentation

Fremont Bridge Overview

General Bridge Information

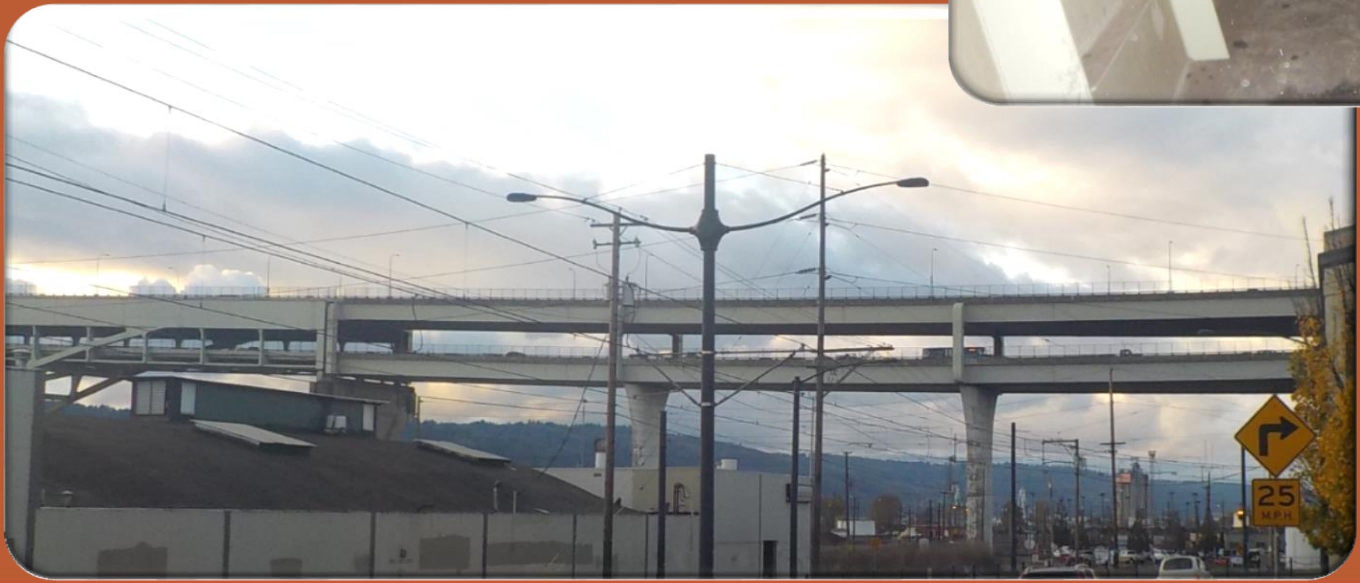
- Main span crosses the Willamette River in downtown Portland, Oregon
- Built in 1973
- Important structure with high traffic routes (122,400 ADT)
- Main span:
    - Double-deck steel tied arch
    - 1,255 ft main span
    - Flags on top of the arch fly 431ft above the water



Fremont Bridge Overview

General Bridge Information

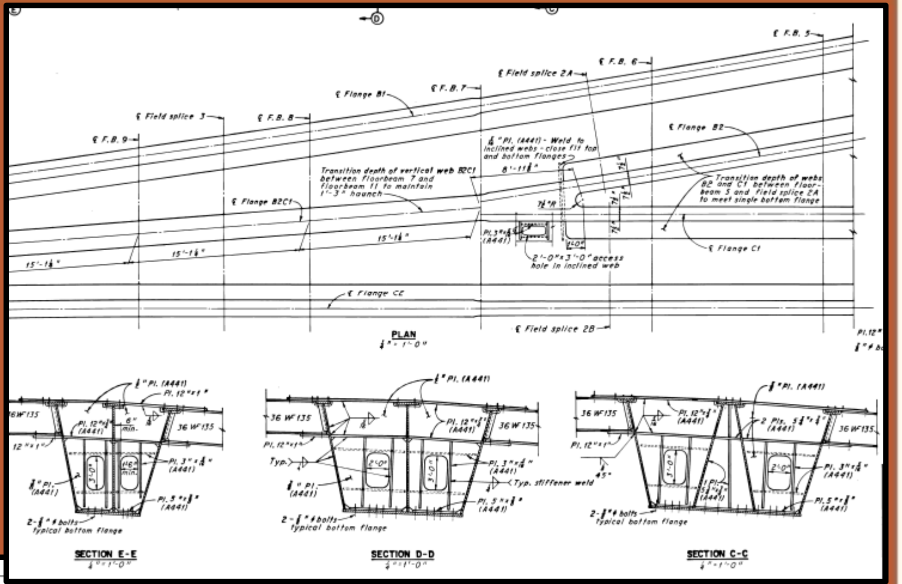
- Approach spans:
    - Steel box girders and reinforced concrete box girders
    - 15 different bridges
    - East approach ramps connection I-5 and city streets to I-405
    - West approach ramps connection Highway 30 to I-405
    - DEA load rated all of the approach bridges and inspected the East approach bridges

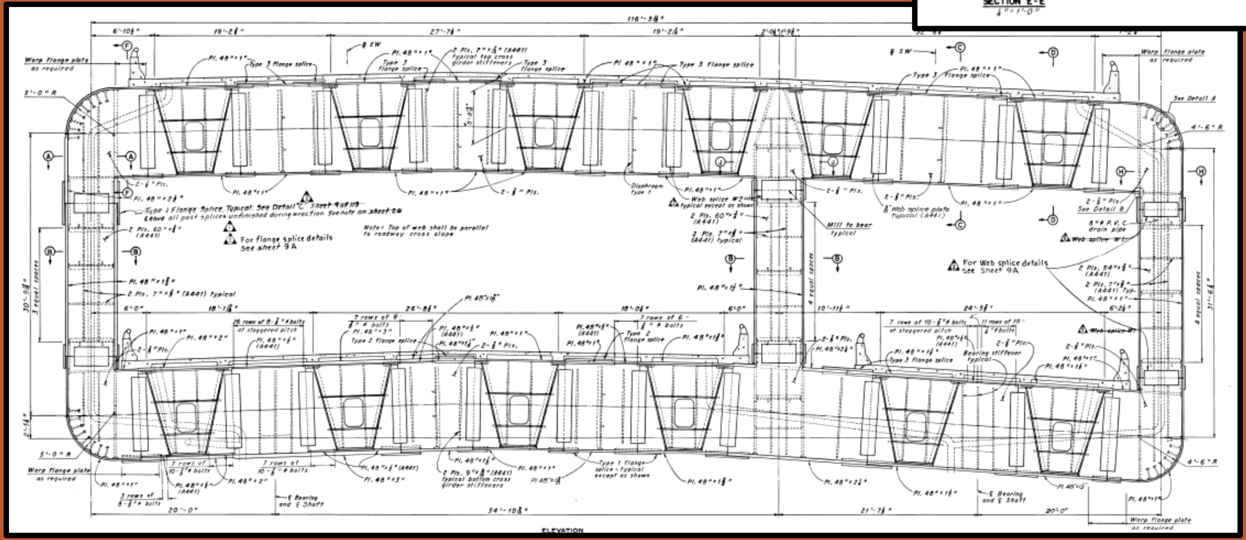


Fremont Bridge Overview

Primary East Approach Ramps:

- Bridge Numbers 08958 and 08958B
- Double deck structures
- Up to six girder lines per deck
- Curved girders
- Splayed/flared girders
- Bifurcated/splitting girders
- Tapering web depths
- Many cross-section changes
- Skewed supports
- Splitting decks
- In-span pin and hanger expansion joints

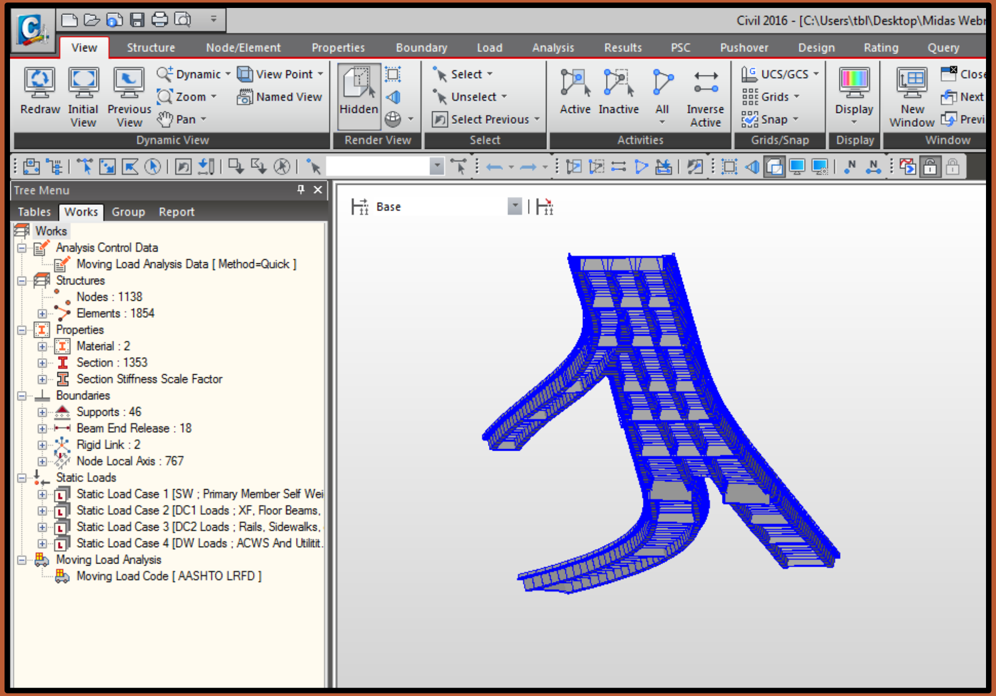




Midas Modeling

Topics:

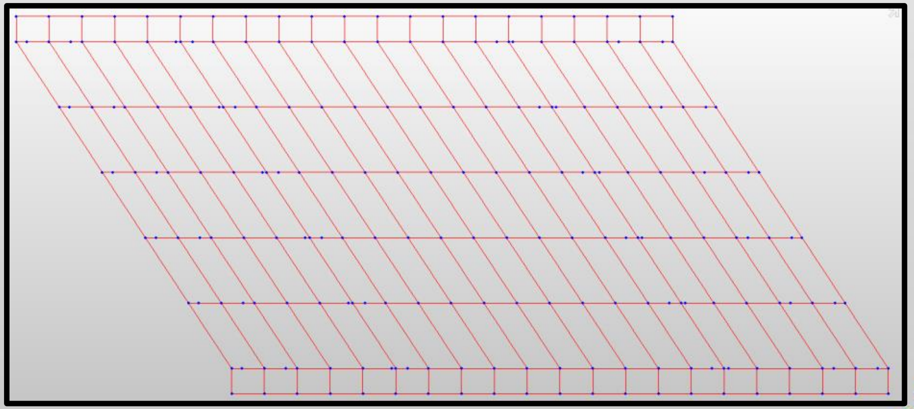
- 2D grillage models
- Model creation using Midas MCT command shell files
- Model analysis
- Model verification
- Model output

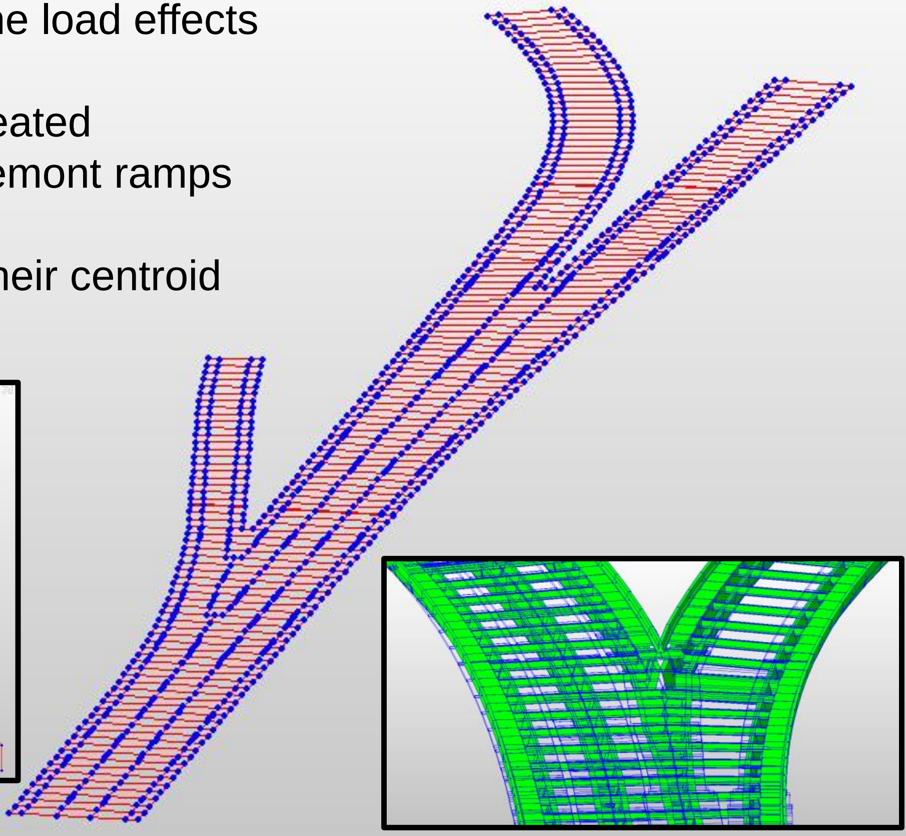


Midas Modeling

2D Grillage Models

- Refined analysis method used to determine load effects for the bridges in Group C
  - 9 unique 2D grillage models were created
  - 3 complex double-deck bridges – Fremont ramps
  - 3 heavily skewed bridges
- 2D model – All elements modeled about their centroid on a horizontal x-y plane

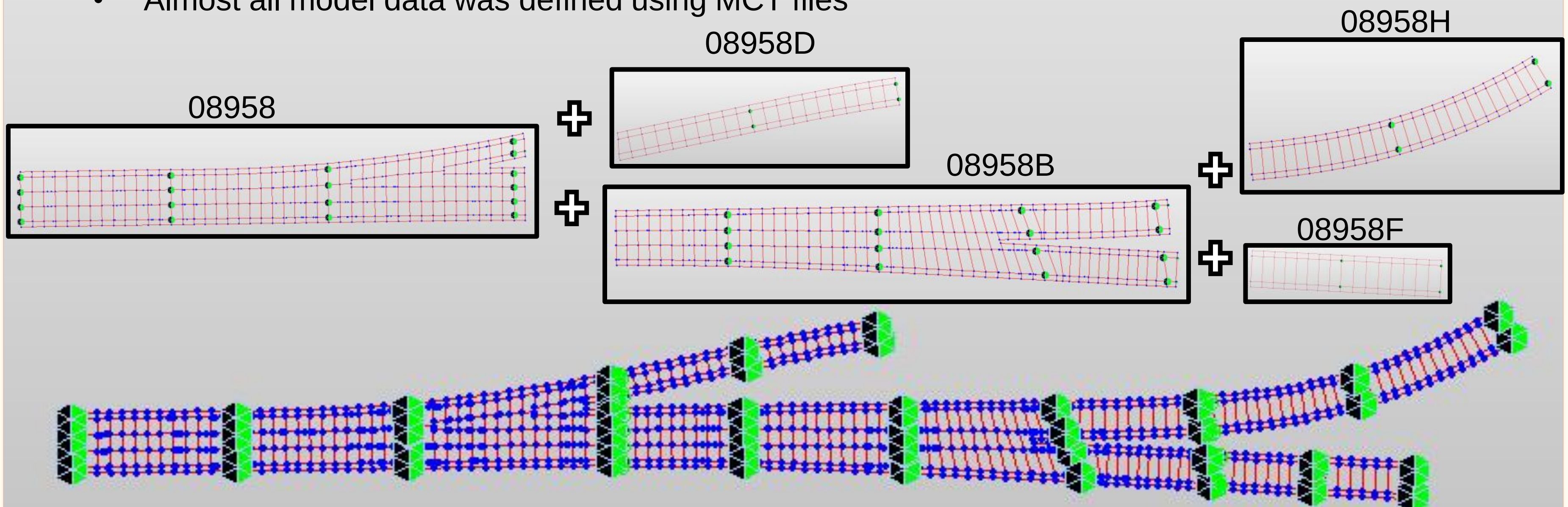




Midas Modeling

2D Grillage Models – Lower 08958 / 08958B Model

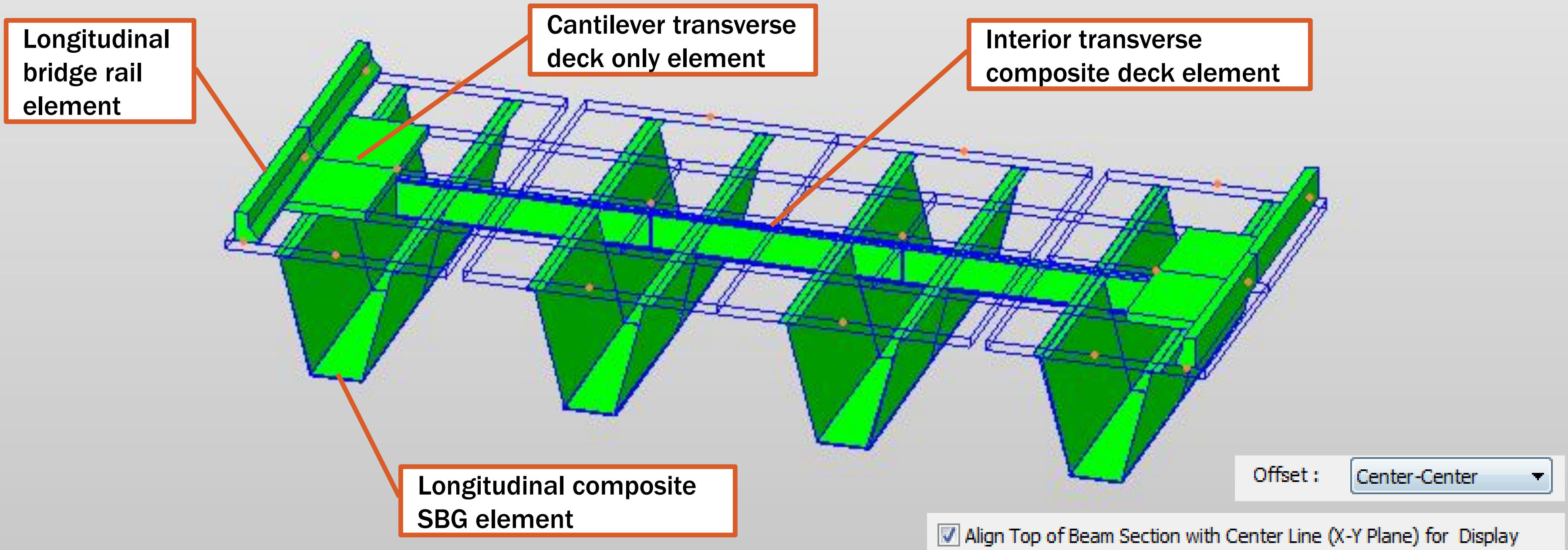
- Bridges 08958 and 08958B were modeled together
  - Using two separate models would require applying dead and live load reactions to the supporting pin and hanger span
- Two spans of three additional approach ramp bridges included
- 1,138 nodes, 1,835 elements, and 1,352 sections
- Multiple traffic line lanes applied for each girder – LL applied to crossbeams
- Almost all model data was defined using MCT files



Midas Modeling

2D Grillage Models – Lower 08958 / 08958B Model

- Individual girder lines are connected with interior transverse composite deck elements at floorbeam and pier nodes
- Cantilever transverse deck only elements are used to model the deck overhang
- Longitudinal bridge rail elements connect free end of cantilever transverse elements

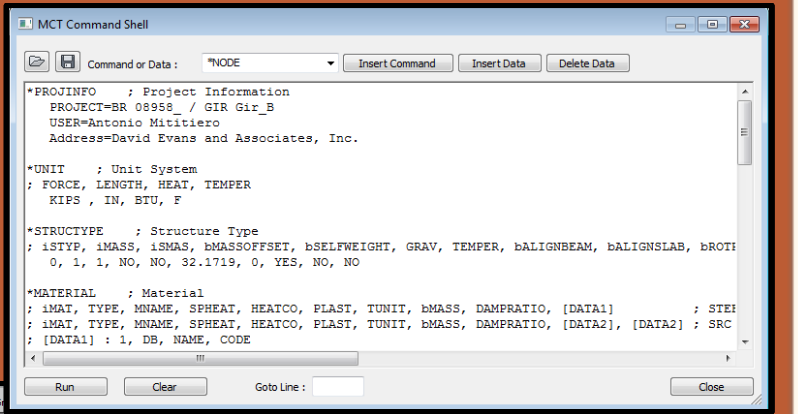


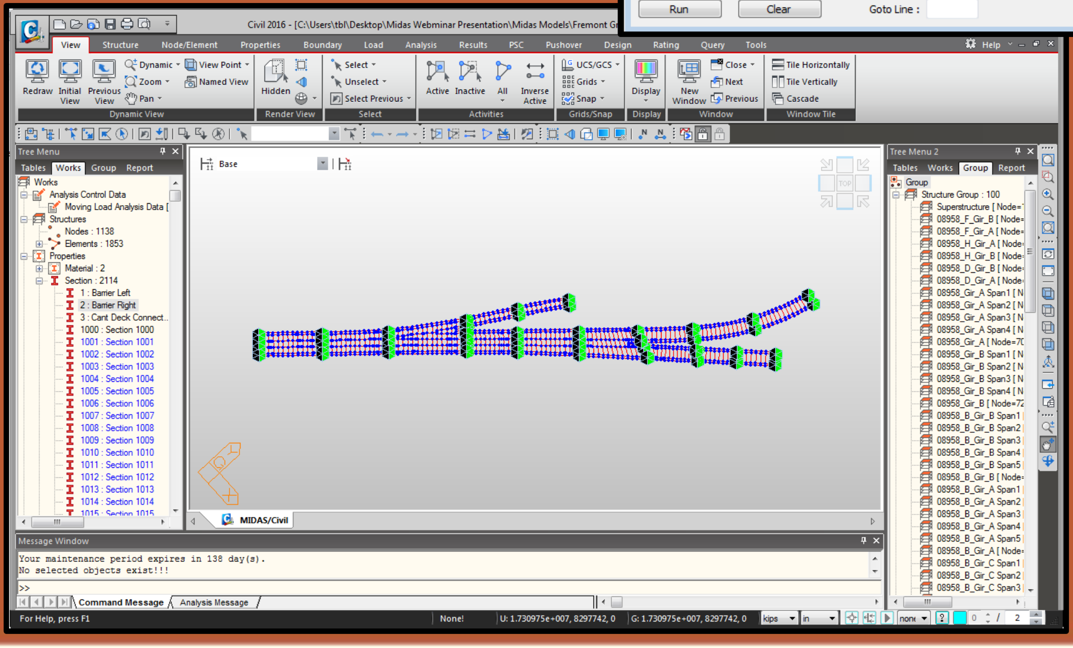
Midas Modeling

Model Creation Using Midas MCT Command Shell Files

Topics

- MCT command shell overview
- General procedure
- Initial model setup
- Nodes
- Composite box girder sections and elements
- Boundary definitions
- Transverse deck elements
- Longitudinal bridge rail elements
- Dead loads
- Live loads





Midas Modeling

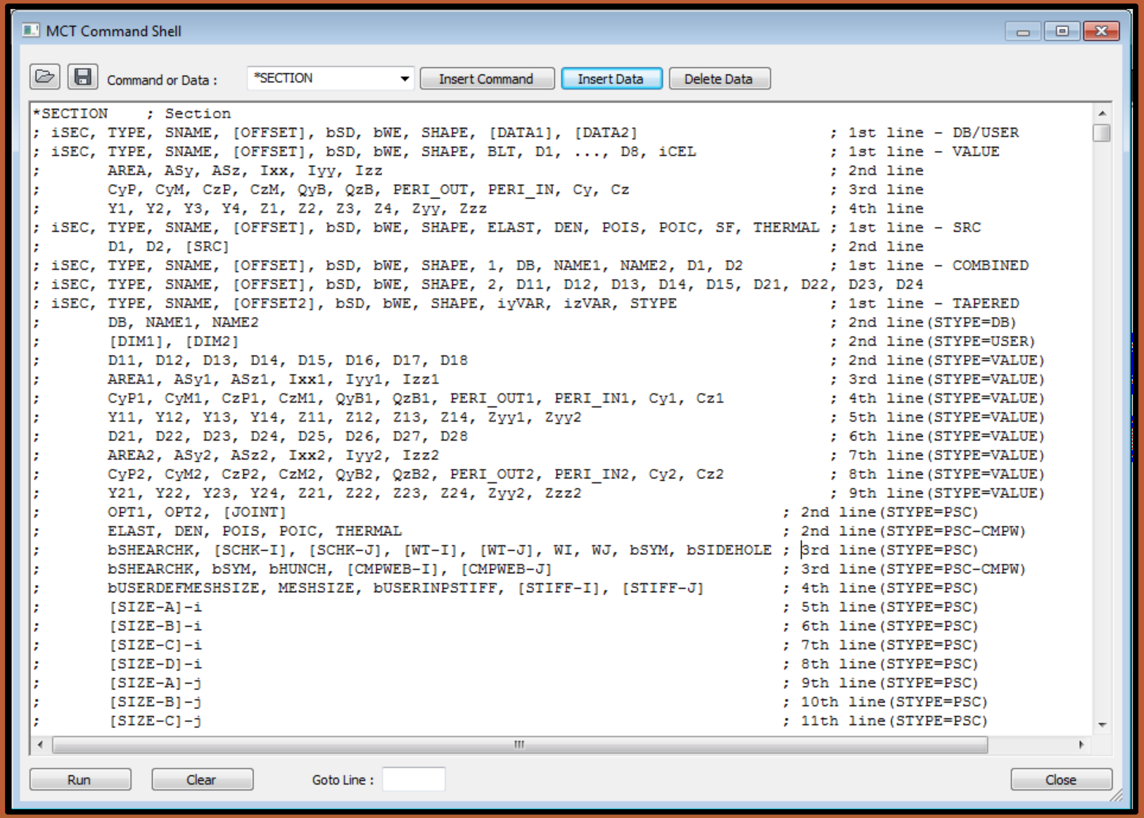
MCT Model Creation – MCT Command Shell Overview

- Allows the use of text commands to create the model data instead of creating the data within the GUI environment
- Speeds up model data creation for repetitive definitions
- Valuable tool for complex models where defining model data in the GUI environment or Bridge Wizard is not practical
- Can reduce errors in model data
  - Less buttons to click
  - Avoids accidently element/node selections
  - Can use checked developed workbooks to automate the creation of the MCT shell files
- Almost everything can be defined with MCT files
- ODOT has several MCT files available to use to define live load definitions, analysis options, dynamic report data, etc.

Midas Modeling

MCT Model Creation – MCT Command Shell Overview

- Inserting a command within the MCT Command Shell window populates the text command AND a description of the command parameters
- Can create MCT file from model data defined within the GUI environment
  - Very helpful for getting familiar with the format of different commands



Midas Modeling

MCT Model Creation – MCT Command Shell Overview

- MCT File Quick Reference
  - http://manual.midasuser.com/EN_TW/Civil/820/Start/14_Appendix/MCT_File_Quick_Reference.htm
  - Describes common command parameters in a more use friendly manner

MCT File Quick Reference

midas Civil

*COMMAND (Functions of midas Civil)
Brief descriptions of the Commands
; Variables that make up the Commands
Description of each variable (method of expression) {initialized value}

* X,Y,Z axis: Basis of Global coordinates

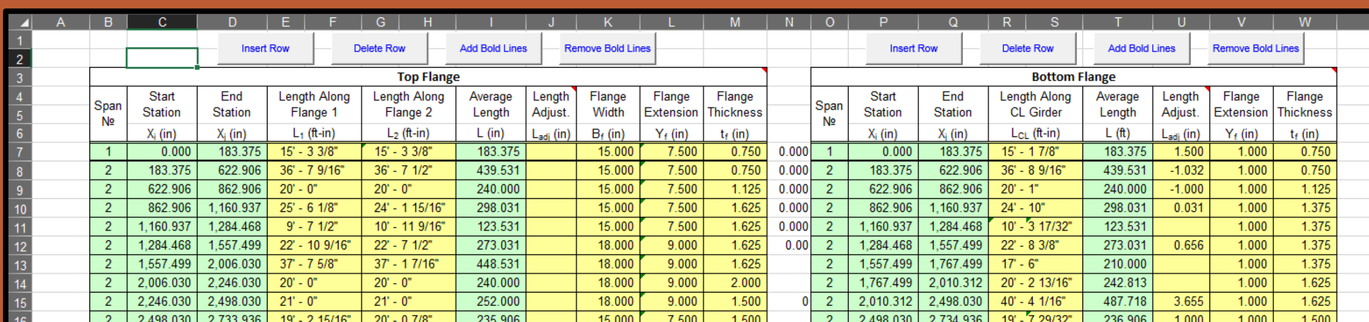
x,y,z axis: Basis of nodal or element local coordinates

*VERSION
Shows the version of midas Civil

Midas Modeling

MCT Model Creation – General Procedure

1) Create Excel workbook to input model data parameters
2) Create macros within the workbook to transform the input data into the appropriate MCT command shell format
3) Open and run the created MCT file in Midas



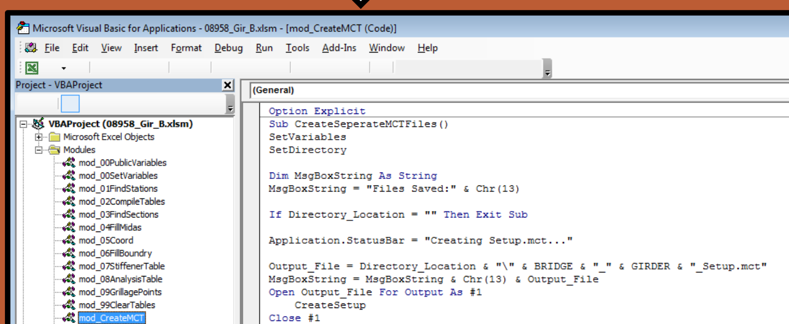
Top Flange

Span №	Start Station X_i (in)	End Station X_j (in)	Length Along Flange 1 L_1 (ft-in)	Length Along Flange 2 L_2 (ft-in)	Average Length L (in)	Length Adjust. L_{adj} (in)	Flange Width B_f (in)	Flange Extension Y_f (in)	Flange Thickness t_f (in)	
1	0.000	183.375	15' - 3 3/8"	15' - 3 3/8"	183.375		15.000	7.500	0.750	0.000
2	183.375	622.906	36' - 7 9/16"	36' - 7 1/2"	439.531		15.000	7.500	0.750	0.000
2	622.906	862.906	20' - 0"	20' - 0"	240.000		15.000	7.500	1.125	0.000
2	862.906	1,160.937	25' - 6 1/8"	24' - 1 15/16"	298.031		15.000	7.500	1.625	0.000
2	1,160.937	1,284.468	9' - 7 1/2"	10' - 11 9/16"	123.531		15.000	7.500	1.625	0.000
2	1,284.468	1,557.499	22' - 10 9/16"	22' - 7 1/2"	273.031		18.000	9.000	1.625	0.00
2	1,557.499	2,006.030	37' - 7 5/8"	37' - 1 7/16"	448.531		18.000	9.000	1.625	
2	2,006.030	2,246.030	20' - 0"	20' - 0"	240.000		18.000	9.000	2.000	
2	2,246.030	2,498.030	21' - 0"	21' - 0"	252.000		18.000	9.000	1.500	0
2	2,498.030	2,733.936	19' - 2 15/16"	20' - 0 7/8"	235.906		15.000	7.500	1.500	

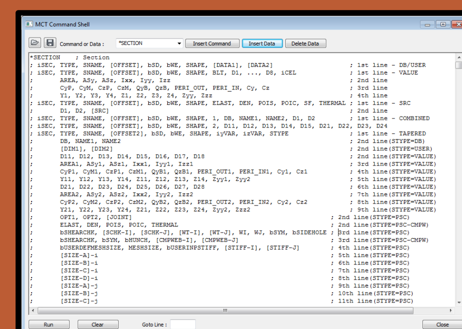
Bottom Flange

Span №	Start Station X_i (in)	End Station X_j (in)	Length Along CL Girder L_{CL} (ft-in)	Average Length L (ft)	Length Adjust. L_{adj} (in)	Flange Extension Y_f (in)	Flange Thickness t_f (in)
1	0.000	183.375	15' - 1 7/8"	183.375	1.500	1.000	0.750
2	183.375	622.906	36' - 8 9/16"	439.531	-1.032	1.000	0.750
2	622.906	862.906	20' - 1"	240.000	-1.000	1.000	1.125
2	862.906	1,160.937	24' - 10"	298.031	0.031	1.000	1.375
2	1,160.937	1,284.468	10' - 3 17/32"	123.531		1.000	1.375
2	1,284.468	1,557.499	22' - 8 3/8"	273.031	0.656	1.000	1.375
2	1,557.499	1,767.499	17' - 6"	210.000		1.000	1.375
2	1,767.499	2,010.312	20' - 2 13/16"	242.813		1.000	1.625
2	2,010.312	2,498.030	40' - 4 1/16"	487.718	3.655	1.000	1.625
2	2,498.030	2,734.936	19' - 7 29/32"	236.906	1.000	1.000	1.500

1) Excel Workbook



2) Macro



3) Midas MCT

Midas Modeling

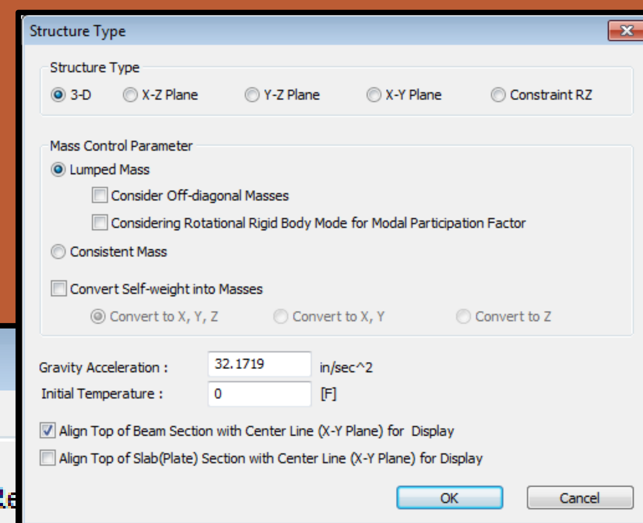
MCT Model Creation – General Procedure

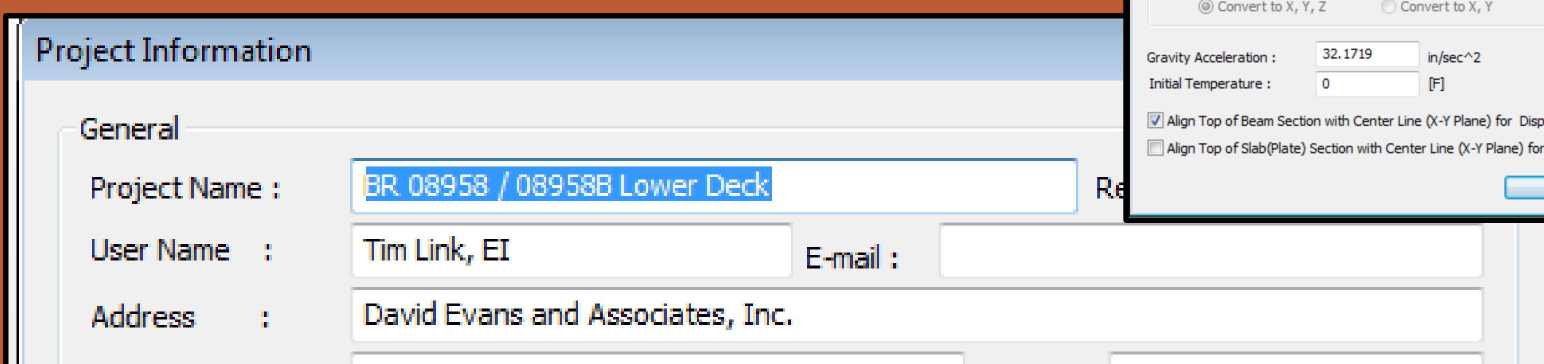
1) Use a workbook to create MCT files for each girder line of each bridge
   - MCT files creates initial model setup, nodes, supports, sections, elements, loads, and structure groups for each span
2) Use a workbook to create MCT files for the interior transverse deck elements
   - MCT files creates modified concrete material property, composite/noncomposite deck sections, interior deck elements, and structure groups
3) Use a workbook to create MCT files for the exterior transverse deck elements and longitudinal bridge rail elements
   - MCT files create edge of deck nodes at each floorbeam/pier, cantilever deck section, stiffness scale factors, bridge rail elements, and structure groups
4) Use a workbook to create MCT files for the moving load definitions
   - MCT files create moving load code, vehicles, moving load cases, moving load sub cases, and traffic line lanes

Midas Modeling

MCT Model Creation – Initial Model Setup

- Project info (*PROJINFO)
- Units (*UNIT)
- Structure type (*STRUCTYPE)
- Material properties (*MATERIAL) – Steel only
- Static load cases (*STLDCASE)
- Selfweight definition (*USE-STLD & *SELFWEIGHT)
- Load combinations (*LOADCOMB)
- Boundary groups (*BNDR-GROUP)
- Custom dynamic report tables (*DYNAGEN-TABLE)

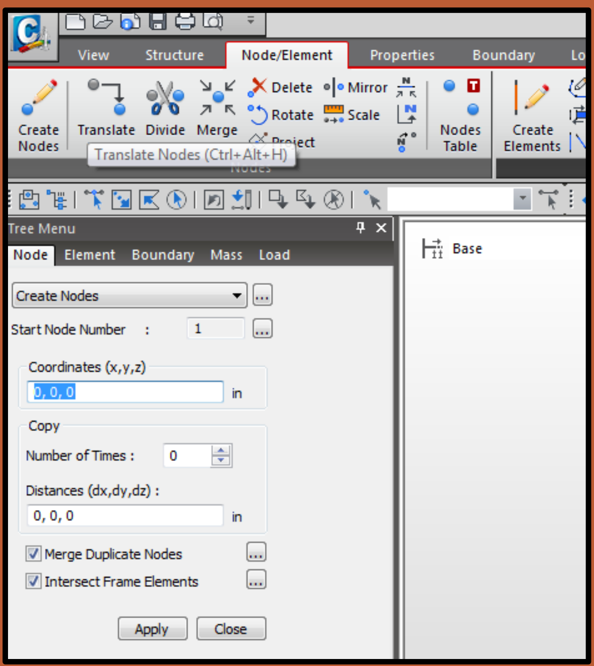




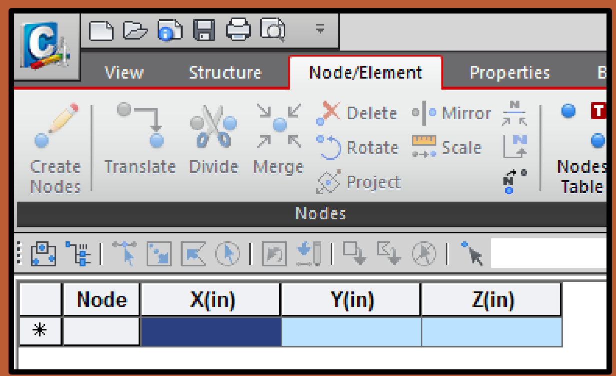
Midas Modeling

MCT Model Creation – Nodes

- Defining nodes in the GUI environment for complicated curved geometry is not practical
- Can also directly copy and paste an Excel nodal coordinates table directly into the Midas Node Table



GUI Method



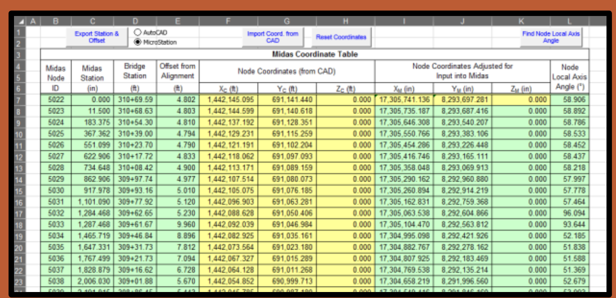
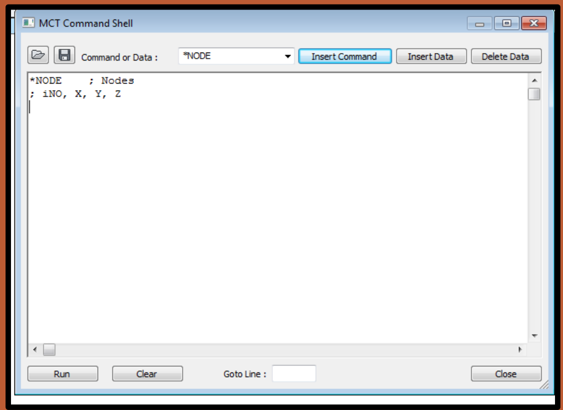


Table Method



MCT Method

Midas Modeling

MCT Model Creation – Nodes

Steps:

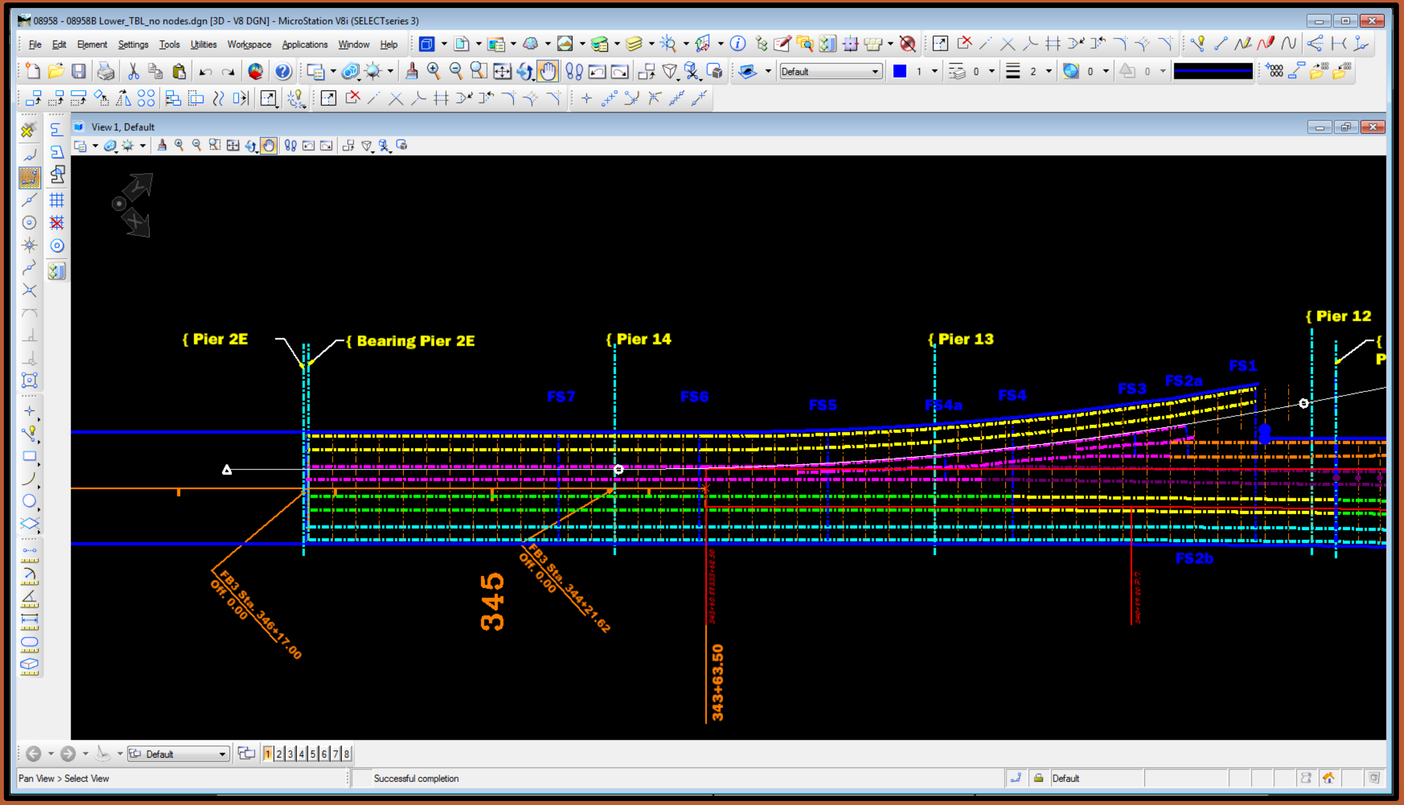
1) Create bridge alignments and framing plans in CAD
2) Create Excel workbook to combine and sort all of the analysis and additional geometry nodes
3) Use the workbook to export the node station and offsets into CAD
4) Export the node global coordinates from CAD back into the workbook and calculate node local axes
5) Use created macro in workbook to create the node MCT file
6) Open and run the node MCT file in Midas Civil

Midas Modeling

MCT Model Creation – Nodes

Step: 1) Create bridge alignments and framing plans in CAD

- Only the alignment is needed to obtain the girder nodal coordinates
- Framing plan serve as a geometry check for the Midas model
- Framing plan was also used to determine bridge geometry inputs that were difficult to directly obtain from the bridge plans



Midas Modeling

MCT Model Creation – Nodes

Step: 2) Create Excel workbook to combine and sort all of the analysis and additional geometry nodes

Export Station & Offset | ○ AutoCAD | ◉ MicroStation | Import Coord. from CAD | Reset Coordinates | Find Node Local Axis Angle

Midas Coordinate Table

Midas Node ID	Midas Station (in)	Bridge Station (ft)	Offset from Alignment (ft)	Node Coordinates (from CAD) X_C (ft)	Y_C (ft)	Z_C (ft)	Node Coordinates Adjusted for Input into Midas X_M (in)	Y_M (in)	Z_M (in)	Node Local Axis Angle (°)
5022	0.000	310+69.59	4.802				0.000	0.000	0.000	
5023	11.500	310+68.63	4.803							
5024	183.375	310+54.30	4.810							
5025	367.362	310+39.00	4.794							
5026	551.099	310+23.70	4.790							
5027	622.906	310+17.72	4.833							
5028	734.648	310+08.42	4.900							
5029	862.906	309+97.74	4.977							
5030	917.978	309+93.16	5.010							
5031	1,101.090	309+77.92	5.120							
5032	1,284.468	309+62.65	5.230							
5033	1,287.468	309+61.67	9.960							
5034	1,465.719	309+46.84	8.896							

Insert Row | Delete Row

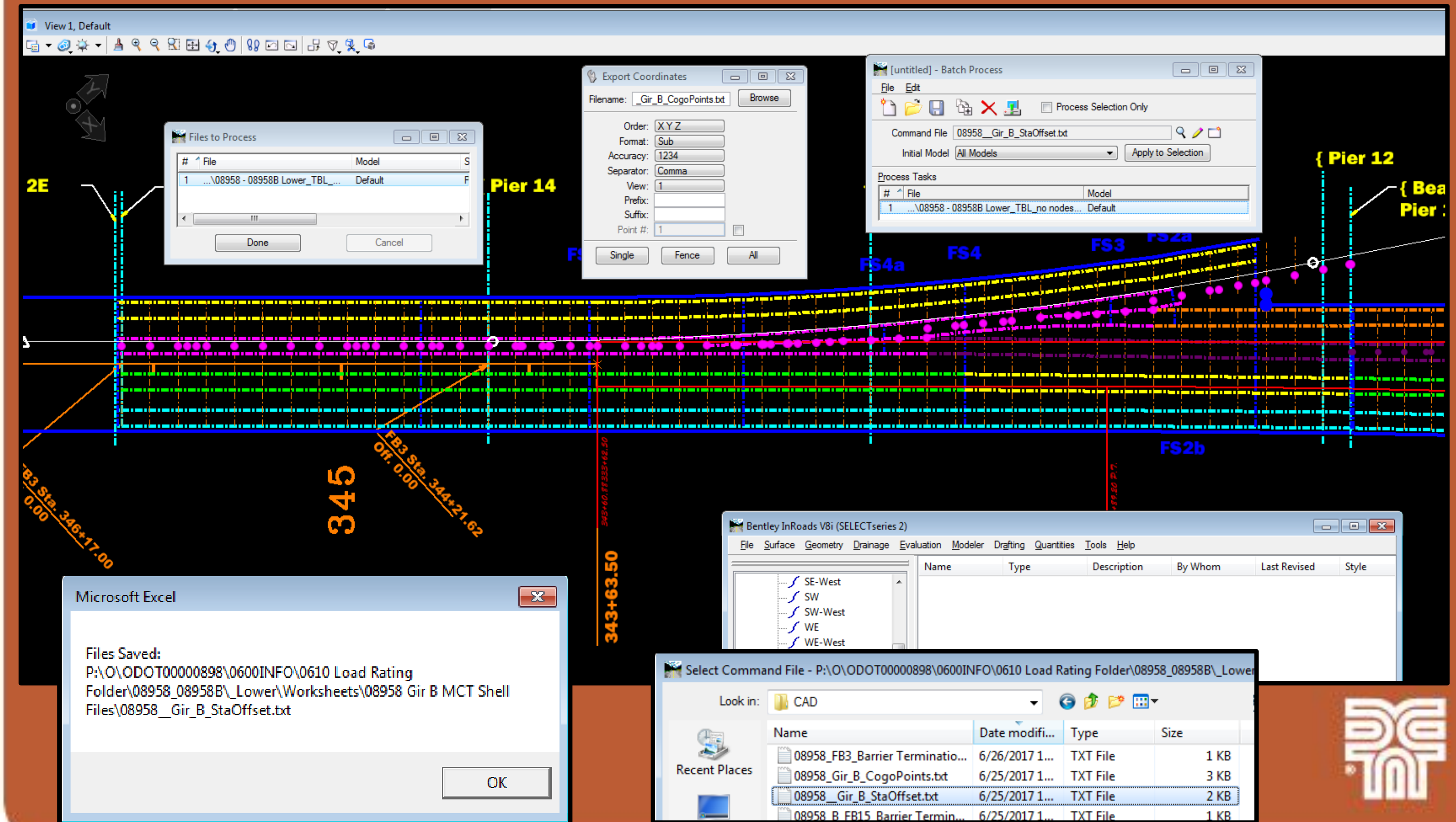
Bridge Station and Offset Table

Description	Midas Station (in)	Bridge Station (ft)	Offset from Alignment (ft)
Bearing Expansion Joint 12	0.000	310+69.59	4.80
Pier 12	183.375	310+54.30	4.81
end of divide (1'1" before FB3)	538.099	310+24.80	4.78
FB3	551.099	310+23.70	4.79
FB 7	1,284.468	309+62.65	5.23
3in after FB 7	1,287.468	309+61.67	9.96
FB 11	2,006.030	309+01.88	5.67
FB 15	2,733.936	308+41.47	4.78
3in after FB 15	2,736.936	308+40.75	9.40
Pier 13	3,100.687	308+10.99	8.01
FB 22	4,150.285	307+23.80	4.95
FS 6	4,900.660	306+61.37	2.98
Pier 14	5,549.750	306+07.43	2.40
Pier 2E	7,894.313	304+12.05	2.40

Midas Modeling

MCT Model Creation – Nodes

Step: 3) Use the workbook to export the node station and offsets into CAD



Midas Modeling

MCT Model Creation – Nodes

Step: 4) Export the node global coordinates from CAD back into the workbook and use the workbook to calculate node local axes

Export Station & Offset | ○ AutoCAD | ◉ MicroStation | Import Coord. from CAD | Reset Coordinates | Find Node Local Axis Angle

Midas Coordinate Table

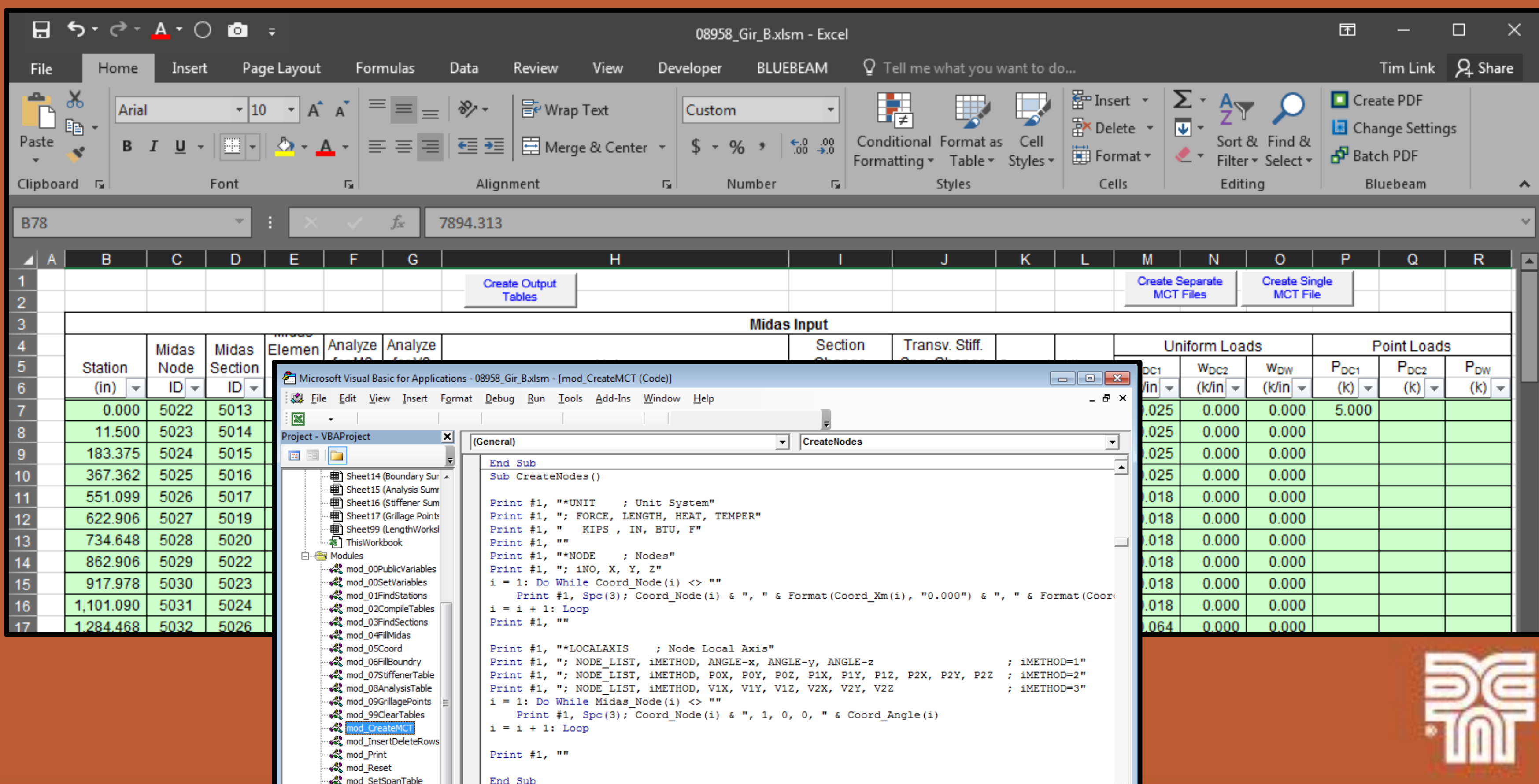
Row	Midas Node ID	Midas Station (in)	Bridge Station (ft)	Offset from Alignment (ft)	Node Coordinates (from CAD) X_C (ft)	Y_C (ft)	Z_C (ft)	Node Coordinates Adjusted for Input into Midas X_M (in)	Y_M (in)	Z_M (in)	Node Local Axis Angle (°)
7	5022	0.000	310+69.59	4.802	1,442,145.095	691,141.440	0.000	17,305,741.136	8,293,697.281	0.000	58.906
8	5023	11.500	310+68.63	4.803	1,442,144.599	691,140.618	0.000	17,305,735.187	8,293,687.416	0.000	58.892
9	5024	183.375	310+54.30	4.810	1,442,137.192	691,128.351	0.000	17,305,646.308	8,293,540.207	0.000	58.786
10	5025	367.362	310+39.00	4.794	1,442,129.231	691,115.259	0.000	17,305,550.766	8,293,383.106	0.000	58.533
11	5026	551.099	310+23.70	4.790	1,442,121.191	691,102.204	0.000	17,305,454.286	8,293,226.448	0.000	58.452
12	5027	622.906	310+17.72	4.833	1,442,118.062	691,097.093	0.000	17,305,416.746	8,293,165.111	0.000	58.437
13	5028	734.648	310+08.42	4.900	1,442,113.171	691,089.159	0.000	17,305,358.048	8,293,069.913	0.000	58.218
14	5029	862.906	309+97.74	4.977	1,442,107.514	691,080.073	0.000	17,305,290.162	8,292,960.880	0.000	57.997
15	5030	917.978	309+93.16	5.010	1,442,105.075	691,076.185	0.000	17,305,260.894	8,292,914.219	0.000	57.778
16	5031	1,101.090	309+77.92	5.120	1,442,096.903	691,063.281	0.000	17,305,162.831	8,292,759.368	0.000	57.464
17	5032	1,284.468	309+62.65	5.230	1,442,088.628	691,050.406	0.000	17,305,063.538	8,292,604.866	0.000	96.094
18	5033	1,287.468	309+61.67	9.960	1,442,092.039	691,046.984	0.000	17,305,104.470	8,292,563.812	0.000	93.644
19	5034	1,465.719	309+46.84	8.896	1,442,082.925	691,035.161	0.000	17,304,995.098	8,292,421.926	0.000	52.185
20	5035	1,647.331	309+31.73	7.812	1,442,073.564	691,023.180	0.000	17,304,882.767	8,292,278.162	0.000	51.838
21	5036	1,767.499	309+21.73	7.094	1,442,067.327	691,015.289	0.000	17,304,807.925	8,292,183.469	0.000	51.588
22	5037	1,828.879	309+16.62	6.728	1,442,064.128	691,011.268	0.000	17,304,769.538	8,292,135.214	0.000	51.369

Midas Modeling

MCT Model Creation – Nodes

Step: 5) Use created macro in workbook to create the node MCT file

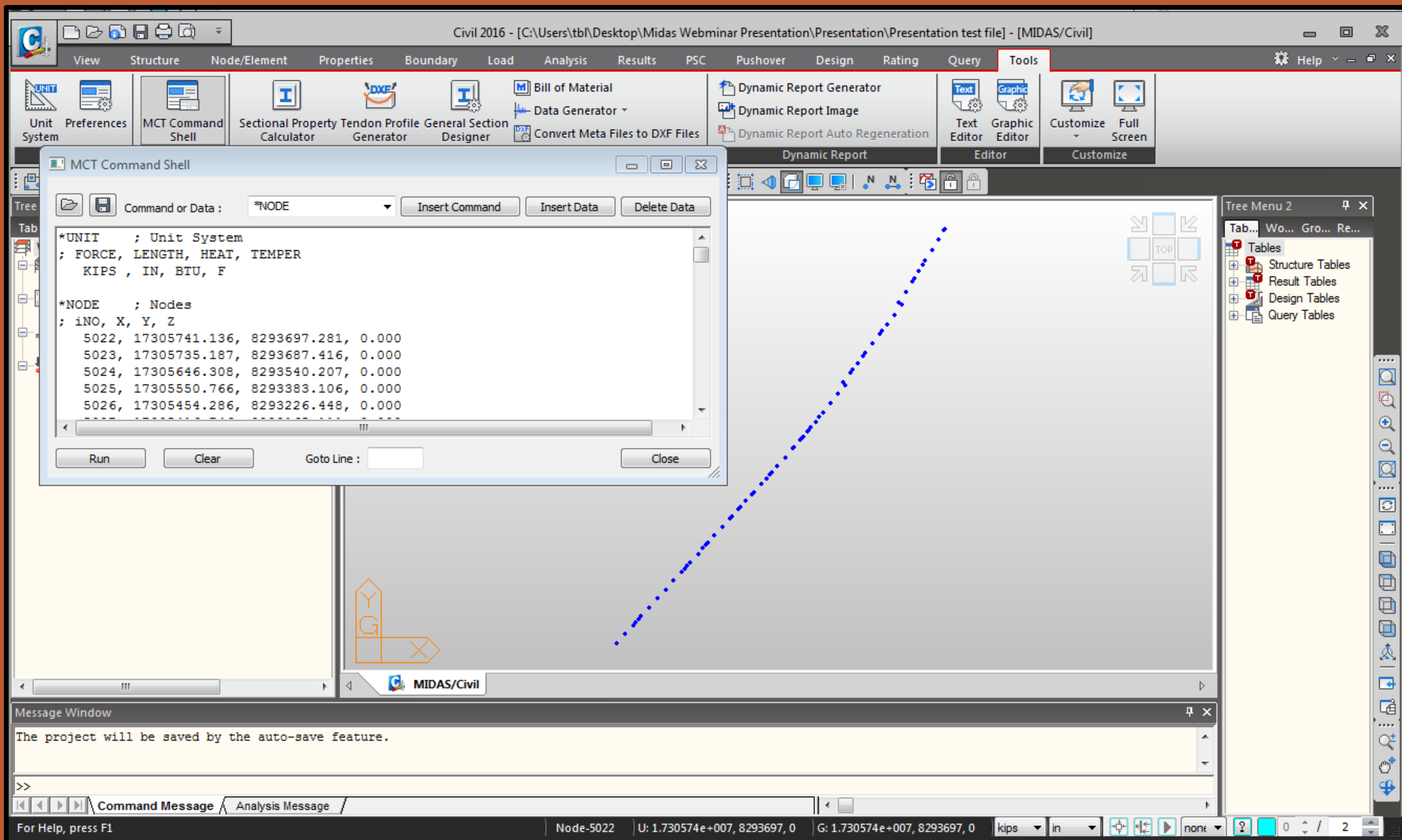
- Node coordinates (*NODE)
- Node local axis (*LOCALAXIS)



Midas Modeling

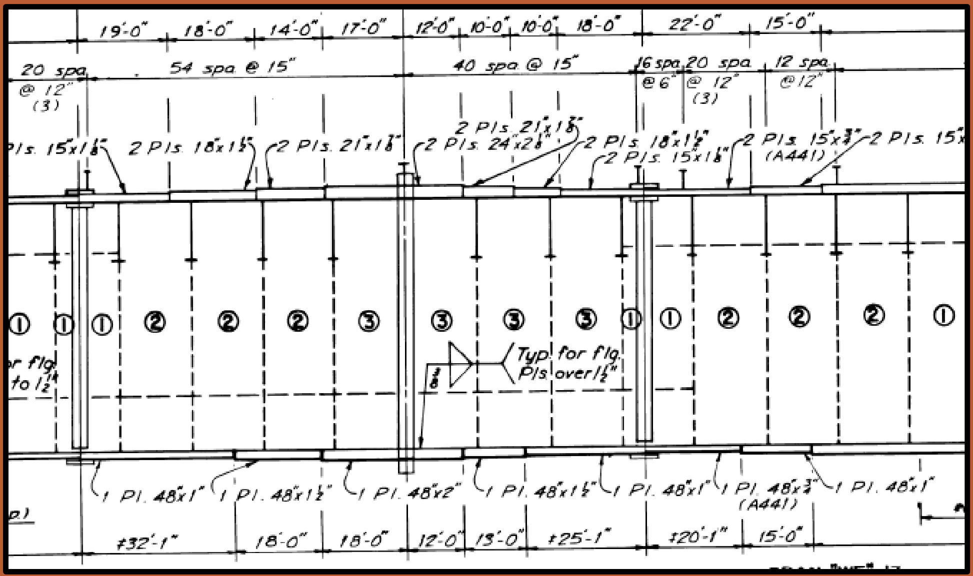
MCT Model Creation – Nodes

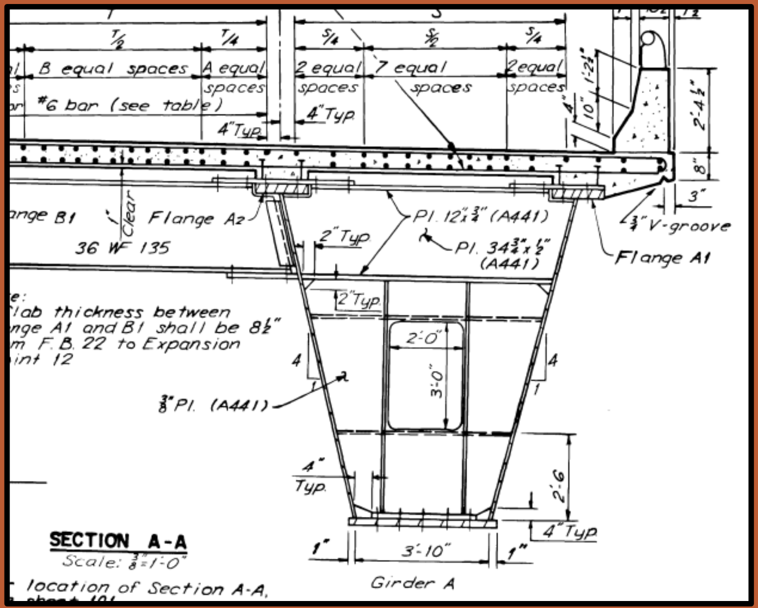
Step: 6) Open and run the node MCT file in Midas Civil



Midas Modeling

MCT Model Creation – Composite Box Girder Sections & Elements





- Excel workbook allows for cross-section components to be entered individually
    - Streamlines process
    - Reduces errors and makes QC easier for complex girders
    - Reduces the number of duplicate sections
    - Eliminates the need to manually calculate component dimensions along a tapering element

Midas Modeling

MCT Model Creation – Composite Box Girder Sections & Elements

Bridge Length Calculations and Web Thickness

Span №	Start Station X_i (in)	End Station X_j (in)	Length Along Flange 1 L_1 (ft-in)	Length Along Flange 2 L_2 (ft-in)	Length Along CL L (in)	Web Thickness t_w (in)
1	0.000	183.375	15' - 3 3/8"	15' - 3 3/8"	183.375	0.438
2	183.375	622.906	36' - 7 9/16"	36' - 7 1/2"	439.531	0.438
2	622.906	1,160.937	45' - 6 1/8"	44' - 1 15/16"	538.031	0.438

Deck Thickness & Uniform Loads

Start Station X_i (in)	End Station X_j (in)	Description	Deck Thickness t_d (in)	Deck to top of web t_h (in)
0.000	183.375	Bear. Exp. Joint 12 to Pier 12	8.750	16.250
183.375	538.099	Pier 12 to end of divide	8.750	16.250

Top Flange

Span №	Start Station X_i (in)	End Station X_j (in)	Length Along Flange 1 L_1 (ft-in)	Length Along Flange 2 L_2 (ft-in)	Average Length L (in)	Length Adjust. L_{adj} (in)	Flange Width B_f (in)	Flange Extension Y_f (in)	Flange Thickness t_f (in)	
1	0.000	183.375	15' - 3 3/8"	15' - 3 3/8"	183.375		15.000	7.500	0.750	0.000
2	183.375	622.906	36' - 7 9/16"	36' - 7 1/2"	439.531		15.000	7.500	0.750	0.000
2	622.906	862.906	20' - 0"	20' - 0"	240.000		15.000	7.500	1.125	0.000

Bottom Flange

Span №	Start Station X_i (in)	End Station X_j (in)	Length Along CL Girder L_{CL} (ft-in)	Average Length L (ft)	Length Adjust. L_{adj} (in)	Flange Extension Y_f (in)	Flange Thickness t_f (in)
1	0.000	183.375	15' - 1 7/8"	183.375	1.500	1.000	0.750
2	183.375	622.906	36' - 8 9/16"	439.531	-1.032	1.000	0.750
2	622.906	862.906	20' - 1"	240.000	-1.000	1.000	1.125

Overall Girder Geometry

Description	Station X (in)	Web Height (along web) H (in)	Web Height (vertical) H_w (in)	Web Slope #V:1H	Slope Angle from Vert. (degrees	Web Spa. at Bottom B_{wb} (in)	Web Spa. at Top B_{wt} (in)	Tributary Width Left B_L (in)	Tributary Width Right B_R (in)	Eff. Deck Width B_{eff} (in)
Bearing Expansion Joint 12	0.000	113.000	109.626	4.000	14.036	46.000	100.813	83.407	95.656	179.063
Pier 12	183.375	113.000	109.626	4.000	14.036	46.000	100.813	83.407	95.719	179.125
end of divide	538.099	113.000	109.626	4.000	14.036	46.000	100.813	83.407	95.469	178.875

Midas Sections

ID	Top Flange Bf_1 (in)	Top Flange tf_1 (in)	Web H_w (in)	Web t_w (in)	Bot. Flange Bf_2 (in)	Bot. Flange tf_2 (in)	Top Flange Bf_3 (in)	Top Flange B_1 (in)	Bot. B_2 (in)	Deck Slab B_c (in)	Deck Slab t_c (in)	H_h+tf_1 (in)	Girder Area A_G (in²)	Deck Area A_D (in²)
5013	15.000	0.750	109.626	0.438	1.000	0.750	7.500	85.813	46.000	179.065	8.750	7.500	157.4	1,566.8
5014	15.000	0.750	109.626	0.438	1.000	0.750	7.500	85.813	46.000	179.096	8.750	7.500	157.4	1,567.1
5015	15.000	0.750	109.626	0.438	1.000	0.750	7.500	85.813	46.000	179.060	8.750	7.500	157.4	1,566.8

Tapered Sections

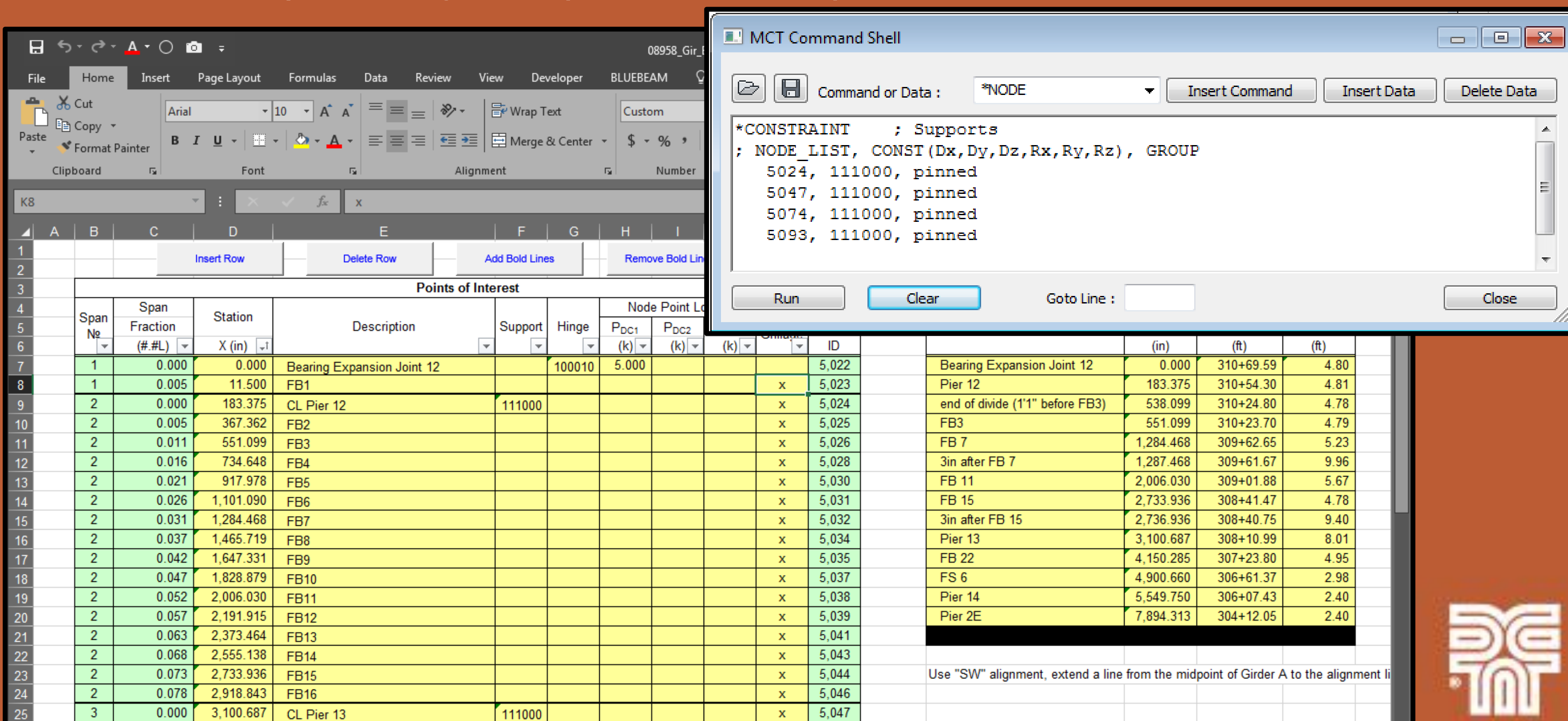
Midas Section ID	i-end Section	j-end Section
5611	5013	5014
5612	5014	5015
5613	5015	5016

- Workbook Macro compiles inputs and creates MCT file
  - Composite sections (*SECTION) – includes tap
  - Elements (*ELEMENT)

Midas Modeling

MCT Model Creation – Boundary Definitions

- Excel workbook includes inputs for supports and expansion joints
- Workbook macro creates MCT file
  - Supports (*CONSTRAINT)
  - Expansion joints (*FRAME-RLS) – beam end release

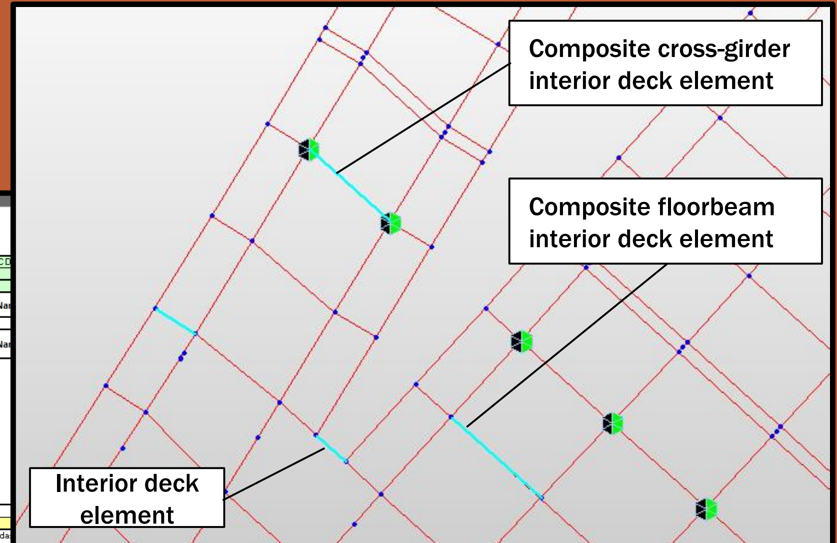


Midas Modeling

MCT Model Creation – Transverse Deck Elements

Multiple transverse elements defined - interior deck elements

- Composite floorbeam w/ trib deck width
- Composite cross-girder w/ trib deck width
- Deck only – used at splitting deck locations



Bridge #:	09268_
Cant Deck XB Iyy Stiffness Mod Factor:	50
FB Steel Poisson's Ratio:	0.3
FB Steel modulus of elasticity (ksi):	29,000
FB Steel unit weight (kci):	0.00028
FB Steel thermal coefficient:	6.50E-06
Steel SW Factor	1.15
Concrete Material Property #:	2
Deck Concrete Strength (ksi):	4.00
Deck Concrete Poisson's Ratio:	0.2
Deck concrete thermal coefficient:	6.00E-06
Ratio of thermal coefficients (Ts/Tc):	1.08
Deck Concrete Unit Weight, w/ reinf (kci):	0.00008
Deck Concrete Modulus of Elasticity (ksi):	3,644
Ratio of modulus of elasticity (Es/Ec):	7.958
Ratio of unit weight (Ds/Dc):	3.757

First Deck Crossbeam Section #:	34000
First Deck Crossbeam Element #:	34000
First Cant Deck Crossbeam Node #:	93000
First Cant Deck Crossbeam Section #:	39000
First Cant Deck Crossbeam Element #:	39000
Barrier Element Section #:	2
First Barrier Element #:	93000
CL of last FB to CL of Exp Joint (in):	11.5

Deck Crossbeam Structure Group:	09268_ Girder B-C D
Cant Deck Crossbeam Structure Group:	
Barrier Elements Structure Group:	

Create Interior Deck Elements MCT File — Output File Na

Create Cantilever Deck Elements MCT — Output File Na

LL Girder: 08958_Gir_A

Girder 1 Nodes

Notes	Midas Station (in)	Midas Node ID	Model X (in)	Model Y (in)	Deck Thickness (in)	Tributary Width Left, B_L (in)	Tributary Width Right, B_R (in)
	Girder:	B		Cant (Y/N):		NO	NO
CL Bearing Pier 2W	0.000	3,000	17,283,580.174	8,268,089.851	7.50	116.531	116.592
FB1	177.734	3,001	17,283,460.573	8,267,958.397	7.50	116.899	116.564
FB2	355.469	3,002	17,283,340.980	8,267,826.936	7.50	117.267	116.536

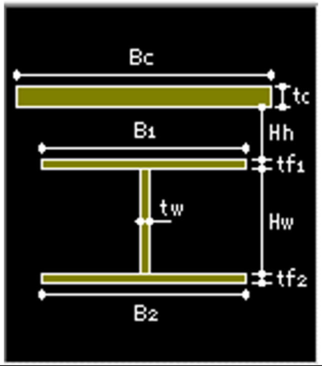
Notes	Midas Station (in)	Mida							Expansion Joint (Yes / No)	
	Girder:									
CL Bearing Pier 2W	0.000	4,000	17,283,407.321	8,268,246.311	7.50	116.562	116.594		No	09268_XB_2
FB1	177.734	4,001	17,283,287.603	8,268,114.961	7.50	116.542	116.594		No	30WF108
FB2	355.469	4,002	17,283,167.886	8,267,983.613	7.50	116.521	116.594		No	30WF108

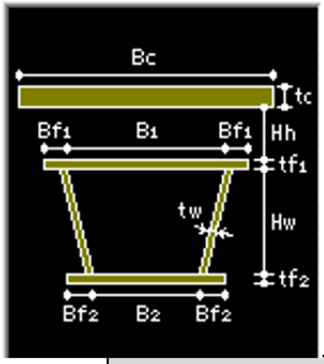
Composite I Sections

	FB Size	Hw (in)	B1 (in)	tf1 (in)	tw (in)	B2 (in)	tf2 (in)
FB_1	30WF108	28.300	10.484	0.760	0.548	10.484	0.760
FB_2	36WF135	33.962	11.945	0.794	0.598	11.945	0.794
FB_3	27WF94	25.416	9.990	0.747	0.490	9.990	0.747
FB_4	09268_XB_2W	93.134	12.000	1.000	0.500	12.000	1.000
FB_5							

Composite Box Sections

		Hw (in)	tw (in)	B1 (in)	Bf1(in)	tf1 (in)	B2 (in)	Bf2 (in)	tf2 (in)
XB_1	09268_XB_1	91.678	0.875	50.500	1.750	5.000	50.500	1.750	3.000
XB_2	09268N_XB_3	77.611	0.750	44.500	1.750	1.625	44.500	1.750	1.625
XB_3	09268E_XB_3	84.402	0.875	44.500	1.750	1.750	44.500	1.750	1.750
XB_4	09268N_XB_4	77.611	0.500	44.500	1.750	1.375	44.500	1.750	1.375
XB_5	09268E_XB_4	84.402	0.875	44.500	1.750	1.750	44.500	1.750	1.750
XB_6									
XB_7									
	Deck Only								



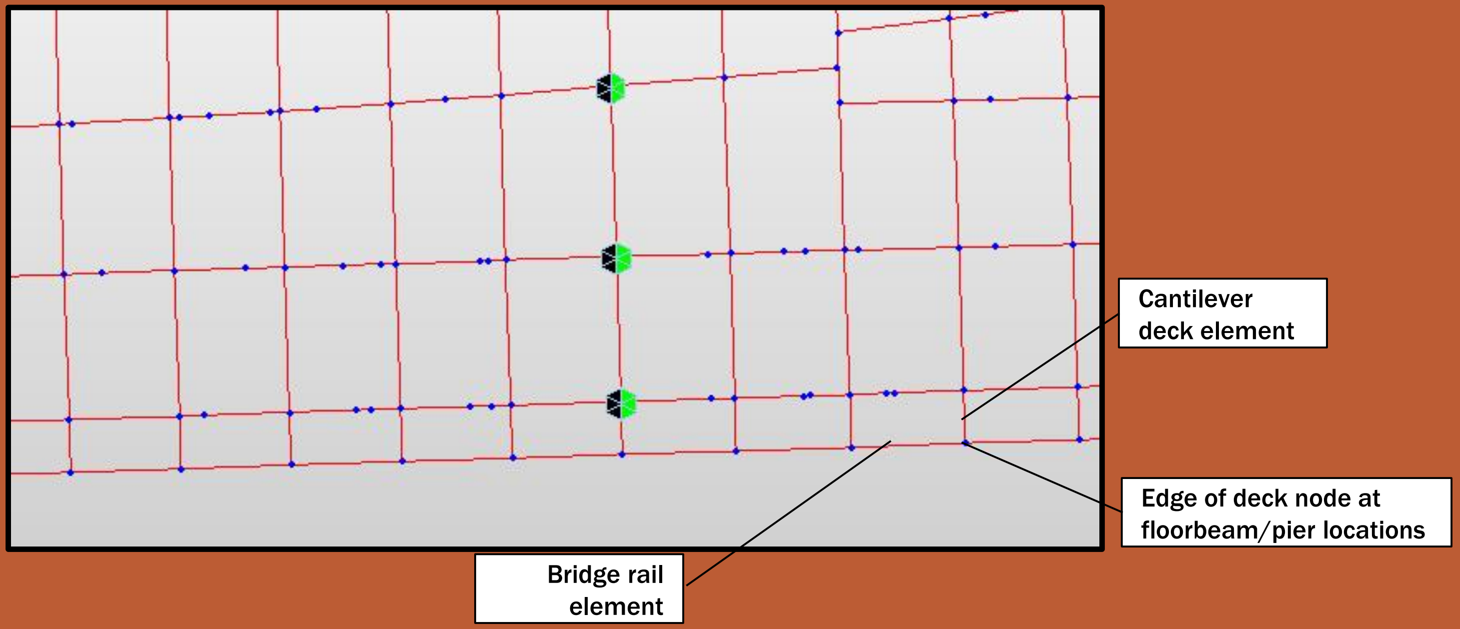


Midas Modeling

MCT Model Creation – Transverse Deck Elements

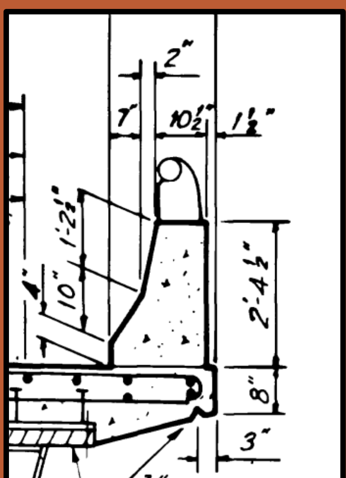
Multiple transverse elements defined - exterior deck elements

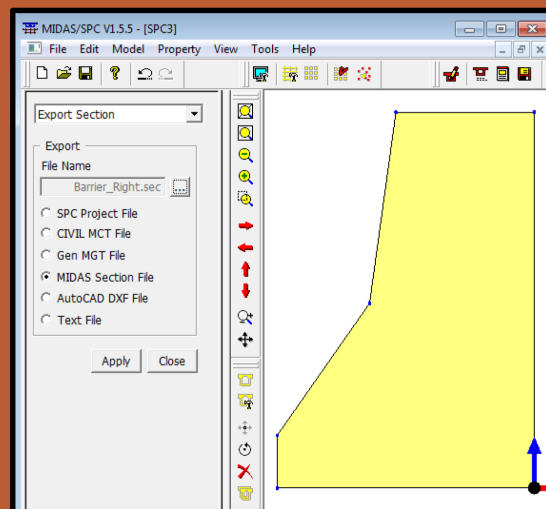
- Used to model deck overhang
- Placed at floorbeam and pier nodes
- Oriented normal to the exterior girder
- Section is deck only with a 50% increase in flexural stiffness to account for the actual location of the exterior web

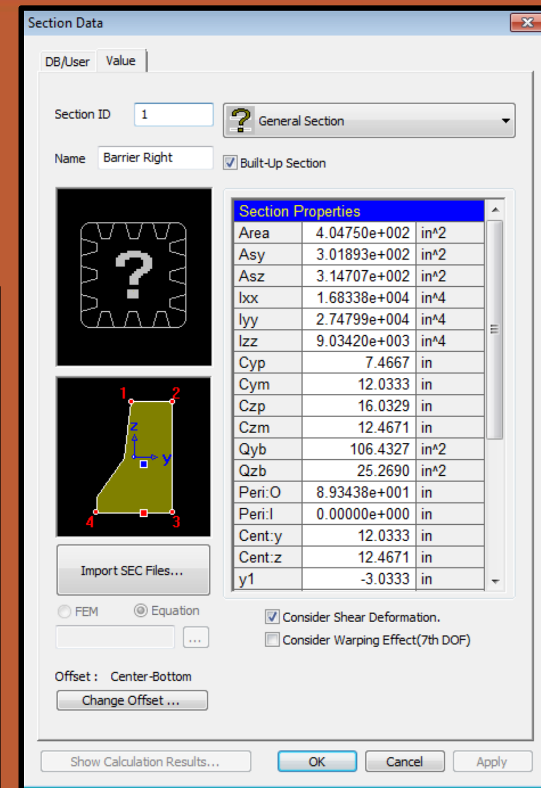


Midas Modeling

MCT Model Creation – Longitudinal Bridge Rail Elements







Plans ⇨ AutoCAD ⇨ Section Property Calculator ⇨ Midas Civil Section

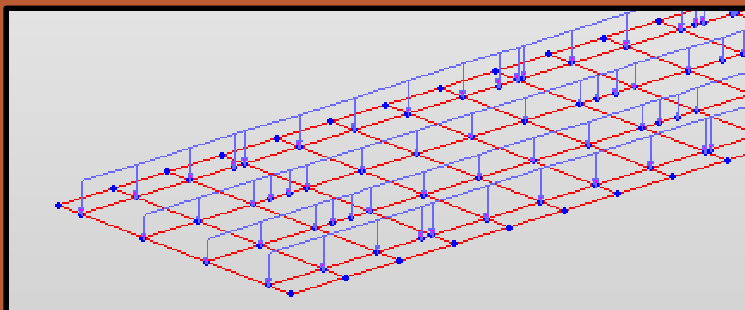
- Modeled the concrete bridge rail as a longitudinal beam element
- Connects adjacent cantilever transverse deck elements at the free end
- Used as the reference beam element for exterior girder live load lane definitions
- Utilized the Midas Section Property Calculator tool with the AutoCad import features

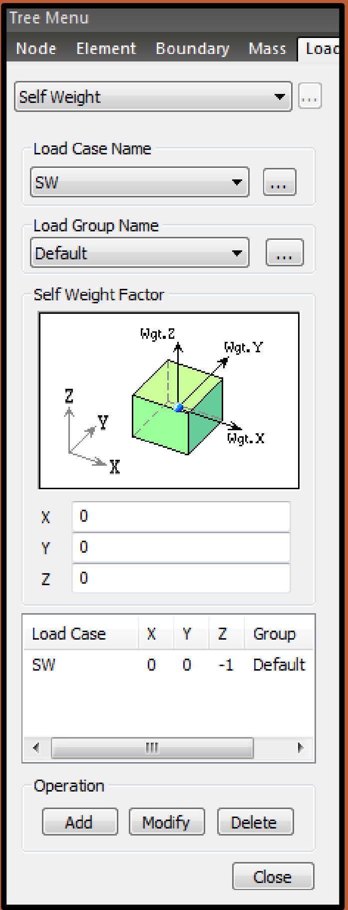
Midas Modeling

MCT Model Creation – Dead Loads

Applied loads

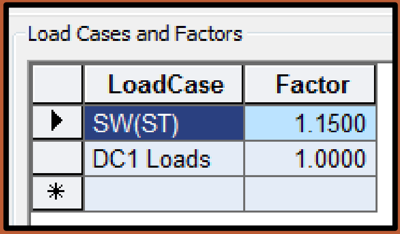
- SW factor
  - Conservatively set as 15%
  - Accounts for stiffeners, splice plates, bolts, welds, and miscellaneous steel components other than the primary SBG steel elements
  - Applied to only steel elements – use modified concrete density
- Composite SBG – steel weight only (Set Ds/Dc=0)
- Deck – transverse deck elements





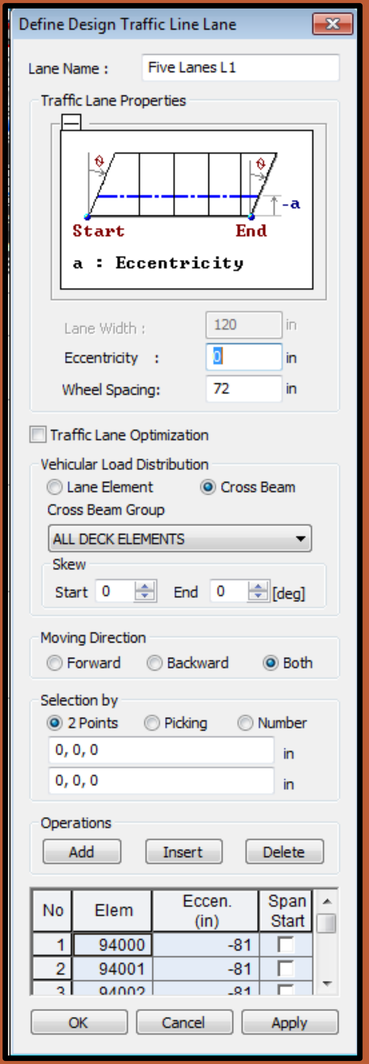
Selfweight

- Loads are applied to SBG elements and nodes
  - Primary expansion joint components selfweight
  - Top flange buildup
  - Wearing surface
  - Additional bridge rail components – metal rail, fence, etc.
  - Utilities

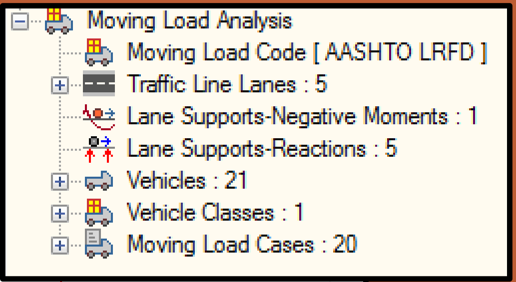


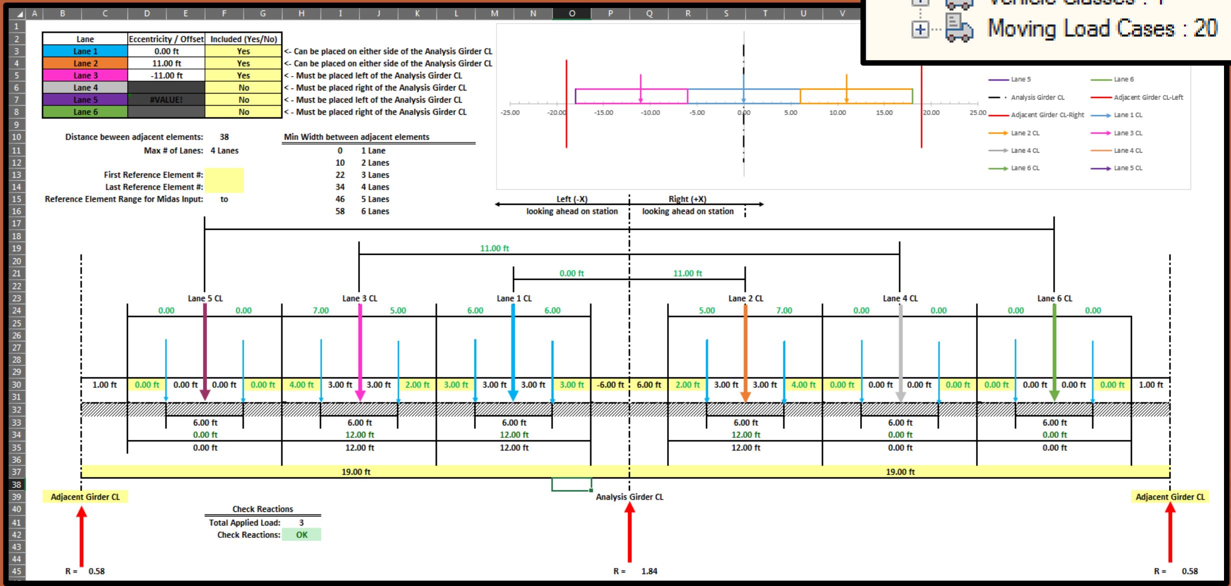
Midas Modeling

MCT Model Creation – Live Loads



- LL demands were determine by defining multiple lanes for each girder
- Excel workbooks were created to allow for quick definitions of moving load parameters and to determine lane locations
- Workbook macro created MCT files do define LL parameters
  - Moving load code
  - 21 vehicles
  - 1 vehicle class
  - Multiple traffic line lanes with span start locations
  - 20 moving load cases with sub load cases



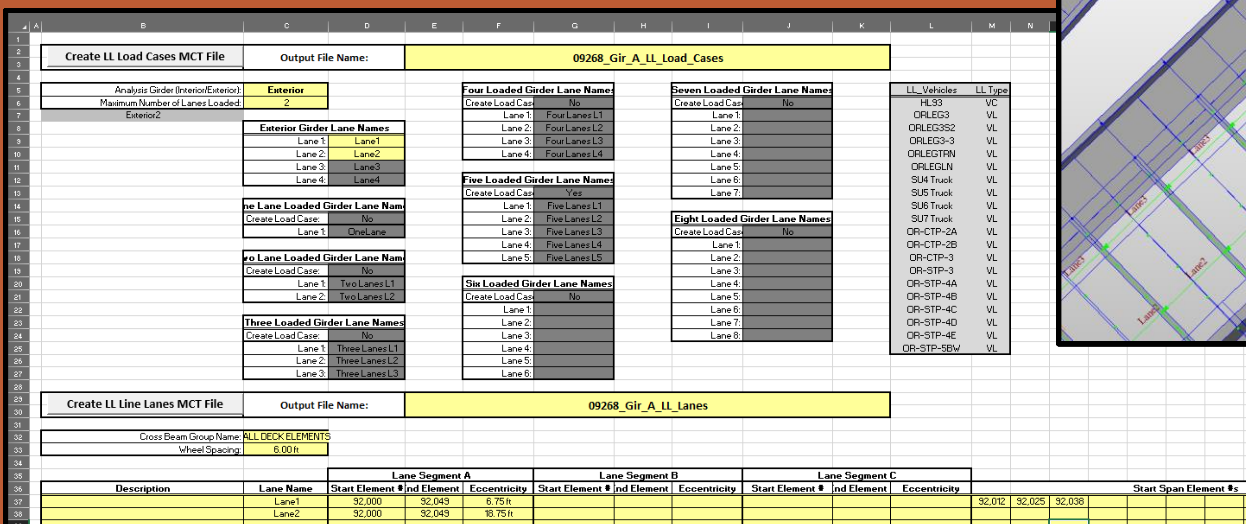


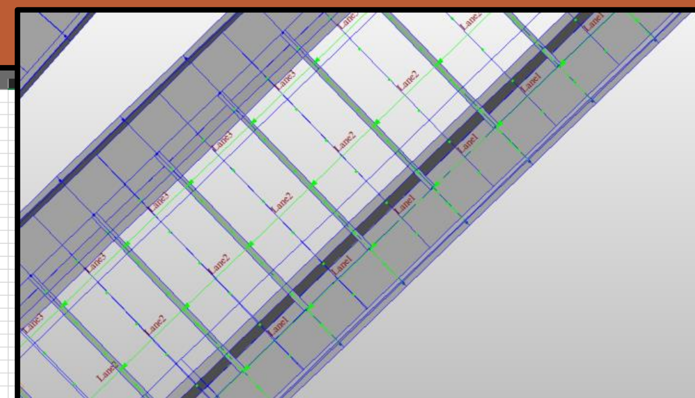
Midas Modeling

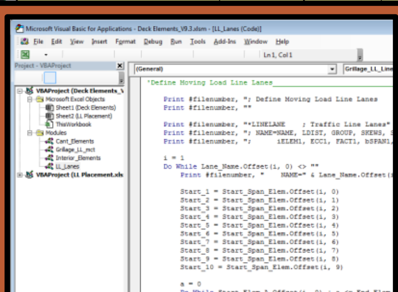
MCT Model Creation – Live Loads

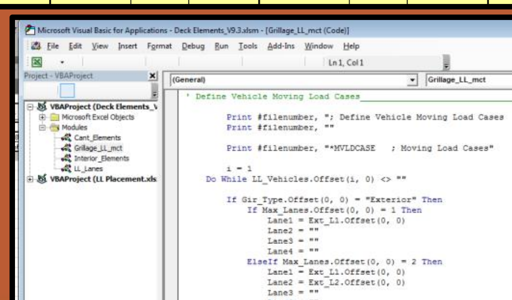
Exterior Girder Live Load

- Lanes were shifted as close as possible to face of the barrier (2ft)
- Longitudinal bridge rail element was used as the reference beam element for lane eccentricity inputs







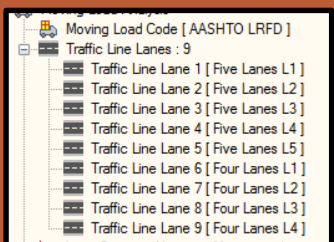


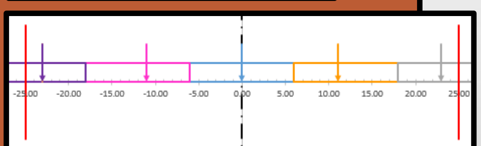
Midas Modeling

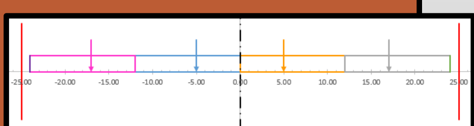
MCT Model Creation – Live Loads

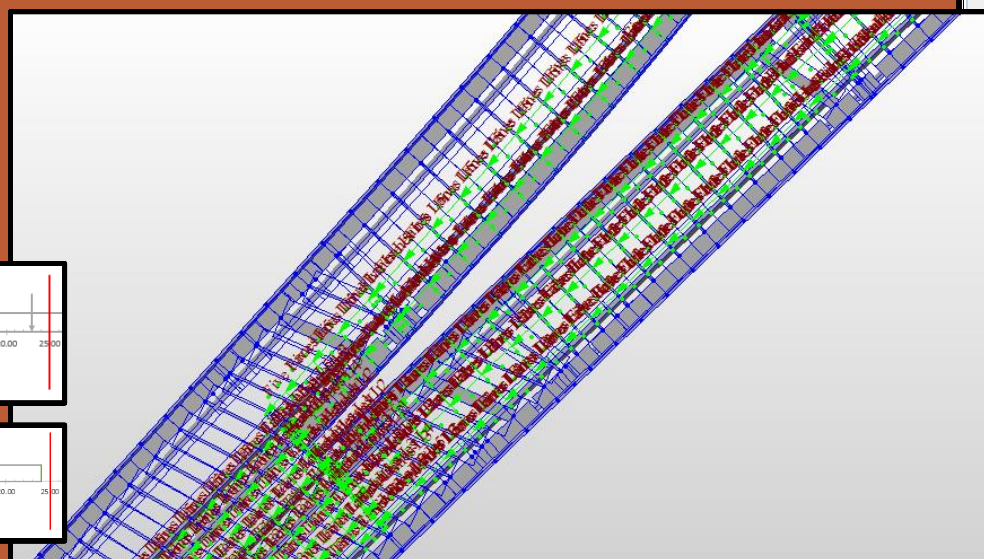
Interior Girder Live Load

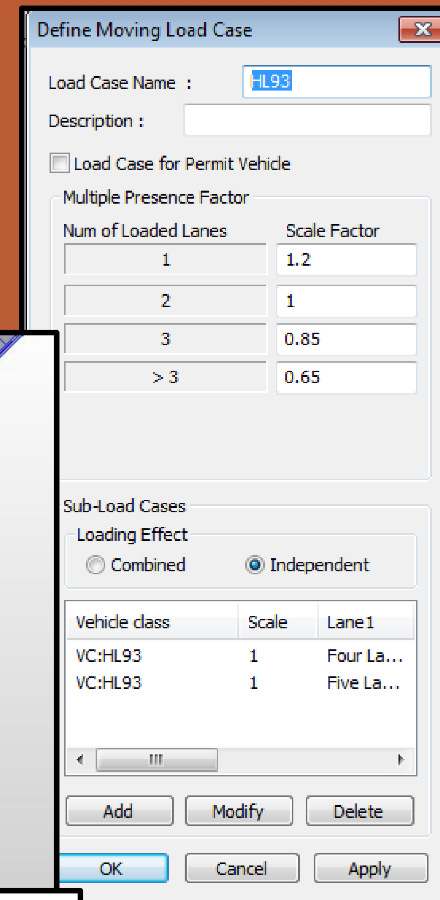
- Moving load sub-load cases were defined to allow for different lane combinations (odd/even)
- Up to 9 unique lanes were defined for some interior girders
- Splitting decks required multiple lane reference elements (both bridge rail elements and SBG elements) for a single lane definition









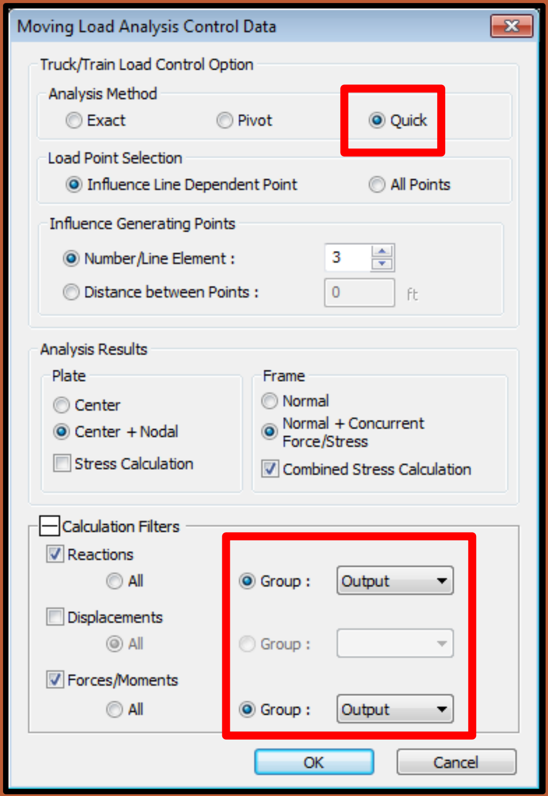


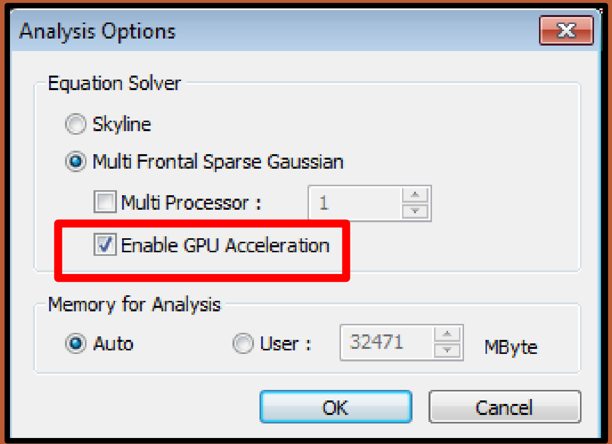
	Lane Segment A			Lane Segment B			Lane Segment C		
Lane Name	Start Element #	End Element #	Eccentricity	Start Element #	End Element #	Eccentricity	Start Element #	End Element #	Eccentricity
Five Lanes L1	94,000	94,081	-6.75 ft	5,033	5,043	-5.00 ft	5,045	5,092	-5.00 ft
Five Lanes L2	94,000	94,081	-18.75 ft	5,033	5,043	-17.00 ft	5,045	5,092	-17.00 ft
Five Lanes L3	95,000	95,024	6.75 ft	5,033	5,043	5.00 ft	5,045	5,092	5.00 ft
Five Lanes L4	95,000	95,024	18.75 ft	5,033	5,043	17.00 ft	5,045	5,092	17.00 ft
Five Lanes L5	94,000	94,081	-30.75 ft						

Midas Modeling

Model Analysis

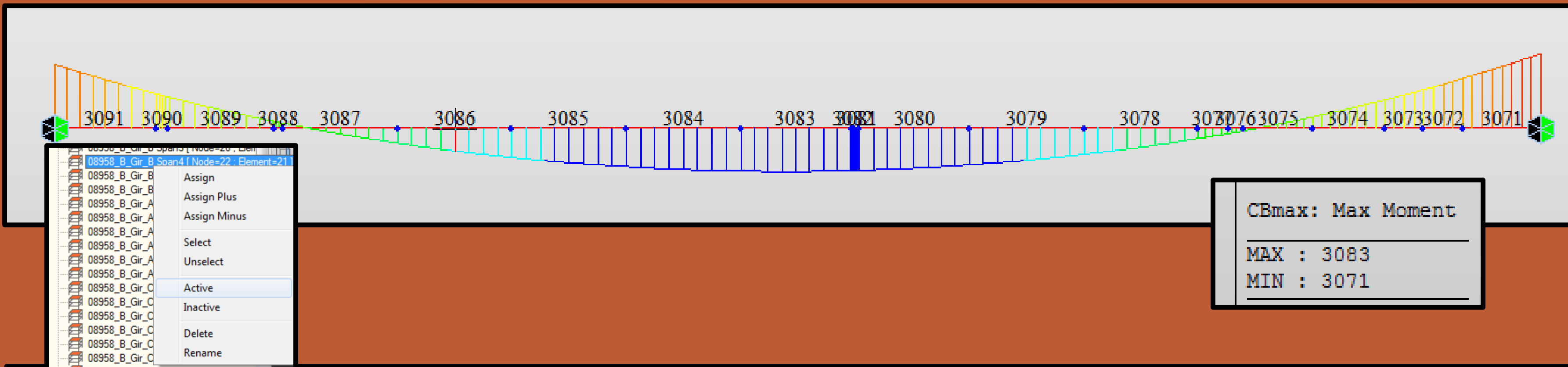
- Running the analysis can take a very long time (hours)
- Run analysis on local hard drive
- Create copies of base model for each girder w/ unique lane locations
- Enable GPU acceleration
- Adjust Moving Load Analysis Control Data
  - Use the Quick Analysis method
    - Significant reduction in runtime with limited loss of accuracy
    - Can use the Quick Analysis option for preliminary results then use the Exact method after results have been confirmed
  - Use Calculation Filters to limit analysis to structure group (girder) of interest and only the desire result type (reactions, displacements, force/moments)

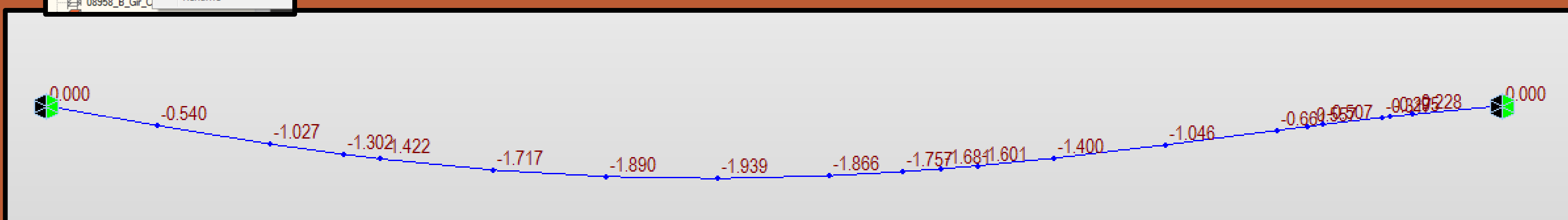


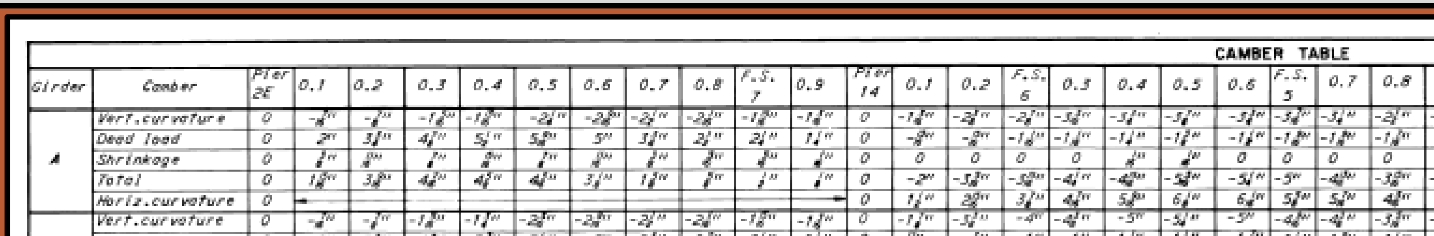


Midas Modeling

Model Verification







- Use of structure groups to easily view individual girder lines
- Check beam diagrams to insure appropriate shear and moment shapes
- Check dead load deflections against as-built camber tables

Midas Modeling

Model Output – Result Tables

	Elem	Load	Part	Component	Axial (kips)	Shear-y (kips)	Shear-z (kips)	Torsion (in*kips)	Moment-y (in*kips)	Moment-z (in*kips)
	5022	HL93(ma	I[5022]	Moment-y	0.00	0.00	0.00	0.00	0.00	0.00
	5022	HL93(ma	J[5023]	Moment-y	0.00	-7.55	-26.31	-1137.80	303.10	192.99
	5023	HL93(ma	I[5023]	Moment-y	1.88	-0.66	-16.61	101.35	323.69	17.47
	5023	HL93(ma	J[5024]	Moment-y	2.73	-1.96	-22.14	701.34	4057.08	136.33
	5024	HL93(ma	I[5024]	Moment-y	4.07	-0.90	-41.95	4594.46	5434.16	-271.67
	5024	HL93(ma	J[5025]	Moment-y	6.38	-1.82	-121.52	4784.54	25597.99	-190.99
	5025	HL93(ma	I[5025]	Moment-y	8.42	-0.71	-66.08	5453.74	25383.81	-310.88
	5025	HL93(ma	J[5026]	Moment-y	8.06	-0.93	-103.49	2403.51	41194.36	-116.89
	5026	HL93(ma	I[5026]	Moment-y	-1.45	0.26	4.37	1812.90	41278.43	156.51
	5026	HL93(ma	J[5027]	Moment-y	-1.45	0.26	4.37	1812.87	40964.07	138.11
	5027	HL93(ma	I[5027]	Moment-y	-1.45	0.25	4.37	1948.47	40957.85	138.11
	5027	HL93(ma	J[5028]	Moment-y	-2.01	0.27	-5.05	2825.18	40841.93	62.75
	5028	HL93(ma	I[5028]	Moment-y	-1.71	0.11	-5.35	3006.13	40839.62	43.98
	5028	HL93(ma	J[5029]	Moment-y	-1.80	0.05	-11.64	2618.70	41853.76	24.50
	5029	HL93(ma	I[5029]	Moment-y	-1.80	0.05	-11.64	2758.01	41844.80	24.50
	5029	HL93(ma	J[5030]	Moment-y	-1.76	-0.01	-29.33	2974.18	43023.75	19.19
	5030	HL93(ma	I[5030]	Moment-y	-1.56	-0.29	-28.04	3003.66	42985.25	0.25
	5030	HL93(ma	J[5031]	Moment-y	-1.56	-0.31	-31.99	3048.21	48826.56	54.91
	5031	HL93(ma	I[5031]	Moment-y	-1.54	-0.37	-29.32	3191.68	48773.22	32.62
	5031	HL93(ma	J[5032]	Moment-y	-1.65	-0.39	-30.73	3302.23	54303.63	98.20
	5033	HL93(ma	I[5033]	Moment-y	0.60	-1.09	-64.50	3833.31	100643.25	-26.70
	5033	HL93(ma	J[5034]	Moment-y	0.60	-1.09	-66.14	3729.69	112342.29	168.55
	5034	HL93(ma	I[5034]	Moment-y	0.39	-0.53	71.26	1221.08	111966.86	121.28
	5034	HL93(ma	J[5035]	Moment-y	0.49	-0.67	-0.68	1375.64	105872.27	238.93
	5035	HL93(ma	I[5035]	Moment-y	0.44	-0.34	79.44	44.26	105670.58	156.16
	5035	HL93(ma	J[5036]	Moment-y	0.49	-0.46	32.19	519.15	98339.07	209.80
	5036	HL93(ma	I[5036]	Moment-y	0.50	-0.45	32.19	829.39	98336.94	209.80
	5036	HL93(ma	J[5037]	Moment-y	0.51	-0.49	16.03	1444.87	97755.59	242.05
	5037	HL93(ma	I[5037]	Moment-y	0.39	-0.26	116.20	-89.19	97552.64	158.57
	5037	HL93(ma	J[5038]	Moment-y	0.46	-0.35	56.48	430.93	82292.15	222.46
	5038	HL93(ma	I[5038]	Moment-y	0.20	-0.15	121.16	-5099.43	82004.75	143.05
	5038	HL93(ma	J[5039]	Moment-y	-0.12	-0.22	42.27	-584.29	66444.87	89.73
	5039	HL93(ma	I[5039]	Moment-y	-0.28	-0.07	114.03	582.30	66532.34	51.38
	5039	HL93(ma	J[5040]	Moment-y	-0.27	-0.07	111.41	348.98	60418.49	54.88
	5040	HL93(ma	I[5040]	Moment-y	-0.27	-0.07	111.41	551.50	60416.97	54.88

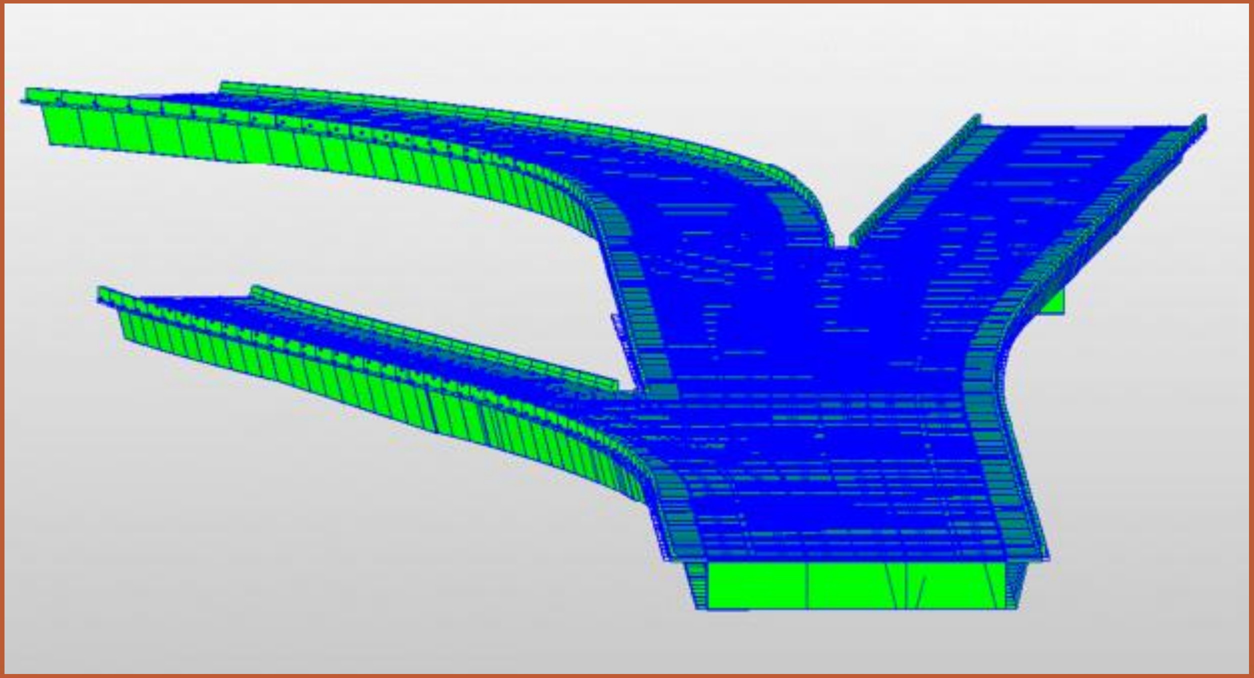
	A	B	C	D	E	F	G	H	I	J
1	**Max Moment**									
2										
3		Set Moment Tbl								
4										
5										
6	**Elem**	**Load**	**Part**	**Component**	**Axial (kips)**	**Shear-y (kips)**	**Shear-z (kips)**	**Torsion (in·kips)**	**Moment-y (in·kips)**	**Moment-z (in·kips)**
7	5022	HL93(max)	I[5022]	Moment-y	0	0	0	0	0	0
8	5022	HL93(max)	J[5023]	Moment-y	0	0	0	0	0	0
9	5023	HL93(max)	I[5023]	Moment-y	4.72	-3.89	-11.19	473.55	104.28	-276.63
10	5023	HL93(max)	J[5024]	Moment-y	5.39	-5.44	-17.33	47.11	3082.91	615.3
11	5024	HL93(max)	I[5024]	Moment-y	5.1	0.65	-43.91	4449.24	4780.26	122.48
12	5024	HL93(max)	J[5025]	Moment-y	7.06	-0.47	-122.5	4635.36	25453	-73.72
13	5025	HL93(max)	I[5025]	Moment-y	8.59	0.07	-67.08	5310.4	25241.04	-161.57
14	5025	HL93(max)	J[5026]	Moment-y	8.22	-0.09	-104.11	2280.08	41301.7	-106.79
15	5026	HL93(max)	I[5026]	Moment-y	-1.56	0.35	4.33	1757.49	41399.84	169.57
16	5026	HL93(max)	J[5027]	Moment-y	-1.56	0.35	4.33	1757.45	41088.61	144.68
17	5027	HL93(max)	I[5027]	Moment-y	-1.57	0.34	4.33	1893.47	41082.56	144.68
18	5027	HL93(max)	J[5028]	Moment-y	-2.12	0.36	-5.08	2769.04	40978.04	59.29
19	5028	HL93(max)	I[5028]	Moment-y	-1.84	0.11	-5.29	2953.28	40976.17	41.74
20	5028	HL93(max)	J[5029]	Moment-y	-1.93	0.06	-11.57	2562.87	41989.89	21.86
21	5029	HL93(max)	I[5029]	Moment-y	-1.93	0.05	-11.57	2702.62	41981.13	21.86
22	5029	HL93(max)	J[5030]	Moment-y	-1.91	-0.01	-29.28	2914.91	43161.81	16.16
23	5030	HL93(max)	I[5030]	Moment-y	-1.7	-0.31	-27.89	2942.55	43122.68	-2.37
24	5030	HL93(max)	J[5031]	Moment-y	-1.7	-0.32	-31.84	2985.93	48938.41	54.39
25	5031	HL93(max)	I[5031]	Moment-y	-1.67	-0.38	-29.08	3124.26	48884.08	31.94
26	5031	HL93(max)	J[5032]	Moment-y	-1.78	-0.39	-30.49	3235.85	54369.57	99.14
27	5033	HL93(max)	I[5033]	Moment-y	0.52	-1.11	-64.42	3789.42	100805.1	-34.84
28	5033	HL93(max)	J[5034]	Moment-y	0.53	-1.11	-66.06	3685.76	112489.4	164.23
29	5034	HL93(max)	I[5034]	Moment-y	0.31	-0.54	71.38	1174.17	112113.7	116.82

Midas Output Tables → **Capacity & RF Workbook**

- Able to quickly copy and paste results form Midas into Excel

Conclusion

- 2D grillage models are an effective refined analysis option for complex bridges and when live load distribution factors are not applicable
- Using MCT command shell files to create large and/or complex models can save time and reduce errors
- Excel spreadsheets and macros can be used to create MCT files to stream line the process



DAVID EVANS AND ASSOCIATES INC.

2D Grillage Analysis of Curved Steel Box Girders

QUESTIONS?

Presented by

Tim Link, PE