2D Grillage Analysis of Curved Steel Box Girders

Presented by
Tim Link, PE
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)
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
- Midas Civil Model
- MCT Shell Files
- ODOT Load Rating Summary Worksheet
- Capacity and RF Worksheet (Template)
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

<table>
<thead>
<tr>
<th>Group</th>
<th>Criteria</th>
<th>Model Description</th>
<th>Live Load Application</th>
</tr>
</thead>
</table>
| 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 431 ft 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
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
  - Describes common command parameters in a more user-friendly manner

---

**MCT File Quick Reference**

*COMMAND (Functions of midas Civil)*

<table>
<thead>
<tr>
<th>Brief descriptions of the Commands</th>
</tr>
</thead>
<tbody>
<tr>
<td>; Variables that make up the Commands</td>
</tr>
<tr>
<td>Description of each variable (method of expression) (initialized value)</td>
</tr>
</tbody>
</table>

* 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
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 & *SELWEIGHT)
- Load combinations (*LOADCOMB)
- Boundary groups (*BNDR-GROUP)
- Custom dynamic report tables (*DYNAGEN-TABLE)

![Project Information](image)
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**
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 serves 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
Step: 2) Create Excel workbook to combine and sort all of the analysis and additional geometry nodes

### Midas Coordinate Table

<table>
<thead>
<tr>
<th>Midas Node ID</th>
<th>Midas Station (in)</th>
<th>Bridge Station (ft)</th>
<th>Offset from Alignment (ft)</th>
<th>Node Coordinates (from CAD)</th>
<th>Node Coordinates Adjusted for Input into Midas</th>
<th>Node Local Axis Angle (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5022</td>
<td>0.000</td>
<td>310+69.59</td>
<td>4.802</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5023</td>
<td>11.600</td>
<td>310+68.83</td>
<td>4.833</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5024</td>
<td>183.375</td>
<td>310+54.30</td>
<td>4.810</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5025</td>
<td>367.362</td>
<td>310+39.00</td>
<td>4.794</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5026</td>
<td>551.059</td>
<td>310+23.70</td>
<td>4.790</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5027</td>
<td>622.906</td>
<td>310+17.72</td>
<td>4.833</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5028</td>
<td>734.648</td>
<td>310+68.42</td>
<td>4.900</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5029</td>
<td>862.906</td>
<td>309+97.74</td>
<td>4.977</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5030</td>
<td>917.978</td>
<td>309+83.16</td>
<td>5.010</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5031</td>
<td>1,101.050</td>
<td>309+77.92</td>
<td>5.120</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5032</td>
<td>1,284.468</td>
<td>309+62.65</td>
<td>5.230</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5033</td>
<td>1,287.468</td>
<td>309+61.67</td>
<td>9.960</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5034</td>
<td>1,465.719</td>
<td>309+45.84</td>
<td>8.896</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Bridge Station and Offset Table

<table>
<thead>
<tr>
<th>Description</th>
<th>Midas Station (in)</th>
<th>Bridge Station (ft)</th>
<th>Offset from Alignment (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearing Expansion Joint 12</td>
<td>0.000</td>
<td>310+69.59</td>
<td>4.80</td>
</tr>
<tr>
<td>Pier 12</td>
<td>183.375</td>
<td>310+54.30</td>
<td>4.81</td>
</tr>
<tr>
<td>end of divider (11” before FB3)</td>
<td>538.099</td>
<td>310+24.80</td>
<td>4.78</td>
</tr>
<tr>
<td>FB3</td>
<td>551.099</td>
<td>310+23.70</td>
<td>4.79</td>
</tr>
<tr>
<td>FB 7</td>
<td>1,284.468</td>
<td>309+62.65</td>
<td>5.23</td>
</tr>
<tr>
<td>3m after FB 7</td>
<td>1,287.468</td>
<td>309+61.67</td>
<td>9.96</td>
</tr>
<tr>
<td>FB 11</td>
<td>2,006.030</td>
<td>309+41.47</td>
<td>6.67</td>
</tr>
<tr>
<td>FB 15</td>
<td>2,733.936</td>
<td>308+41.47</td>
<td>4.78</td>
</tr>
<tr>
<td>3m after FB 15</td>
<td>2,736.936</td>
<td>308+40.75</td>
<td>9.40</td>
</tr>
<tr>
<td>Pier 13</td>
<td>3,180.687</td>
<td>308+10.99</td>
<td>8.61</td>
</tr>
<tr>
<td>FB 22</td>
<td>4,150.286</td>
<td>307+23.80</td>
<td>4.96</td>
</tr>
<tr>
<td>FS 6</td>
<td>4,900.660</td>
<td>306+61.37</td>
<td>2.08</td>
</tr>
<tr>
<td>Pier 14</td>
<td>5,549.750</td>
<td>306+07.43</td>
<td>2.40</td>
</tr>
<tr>
<td>Pier 2E</td>
<td>7,894.313</td>
<td>304+12.05</td>
<td>2.40</td>
</tr>
</tbody>
</table>
Step: 3) Use the workbook to export the node station and offsets into CAD.
Step: 4) Export the node global coordinates from CAD back into the workbook and use the workbook to calculate node local axes.
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
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**

<table>
<thead>
<tr>
<th>Span No</th>
<th>Start Station</th>
<th>End Station</th>
<th>Length Along Flange 1</th>
<th>Length Along Flange 2</th>
<th>Length Along CL</th>
<th>Web Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.000</td>
<td>183.375</td>
<td>15’ - 3 /3”</td>
<td>15’ - 3 /3”</td>
<td>183.375</td>
<td>0.438</td>
</tr>
<tr>
<td>2</td>
<td>183.375</td>
<td>622.906</td>
<td>36’ - 7 9/16”</td>
<td>36’ - 7 /12”</td>
<td>439.531</td>
<td>0.438</td>
</tr>
<tr>
<td>3</td>
<td>622.906</td>
<td>1420.937</td>
<td>46’ - 6 1/8”</td>
<td>46’ - 6 1/8”</td>
<td>523.931</td>
<td>0.438</td>
</tr>
</tbody>
</table>

**Deck Thickness & Uniform Loads**

<table>
<thead>
<tr>
<th>Start Station</th>
<th>End Station</th>
<th>Description</th>
<th>Deck Thickness</th>
<th>Deck to top of web</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>183.375</td>
<td>Bear. Exp. Joint 12</td>
<td>8.750</td>
<td>16.250</td>
</tr>
<tr>
<td>183.375</td>
<td>536.099</td>
<td>Pier 12 to end of divide</td>
<td>8.750</td>
<td>16.250</td>
</tr>
</tbody>
</table>

**Overall Girder Geometry**

<table>
<thead>
<tr>
<th>Description</th>
<th>Station</th>
<th>Web Height (along web)</th>
<th>Web Height (vertical)</th>
<th>Web Slope</th>
<th>Slope Angle from Vert.</th>
<th>Web Spa. at Bottom</th>
<th>Web Spa. at Top</th>
<th>Tributary Width Left</th>
<th>Tributary Width Right</th>
<th>Eff. Deck Width</th>
<th>B_eff (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearing Expansion Joint 12</td>
<td>0.000</td>
<td>113.000</td>
<td>109.628</td>
<td>4.000</td>
<td>14.036</td>
<td>46.000</td>
<td>100.813</td>
<td>83.407</td>
<td>95.650</td>
<td>179.063</td>
<td></td>
</tr>
<tr>
<td>Pier 12</td>
<td>183.375</td>
<td>113.000</td>
<td>109.628</td>
<td>4.000</td>
<td>14.036</td>
<td>46.000</td>
<td>100.813</td>
<td>83.407</td>
<td>95.719</td>
<td>179.125</td>
<td></td>
</tr>
<tr>
<td>end of divide</td>
<td>536.099</td>
<td>113.000</td>
<td>109.628</td>
<td>4.000</td>
<td>14.036</td>
<td>46.000</td>
<td>100.813</td>
<td>83.407</td>
<td>95.460</td>
<td>178.875</td>
<td></td>
</tr>
</tbody>
</table>

**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
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

Composite cross-girder interior deck element
Composite floorbeam interior deck element
Interior deck element
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

- 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
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 determined 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
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
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 with 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 desired 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

<table>
<thead>
<tr>
<th></th>
<th>Load</th>
<th>Part Component</th>
<th>Axial (kips)</th>
<th>Shear-x (kips)</th>
<th>Shear-y (kips)</th>
<th>Torsion (kips)</th>
<th>Moment-x (kip-in)</th>
<th>Moment-y (kip-in)</th>
<th>Moment-z (kip-in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5022</td>
<td>H19 (max)</td>
<td>[5022] Moment-y</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.65</td>
<td>0.65</td>
<td>0.65</td>
<td></td>
</tr>
<tr>
<td>5022</td>
<td>H19 (max)</td>
<td>[5022] Moment-y</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.65</td>
<td>0.65</td>
<td>0.65</td>
<td></td>
</tr>
<tr>
<td>5022</td>
<td>H19 (max)</td>
<td>[5022] Moment-y</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>5022</td>
<td>H19 (max)</td>
<td>[5022] Moment-y</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
<td></td>
</tr>
</tbody>
</table>

• 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 streamline the process
2D Grillage Analysis of Curved Steel Box Girders

QUESTIONS?

Presented by
Tim Link, PE