# 2016 Elite Engineers Webinar Series

MIDAS

### Pushover Analysis of a Torsionally Eccentric Cellular Abutment

Date 11/03/2016 3 PM – 4 PM Eastern Time

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#### MIDAS Ch2m:

### **Presentation Outline**

- Project Overview
- Superstructure Analysis
- Substructure Analysis
  - Substructure Model
  - Elastic Analysis
  - Inelastic Analysis
- Pushover Analysis in Midas Civil 3D
  - Elastic Model
  - General Section Designer
  - Pushover Analysis
- Result Comparisons
- Shear Design of Column and Element Detailing





### **Presentation Overview**

- Presentation Objectives
  - Develop understanding of:
    - Modeling Techniques
    - Inelastic Analysis
    - Midas General Section Designer
    - Midas Civil 3D Pushover Analysis
- Limitations of Presentation
  - Presentation will not:
    - Discuss foundation bearing and sliding capacity
    - Explain all theory behind topics
    - Provide all steps required to use software
    - Provide algorithms used for calculations





- Led by Central Federal Lands
- Funded by Federal Lands Access Program
- Project Location
  - Tahoe National Forest
  - Placer County, CA
  - Tahoe City, CA





#### MIDAS ch2m:

- Structure Selection
  - Original Structure
    - Three Spans
    - Deep Foundations
    - Complicated Geometry
  - Revised Design
    - Single Main Span
    - Shallow Foundations
    - Square Geometry





- Truckee River Bridge
- Bridge Description
  - 119'-0" Simple Span Decked Bulb Tee Girder
  - 14'-0" Cellular Abutments
    - Retaining wall toward Embankment
    - Columns toward River





### **Project Overview**

### Bridge Elevation







### Superstructure

- AASHTO LRFD 2012 6<sup>th</sup> Edition with Caltrans Amendments
- Decked Bulb Tee Girders UDOT Typical Section
- Level Bearing Seats
- Steel Reinforced Elastomeric Bearing Pads
- CIP Concrete Topping
- CIP Diaphragms
- CIP Barriers





### Midas Civil 3D Superstructure Wizard

- Not used for primary design
- Used to verify distribution factors were conservative



Superstructure Model with Abutments



### For Interior Moment with 2 trucks

- AASHTO Equations g=0.52
- CONSPAN Grillage g=0.46
- Midas Grillage g=0.41



Caltrans P15 Permit Truck



### Midas Civil 3D Superstructure Wizard







- Design Codes
  - AASHTO LRFD 2012 6<sup>th</sup> Edition with Caltrans Amendments
  - AASHTO LRFD 2011 Guide Specifications for Seismic Design of Highway Bridges
  - Caltrans Seismic Design Criteria 2013 v.1.7
- Substructure Overview
  - Spread Footing with Toe Walls
  - Columns with Corbel for Girder Supports
  - Retaining Wall as Backwall
  - Solid Top Slab with Utility Voids





Side Elevation

**Front Elevation** 



- Substructure Model
  - Solid Element Model in CSiBridge
  - Plate Element Model in Midas Civil 3D
  - Beam Element Model was used for Corbel Design





### Elastic Properties of Column

- Used for Initial Design
- Nominal Material Properties
- No Confined Concrete
- Rectangular Section



Column Section with Nominal Material Properties



### Element Design

- Bottom Slab, Back Wall, Top Slab
  - Plate Analysis
  - Design Forces per 1 ft Strip
  - Reinforced Concrete Design<sup>\*</sup>
- Corbel Beam
  - Stiffness considerations
  - Designed as idealized beam
  - TxDOT Design Example based on AASHTO 2010
    - AASHTO 5.13.2.4
- Columns
  - Designed to Remain elastic during Design Event





County: Any Hwy: Any

Design: BRG Date: 6/2010

Inverted Tee Bent Cap Design Example

Design example is in accordance with the AASHTO LRFD Bridge Design Specifications, 5th Ed. (2010) as prescribed by TxDOT Bridge Design Manual - LRFD (May 2009).





- Inelastic Analysis
  - Determine design value for base shear to ensure ductile plastic hinging in column



Column Shear Failure http://www.arch.virginia.edu/~km6e/tti/ttisummary/full/mex-city-shear-col-noted.jpeg



Column Plastic Hinge http://www.dot.ca.gov/hq/esc/earthquake\_engineering/da mage\_report/1\_Visual\_Catalog\_of\_RC\_Bridge\_Damage.pdf



- Seismic Design
  - PGA 0.44G T=0
  - Site Class D
  - Seismic Design Category D
  - Isolated Shear Key
  - Shear Key for ¼ Superstructure Weight
  - Minimum Seat Width
  - Considered Deflection for Utilities



Shear Key Detail



- Inelastic Section Properties
  - Expected Material Properties
    - 1.3 x f<sup>°</sup><sub>c</sub> (5.85 ksi)
    - 1.13 x f<sub>y</sub> (68 ksi)
  - Concrete Confined Inside Spirals



Column Section with Expected Material Properties



**Column Section** 



### Moment Curvature Analysis

• Determine Curvature of Section at increasing Moments



State	Curvature *10^-3 (1/in)	Moment (kip×in)
a.Crack	0.030227	3007.628
b.Yield(Init.)	0.186939	6717.772
c.Yield	1.767234	7098.877
d.Ultimate(conc)	3.384659	7325.386
e.Ultimate(rebar)	-	-
f.Yield(ideal)	0.230062	8267.406



- Pushover Analysis
  - Moment Curvature Analysis
  - Determine Overstrength Moments
    - $M_{po}=1.2 \times M_p$  Caltrans SDC Section 4.3
  - Calculate Shear with only Service Axial Force (Dead Load)
    - $V_o = (M_{po-top} + M_{po-bot})/h$
  - Sum Base Shears
  - Apply Total Shear as Lateral Force
  - Recalculate Axial Forces Include Overturning
  - Iterate until Lateral Force and Total Shear Converge



Pushover Analysis





### Pushover Analysis

#### **Abutment Pushover**

#### **Transverse Pushover**

Cap beam assumed to be rigid for pushover analysis

Column Height 14.2 ft Column Spacing 15.25 ft (between exterior columns) Lp (in) 23.01 Plastic Hinge L 1.92 ft P\_top 270 kips (DL from bridge + DL of cap beam)

Column Weight 8.5 kips

Trial 0					Trial 1								
Co	lumn	P_ot	P_top	P_bott	Mo_top	Mo_bott	Vo	P_ot	P_top	P_bott	Mo_top	Mo_bott	Vo
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	1	0.00	250	259	630.2	634.5	89.07	-99.52	170	179	588.9	593.5	83.27
	2	0.00	250	259	630.2	634.5	89.07	-33.17	237	245	623.5	627.8	88.12
	3	0.00	250	259	630.2	634.5	89.07	33.17	303	312	657.1	661.1	92.83
	4	0.00	250	259	630.2	634.5	89.07	99.52	370	378	688.4	692.4	97.24
					Total		356.261				Total		361.46

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356.261

1.439% converge =



- Torsional Eccentricity
  - Bending about both Column Axes
  - Restraint from Back Wall













- General Procedure
  - Create Elastic Model in Midas Civil 3D (Midas)
  - General Section Designer (GSD)
    - Inelastic Section Properties
    - Moment Curvature Analysis
  - Pushover Analysis
    - Define Hinge and Assign Plastic Hinge
    - Perform Analysis



- Elastic Model
  - Elements must be similar to those used in GSD
    - Used to calculate initial elastic properties in pushover analysis
  - Items to verify
    - Material Properties
    - Section Properties
    - Reinforcement Steel Layout
  - Alternatively, Properties can be entered in GSD and Linked to Midas





### General Section Designer





### • GSD – Material - Unconfined Concrete





### • GSD – Confined Area





Nonlinear propertie

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### • GSD – Steel Properties





### • GSD – Steel Pattern





### • GSD – Run Analysis





### • GSD – Moment Curvature



#### MIDAS Ch2m:

### **Pushover Analysis in Midas Civil 3D**

### • GSD – Link to Midas Civil



#### MIDAS Ch2m:

### **Pushover Analysis in Midas Civil 3D**

### • GSD – Export Hinge





### • Midas - Pushover Analysis





### • Midas - Pushover Analysis – Define Hinge





### • Midas - Pushover Analysis – Define Hinge





### • Midas - Pushover Analysis – Assign Hinge





### • Midas - Pushover Analysis – Load Case

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#### MIDAS Ch2m:

# **Pushover Analysis in Midas Civil 3D**

### • Midas - Pushover Analysis – Global Control Options

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### • Midas - Pushover Analysis – Perform Analysis





### • Midas - Pushover Analysis – Results – Pushover





### • Midas - Pushover Analysis – Results – Force Effects





### • Midas - Pushover Analysis – Single Column





### • Midas - Pushover Analysis – Frame





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# **Pushover Analysis in Midas Civil 3D**

### • Midas - Pushover Analysis – Full Plate Model



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• Additional Shear Capacity Available



Midas - Pushover Analysis – Full Plate Model



**Transverse Shear** 



Longitudinal Shear



- Midas Pushover Analysis Full Plate Model
  - Column Loses Shear Capacity at Step 33
  - Continues to Load backwall
  - Element model is required for Backwall Hinging









#### • Moment Curvature





### • Pushover Analysis

- Both methods resulted in nearly V=90k per column
- Slight Variations from Interaction with Model Elements

Trial 1						
P_ot	P_top	P_bott	Mo_top	Mo_bott	Vo	
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-33.17	237	245	623.5	627.8	88.12	
33.17	303	312	657.1	661.1	92.83	
99.52	370	378	688.4	692.4	97.24	
Total					361.46	





### Reasons for differences

- Steel Model
  - Xtract Bilinear with Strain Hardening
  - GSD Kent and Park with Strain Hardening
  - Results vary by 25% without strain hardening
- Variations in calculations



# **Shear Design and Element Detailing**



# **Shear Design**

### • Followed AASHTO LRFD Guide Spec – Section 8.6

- Concrete Strength (Vc)
- Rebar Strength considering spirals only (Vs)



Column Detailing - Section

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### **Element Detailing**

- Columns
  - Caltrans SDC Section 8
    - Longitudinal Embedment 8.2
  - AASHTO LRFD Guide Spec Section 8.8
    - Spiral terminations 8.8.7



Column Detailing - Section



**Column Detailing** 

#### MIDAS ch2m:

# **Element Detailing**

- Corbel Beam
  - AASHTO LRFD Guide Spec Section 8.13
    - Determine Level of Detailing
    - Principal Stress Checks for SDC D
    - Calculated Based on Column Moments





# **Element Detailing**

- Slabs
  - Caltrans SDC Section 8
  - AASHTO LRFD Guide Spec Section 8.8







# Summary

- Elastic Analysis
- Inelastic Analysis
- Midas Civil 3D Pushover Analysis
- Result Checking
- Shear Design



# Acknowledgements

- Midasoft
- Central Federal Lands
- CH2M
- Design Workshop
- LEAP CONSPAN
- CSiBridge
- TxDOT
- XTRACT



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### Questions







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