

# 3D Modeling Capabilities Available in AASHTOWare Bridge Design and Rating



Iowa Department of Transportation  
Workshop on 3D Design and Modeling for Highway  
Structures  
April 15, 2015

# Topics



1. AASHTOWare
2. Software Overview
3. 3D Features and Capabilities
4. Summary



# AASHTOWare Bridge Products



## **AASHTOWARE Bridge Rating™**

*(formerly Virtis)*

Bridge Load Rating



## **AASHTOWARE Bridge Design™**

*(formerly Opis)*

Bridge Design



## **AASHTOWARE Bridge Management™**

*(formerly Pontis)*

Bridge Management





- Joint Development Effort
- Pooled Resources
- Software is owned by AASHTO
- Managed by a Task Force
- Tested by users (Technical Advisory Group)



# Task Force Members



- Todd Thompson, South Dakota DOT , Chairman
- Dean Teal, Kansas DOT
- Jeff Olsen, Montana DOT
- Amjad Waheed, Ohio DOT
- Joshua Dietsche, Wisconsin DOT
- Judy Skeen – AASHTO Project Manager
- Tom Saad – FHWA Liaison



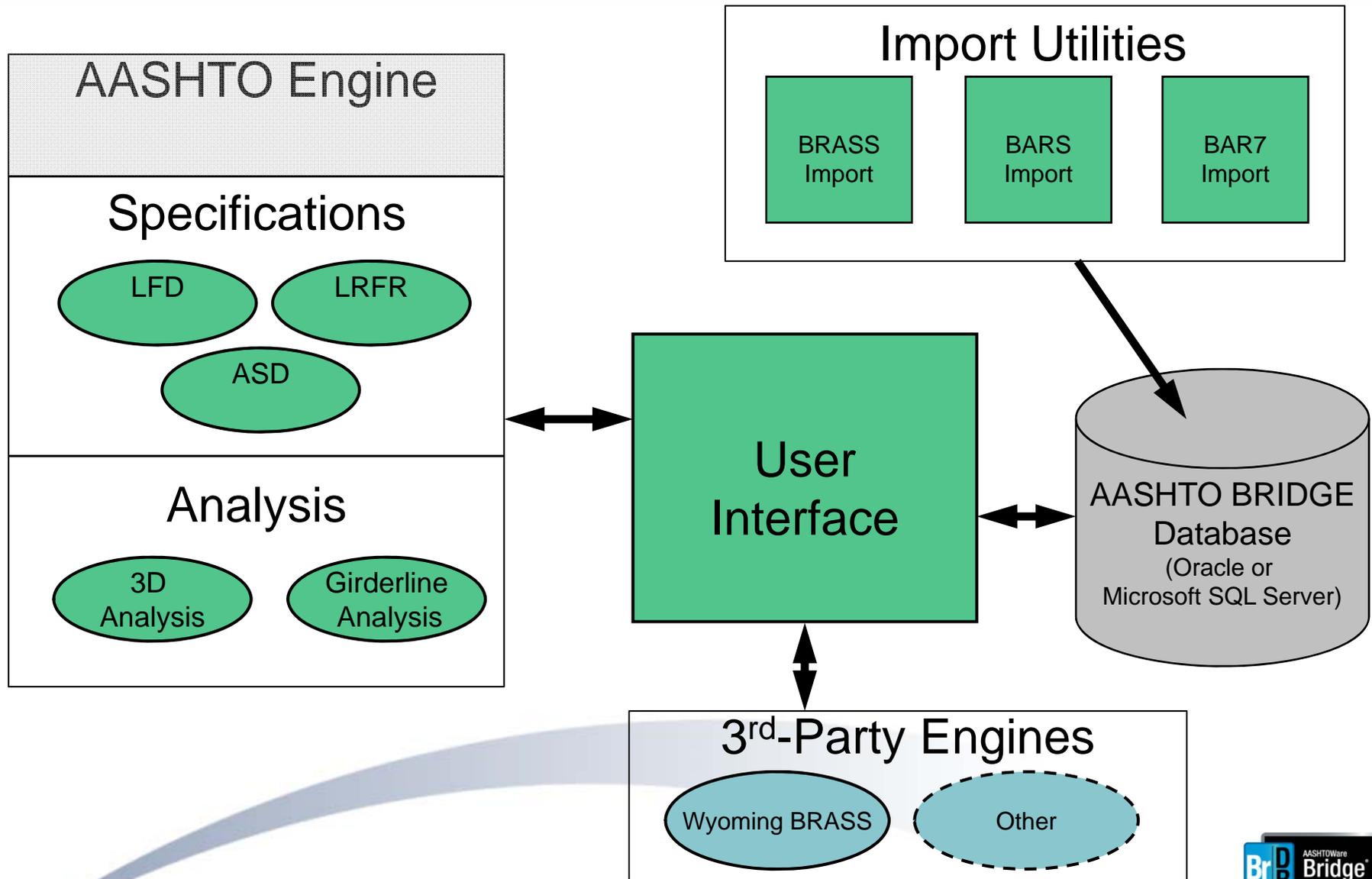
# Software Overview



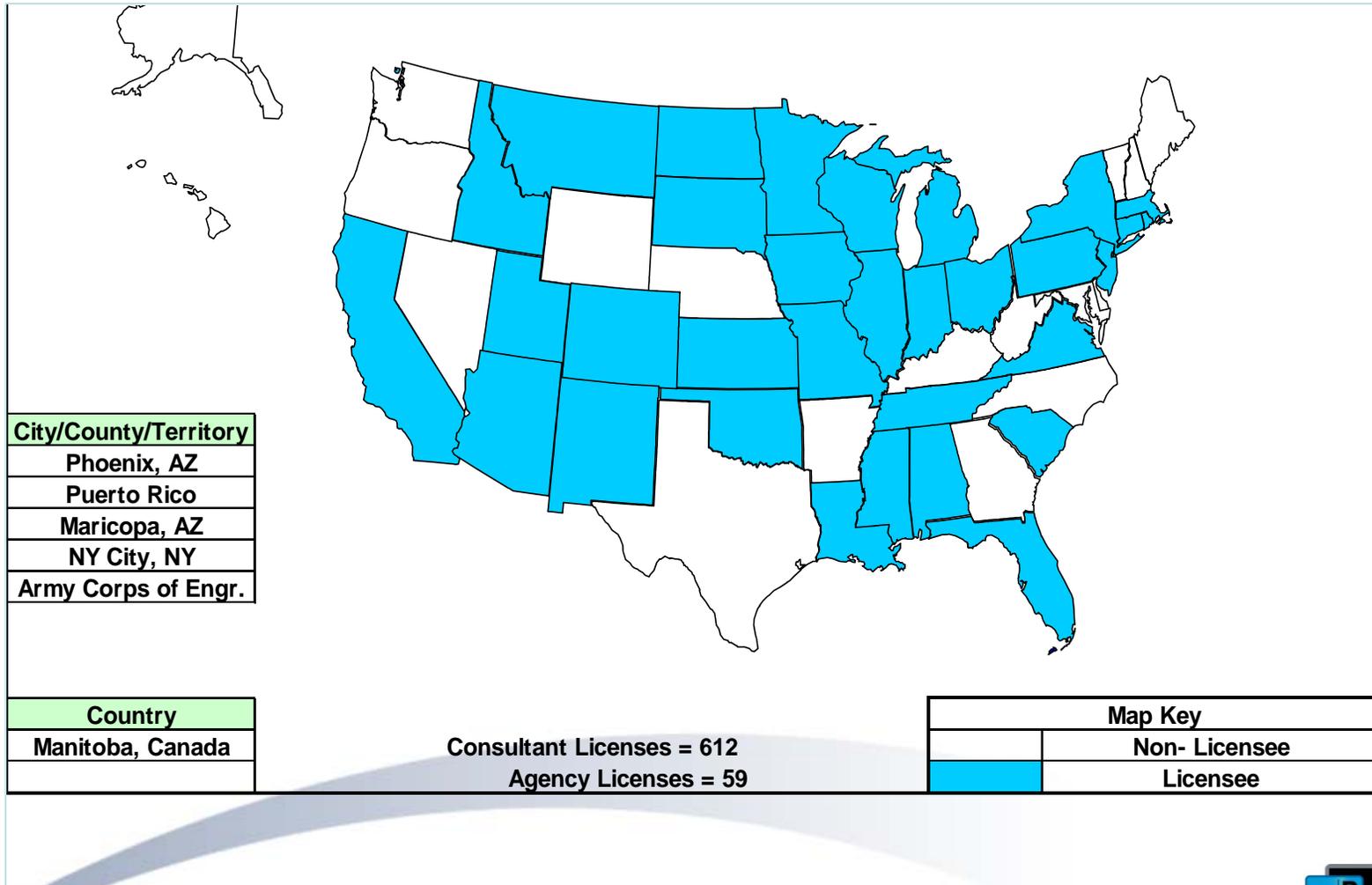
- Product Concept
- Licensees
- Major Capabilities



# Product Concept



# BrDR Licenses (FY 2015)



# Capabilities



Analysis, Load Rating, and Specification Checking  
of common bridge types

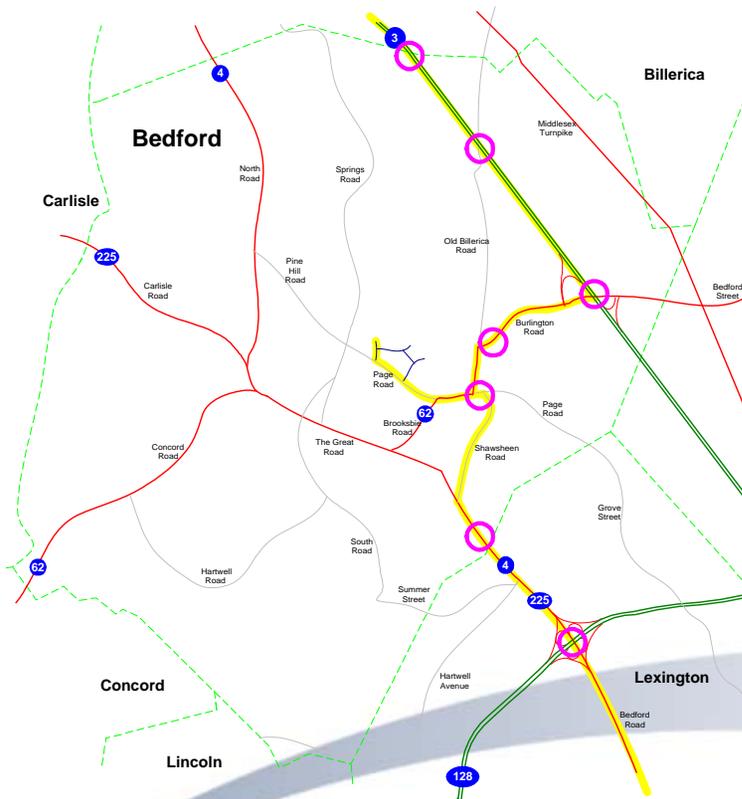


# Capabilities

AASHTOWare

AASHTO

## Support of Permit Routing



# Capabilities

Load rating based on inspection results



# Capabilities



Comparison validation - enter a bridge once and...

- Compare results between engines
- Compare results between different specifications (ASD, LFD, LRFR, LRFD)
- Compare results between different versions of the LRFD/LRFR specifications
- Compare results between 3D and girder-line analysis



## Steel Girder Superstructures

- Rolled shapes
- Welded plate girders
- Built-up I shapes
- Straight and curved



## PS Concrete Superstructures

### Precast shapes

- I beams
- Boxes
- Multi-stem Tee
- U beams



## Reinforced Concrete Superstructures

- Tee beams
- Slab lines
- I beams



## Reinforced and Post-Tensioned Concrete Multi-Cell Box Superstructures

- LRFD/LRFR
- User-defined box cross sections
- Line girder analysis, full box along with web-lines
- Integral with pier

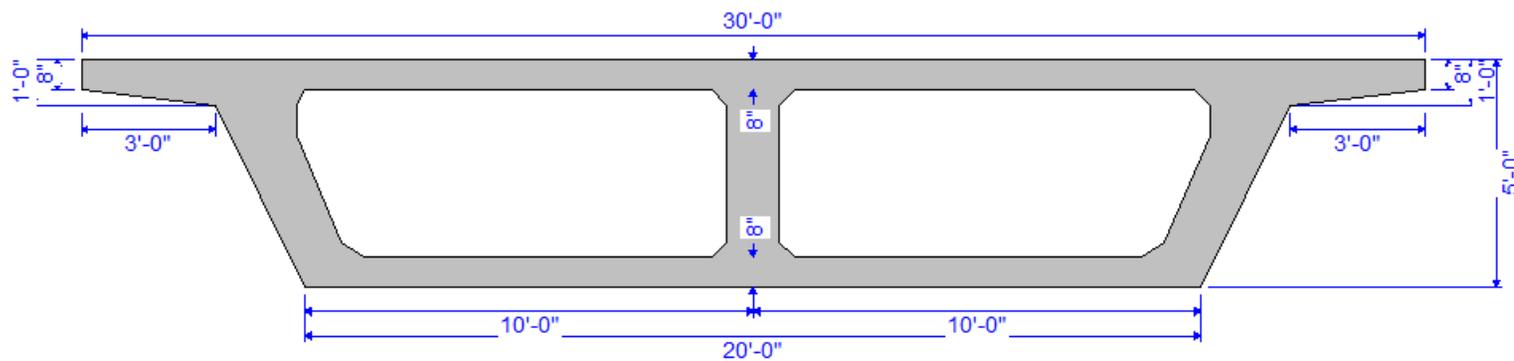


# Capabilities – Multi-cell boxes



Reinforced Concrete

Post-tension Concrete



# Capabilities



## Trusses (LFD)

- Continuous spans
- Suspended spans
- Counters
- Deck Trusses
- Through Trusses



## Floor Systems (ASD and LFD)

- Girder-Floorbeam-Stringer
- Girder-Floorbeam
- Truss-Floorbeam-Stringer
- Truss-Floorbeam
- Floorbeam-Stringer



# Capabilities



## Reinforced Concrete Box Culverts (LRFR/LFR)

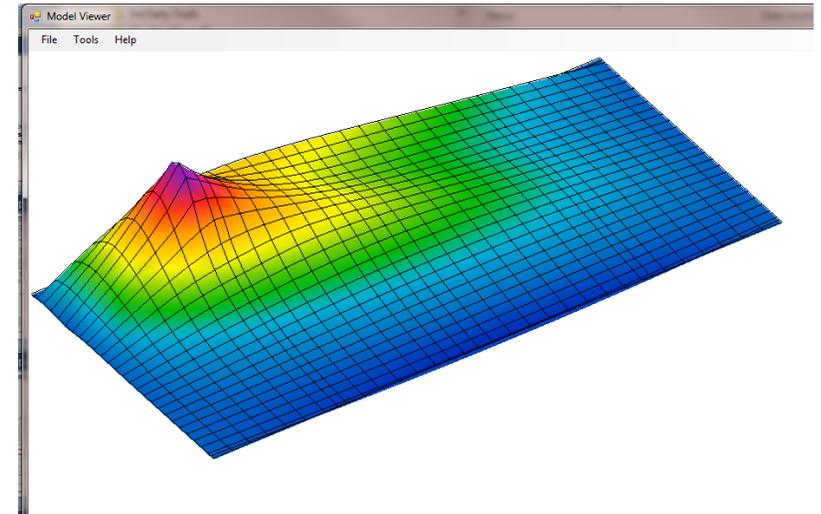
- Sloping fill
- Multiple cells
- Optional bottom slab
- Optional haunches



# Capabilities

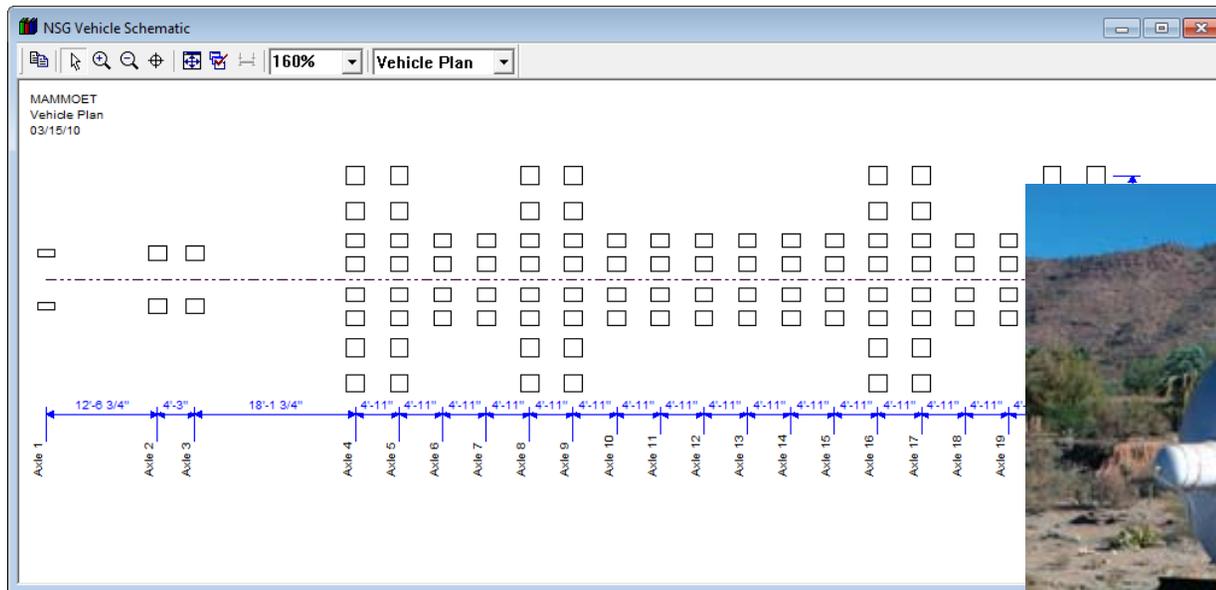
## 3D Analysis

- Straight and curved steel multi-girder systems
- Straight PS and RC multi-girder systems
- Dead and Live loads
- Live load - moves vehicles on influence surfaces to compute maximum and minimum effects



# Capabilities

## Analysis of nonstandard gage vehicles



## Non-standard gage analysis

- Describe a non-standard gage vehicle
  - Unlimited number of axles
  - Unlimited number of wheels per axle
- Describe a loading path for the vehicle
- 3D analysis – loading of an influence surface for live load actions
- Rating

# AASHTO LRFD Spec Checking



Virtis/Opis/OpisSub - PCITrainingBridge4

File Edit View Bridge Substructure Tools Window Help

Bridge Workspace - PCITrainingBridge4

PCITrainingBridge4

Materials

Specification Checks for Member Alternative #2 (9.9.4) - 23 of 562

- Superstructure Component
  - Prestress Calculations
  - Stage 1
  - Stage 2
  - Stage 3
    - Member Alternative #2 (9.9.4)
      - Span 1 - 0.00 ft.
      - Span 1 - 0.70 ft.
      - Span 1 - 2.00 ft.
      - Span 1 - 6.00 ft.
      - Span 1 - 12.00 ft.
      - Span 1 - 24.00 ft.
      - Span 1 - 36.00 ft.
      - Span 1 - 48.00 ft.
      - Span 1 - 60.00 ft.
      - Span 1 - 72.00 ft.
      - Span 1 - 84.00 ft.
      - Span 1 - 96.00 ft.
      - Span 1 - 108.00 ft.
      - Span 1 - 120.00 ft.

Specification Reference

- 5.11.4.2 Bonded Strand
- 5.4.2.5 Poisson's Ratio
- 5.4.2.6 Modulus of Rupture
- ✓ 5.5.3.1 Fatigue Limit State - C
- NA 5.5.3.2 Reinforcing Bars
- 5.7.2.2 Rectangular Stress Dis
- ✓ 5.7.3.2 Flexural Resistance (P
- ✓ 5.7.3.3.2 Minimum Reinforce
- ✓ 5.8.2.5 Minimum Transverse
- ✓ 5.8.2.7 Maximum Spacing of
- ✓ 5.8.3.3 Nominal Shear Resiste
- 5.8.3.4 Procedures for Determ
- ✓ 5.8.3.5 Longitudinal Reinforc
- ✓ 5.8.4 Interface Shear Transfe
- ✓ 5.8.4.4 Minimum Area of Inte
- ✓ 6A.4.2.1 Design Load Rating
- ✓ 6A.4.2.1 General Load Rating
- ✓ 6A.4.2.1 General Load Rating
- Computation of Vp
- Cracked\_Moment\_of\_Inertia
- Cracked\_Moment\_of\_Inertia
- PS\_Basic\_Properties Calculat
- PS\_Gross\_Composite\_Section

Spec Check Detail for 5.7.3.2 Flexural Resistance (Prestressed Concrete)

5 Concrete Structures  
 5.7 Material Properties  
 5.7.3 Flexural Members  
 5.7.3.2 Flexural Resistance  
 (AASHTO LRFD Bridge Design Specifications, Fifth Edition - 2010, with 2010 interi

PS I Wide - At Location = 60.0000 (ft) - Left Stage 3

Cross Section Properties

Name: BT-72  
 Girder f'c = 6.50 (ksi) Girder f'ci = 5.80 (ksi)  
 Slab f'c = 4.00 (ksi)

Effective Slab Width = 108.00 (in)  
 Effective Slab Thickness = 7.50 (in)  
 Haunch Width = 42.00 (in)  
 Haunch Thickness = 0.50 (in)  
 Beam Height = 72.00 (in)

Total Aps = 7.34 (in<sup>2</sup>)  
 Total CGS = 6.92 (in)

Eff Aps = 7.34 (in<sup>2</sup>)  
 Eff CGS = 6.92 (in)

Limit State	Load Combination	Mu kip-ft	Phi	Mr= Phi * Mn kip-ft	Mr/Mu
STR-I	1, DesInv	9315.60	1.000	11240.68	1.21
STR-I	1, DesInv	4636.88	1.000	11240.68	2.42
STR-I	1, DesOp	8246.18	1.000	11240.68	1.36
STR-I	1, DesOp	4636.88	1.000	11240.68	2.42
STR-I	2, DesInv	8583.00	1.000	11240.68	1.31
STR-I	2, DesInv	4636.88	1.000	11240.68	2.42
STR-I	2, DesOp	7681.03	1.000	11240.68	1.46
STR-I	2, DesOp	4636.88	1.000	11240.68	2.42
SER-III	1, DesInv	5776.35	1.000	11240.68	1.95
SER-III	1, DesInv	3637.50	1.000	11240.68	3.09
SER-III	2, DesInv	5441.44	1.000	11240.68	2.07
SER-III	2, DesInv	3637.50	1.000	11240.68	3.09

Load Combination Legend:



# AASHTO LRFD Spec Checking



Bridge ID : 28  
Bridge : Draft Bridge (jso 10-2013)  
Superstructure Def : three span steel  
Member : G1  
Analysis Preference Setting : None

NBI Structure ID : L33028000\_07001  
Bridge Alt :  
Member Alt : exterior G1

AASHTO LRFD Specification, Edition 7, Interim 0

## Specification Check Summary

Article	Status
Flexure (6.10.7.1.1, 6.10.7.2.1)	Pass
Shear (6.10.9)	Pass
Fatigue (6.10.5.3)	NA
Serviceability (6.10.4.2.2)	Pass
Constructability (6.10.3.2.1, 6.10.3.2.2, 6.10.3.2.3)	Pass
Transverse Stiffeners (6.10.11.1.2, 6.10.11.1.3)	Pass
Longitudinal Stiffeners (6.10.11.3.1, 6.10.11.3.2, 6.10.11.3.3)	NA
Bearing Stiffeners (6.10.11.2.2, 6.10.11.2.3, 6.10.11.2.4)	Pass
Shear Connector (6.10.10.1, 6.10.10.4)	NA

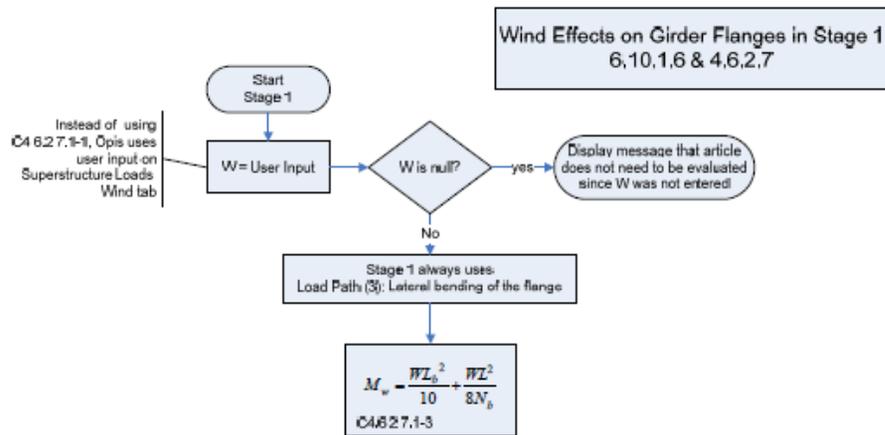


# Bridge Workspace - Design

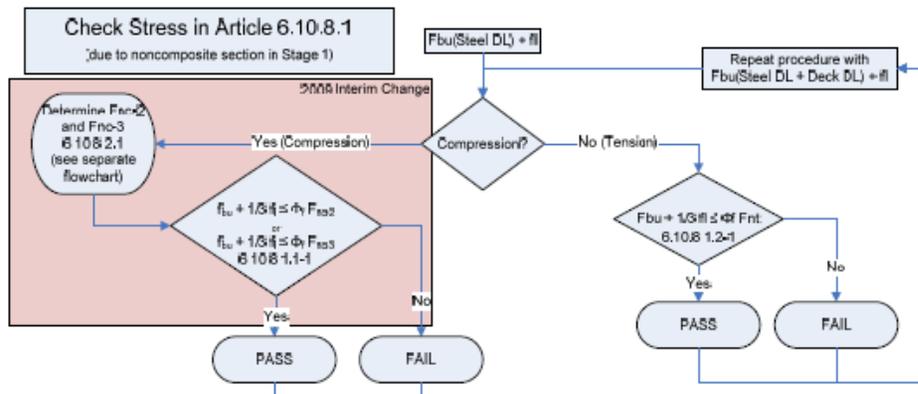


## LRFD Method of Solution Manual

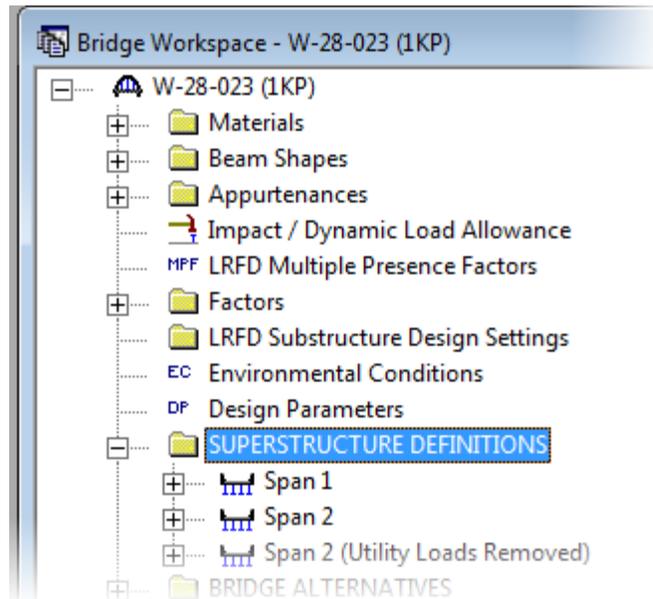
LRFD 5<sup>th</sup> Edition



Includes detailed flow charts



# Bridge Definition

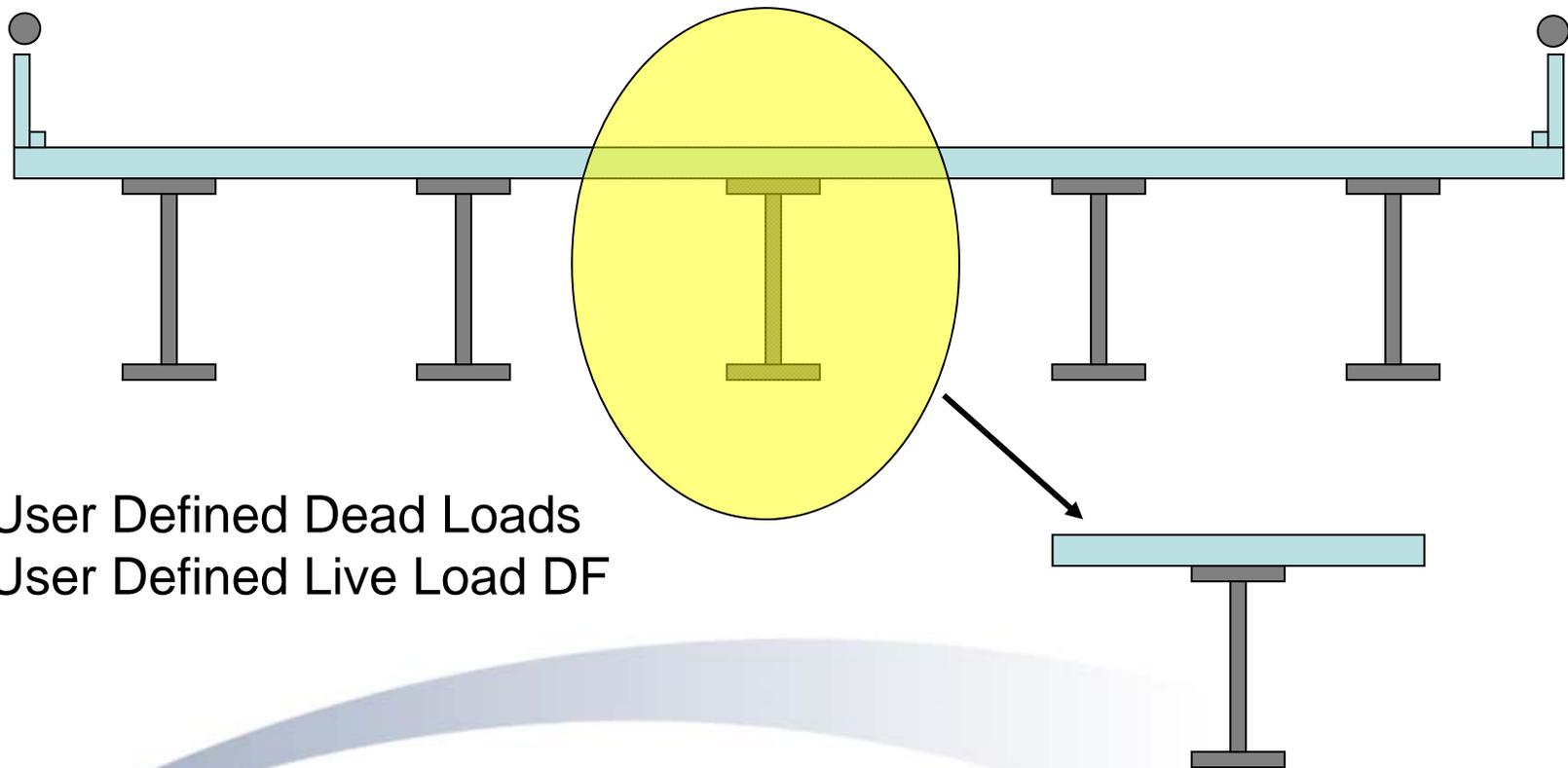


Detailed description of each structure within the bridge.

- System definition
- Line definition

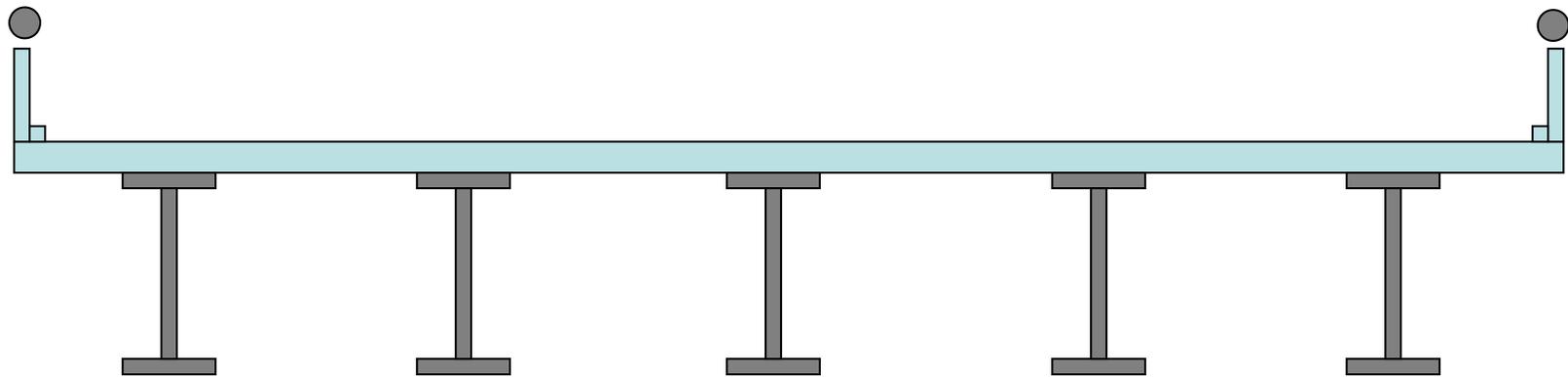


## Line Definition



- User Defined Dead Loads
- User Defined Live Load DF

## System Definition



- System Computed Dead Loads
- System Computed Live Load Distribution Factors
- Suitable for 3D analysis



# Bridge Workspace



Structure Typical Section

Deck | Deck (Cont'd) | Parapet | Median | Railing | Generic | Sidewalk | Lane Position | Wearing Surface

Superstructure definition reference line is  the bridge deck.

	Start	End
Distance from left edge of deck to superstructure definition reference line =	23.92 ft	23.92 ft
Distance from right edge of deck to superstructure definition reference line =	23.92 ft	23.92 ft
Left overhang =	1.41 ft	1.41 ft
Computed right overhang =	1.42 ft	1.42 ft

OK    Ap

Schematics: Bridge Typical Cross Section View

W-28-023 (1KP)  
Mass DOT - Span 1  
State Route 2A / State Route 2  
03/15/10

47'-10"

45'-3"

Deck Thickness 8"

Travelway 1

1" 3 ksi Cement Concrete

Haunch Th. 2 1/16"

G1 G2 G3 G4 G5 G6 G7

1'-4 15/16"

6@7'-6" = 45'-0"

Used to define:

- Deck, wearing surface, lane positions
- Parapets, medians, railings, sidewalks



# Bridge Workspace



Choose analysis module and spec version...

Member Alternative Description

Member Alternative: Plate Girder

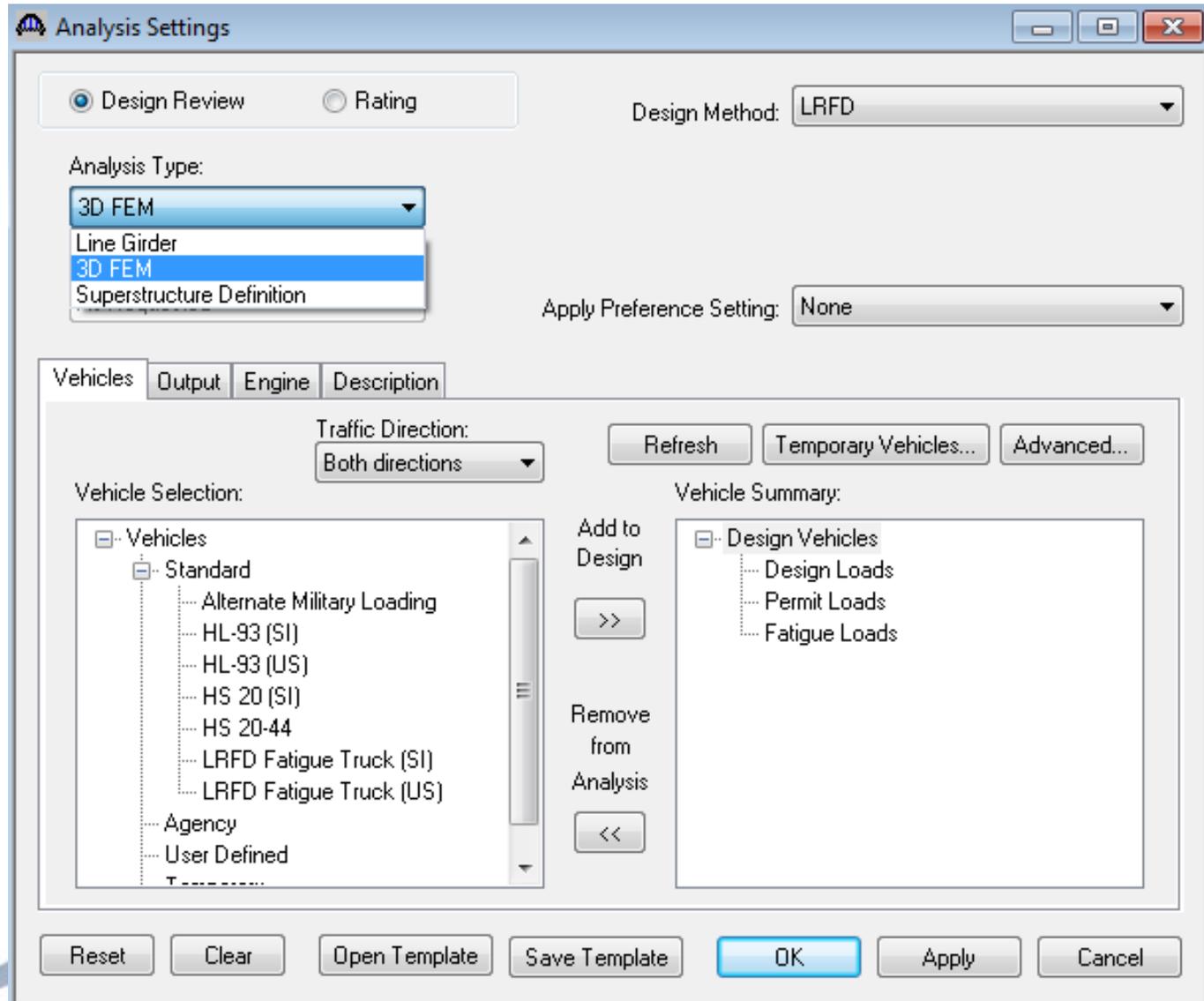
Description Specs Factors Engine Import Control Options

Analysis Method Type	Analysis Module	Selection Type	Spec Version	Factors
ASD	AASHTO ASD	System Default	MBE 2nd 2014i, Std 17th	N/A
LFD	AASHTO LFD	System Default	MBE 2nd 2014i, Std 17th	2002 AASHTO Std. Specifications
LRFD	AASHTO LRFD	System Default	LRFD 7th	2014 AASHTO LRFD Specifications
LRFR	AASHTO LRFR	Override	MBE 2nd 2014i, LRFD 7th	2011 (2014 Interim) AASHTO LRFR Spec

The 'Analysis Module' and 'Spec Version' columns are highlighted with red boxes. The 'Spec Version' dropdown menu is open, showing a list of options with 'MBE 2nd 2014i, LRFD 7th' selected.



# Bridge Workspace – Design Review



# 3D Features and Capabilities



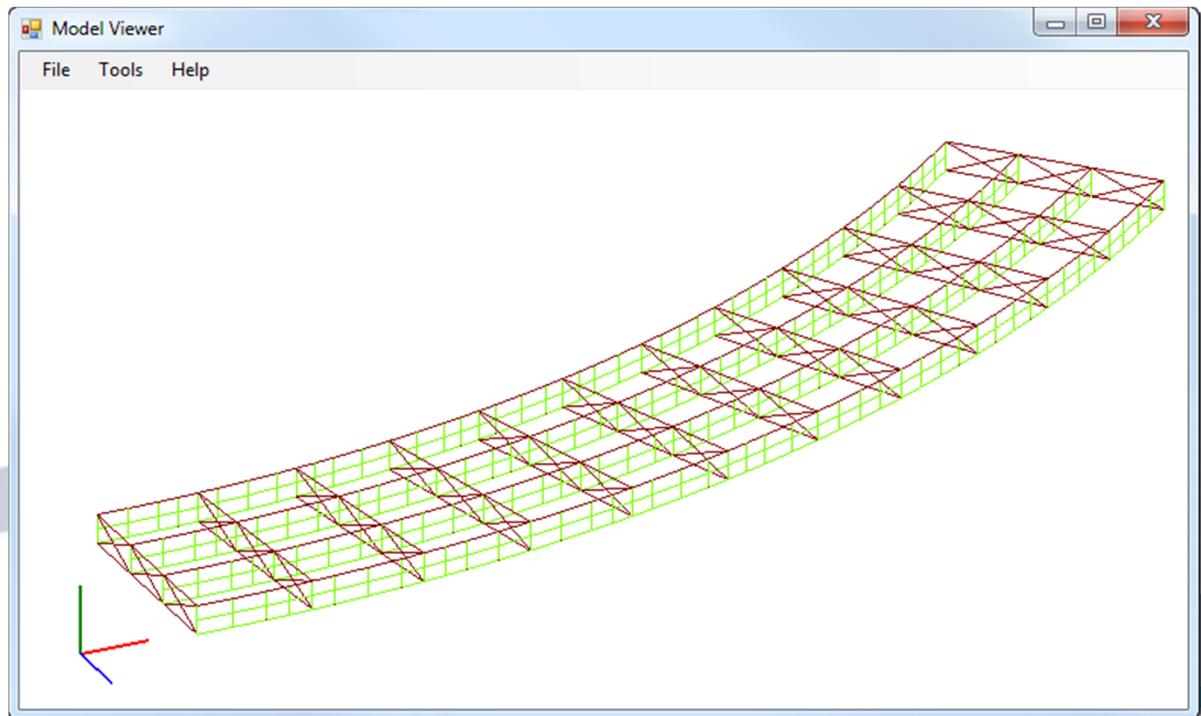
- Multi-Girder Superstructures
  - Steel (Straight or Curved)
  - Prestressed Concrete (Straight)
  - Reinforced Concrete (Straight)



# 3D Features and Capabilities



- Automated 3D Model Generation for Structural Analysis and Design
- 3D Model Viewer



# 3D Features and Capabilities



- Multi-Girder Superstructures

- Analysis of diaphragms

- Spec-checking and rating of diaphragms coming soon

Diaphragm Definition

Name: X Frame

Diaphragm types: Diaphragm type: Type 1

Member	Shape	Section Orientation	Section Location	Material
AB	L 6x6x0.4375	Vertical	Top Left	Grade 50
CD	L 6x6x0.4375	Vertical	Top Left	Grade 50
AD	L 6x6x0.4375	Vertical	Top Left	Grade 50
CB	L 6x6x0.4375	Vertical	Top Left	Grade 50

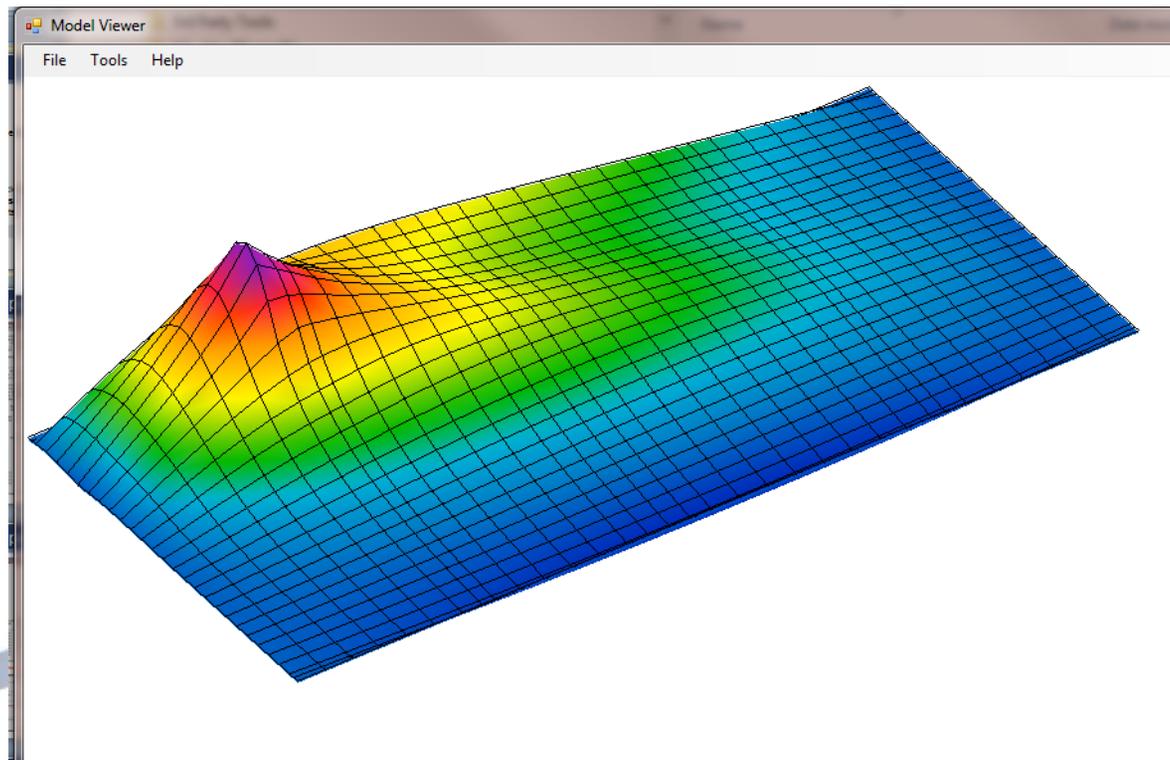
Connection	Support Type	Y (in)	Measured From
A	Pinned		Top of Web
B	Pinned		Top of Web
C	Pinned		Bottom of Web
D	Pinned		Bottom of Web



# 3D Features and Capabilities

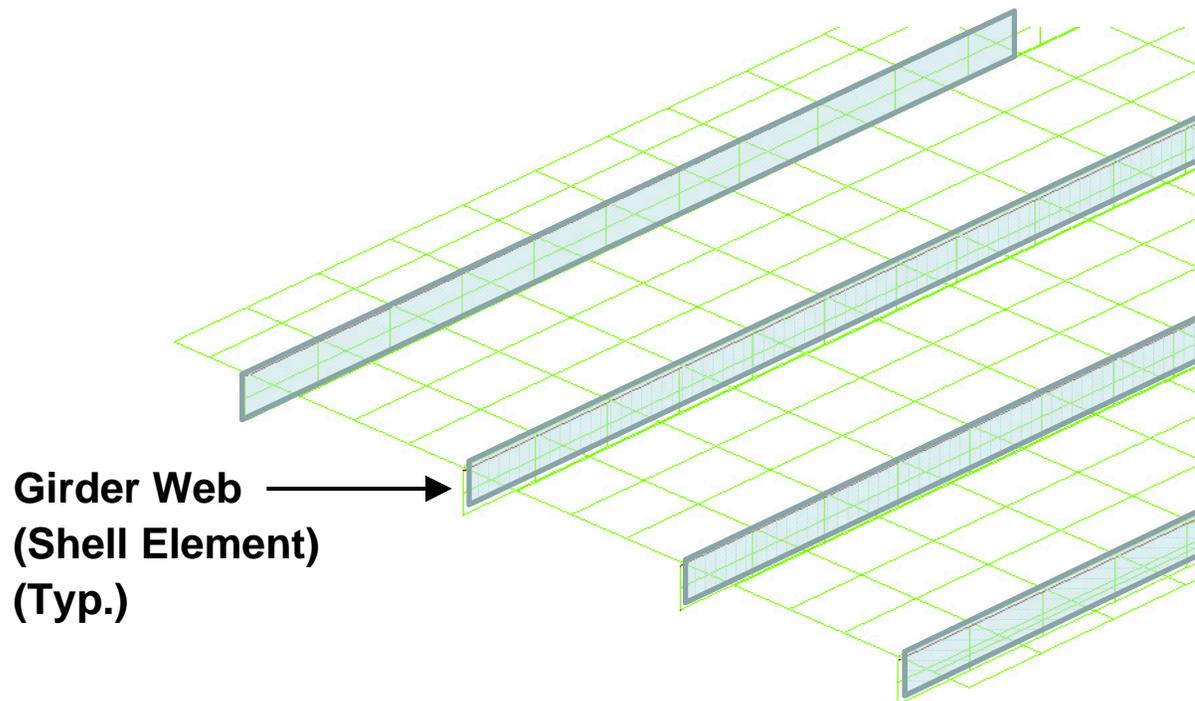


- Live load - moves vehicles on influence surfaces to compute maximum and minimum effects
- Longitudinal and transverse live load analysis or user-defined vehicle loading path



## Shell elements:

- Are used for the steel girder web and the deck
- Have four nodes with six DOFs at each node

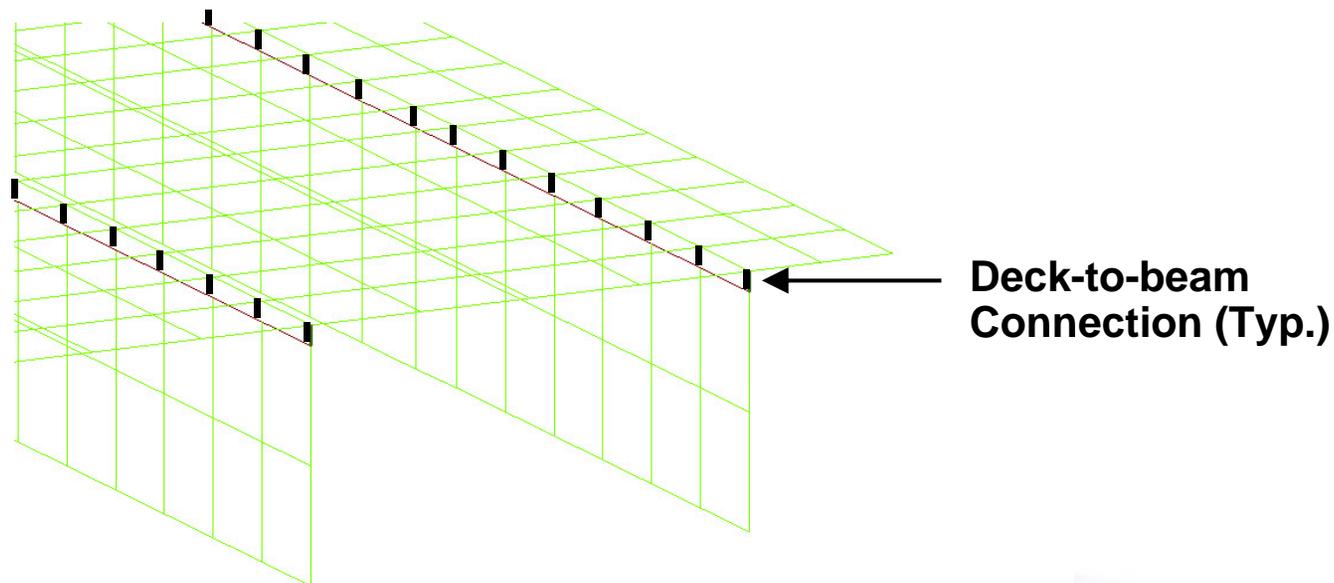


# 3D Model Generation



## Deck-to-beam connection:

- Master-slave constraints
- Connects center of gravity of deck to girder top flange

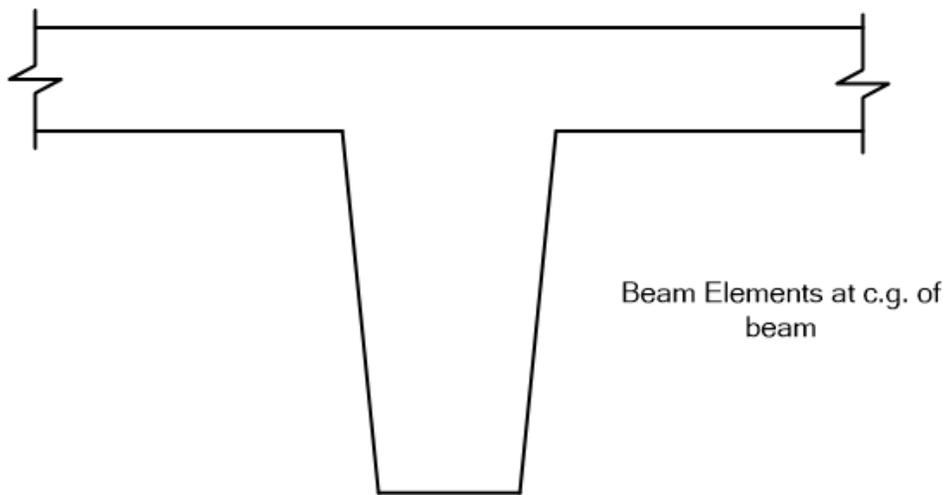


# 3D Model Generation

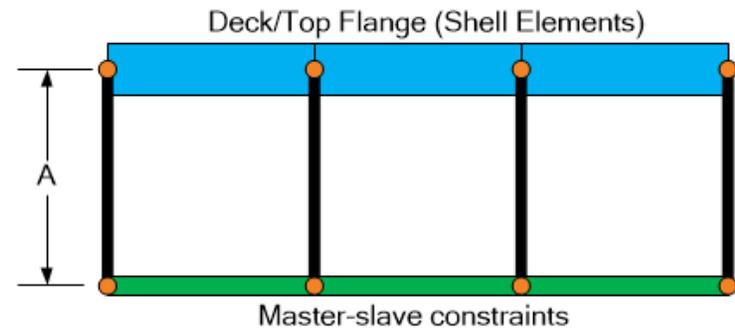


## Modeling of reinforced concrete sections:

- Beam elements used for reinforced concrete beam
- Shell elements used for deck/top flange
- Master-Slave constraints used for connection



Reinforced Concrete Section



Partial Elevation View of Model

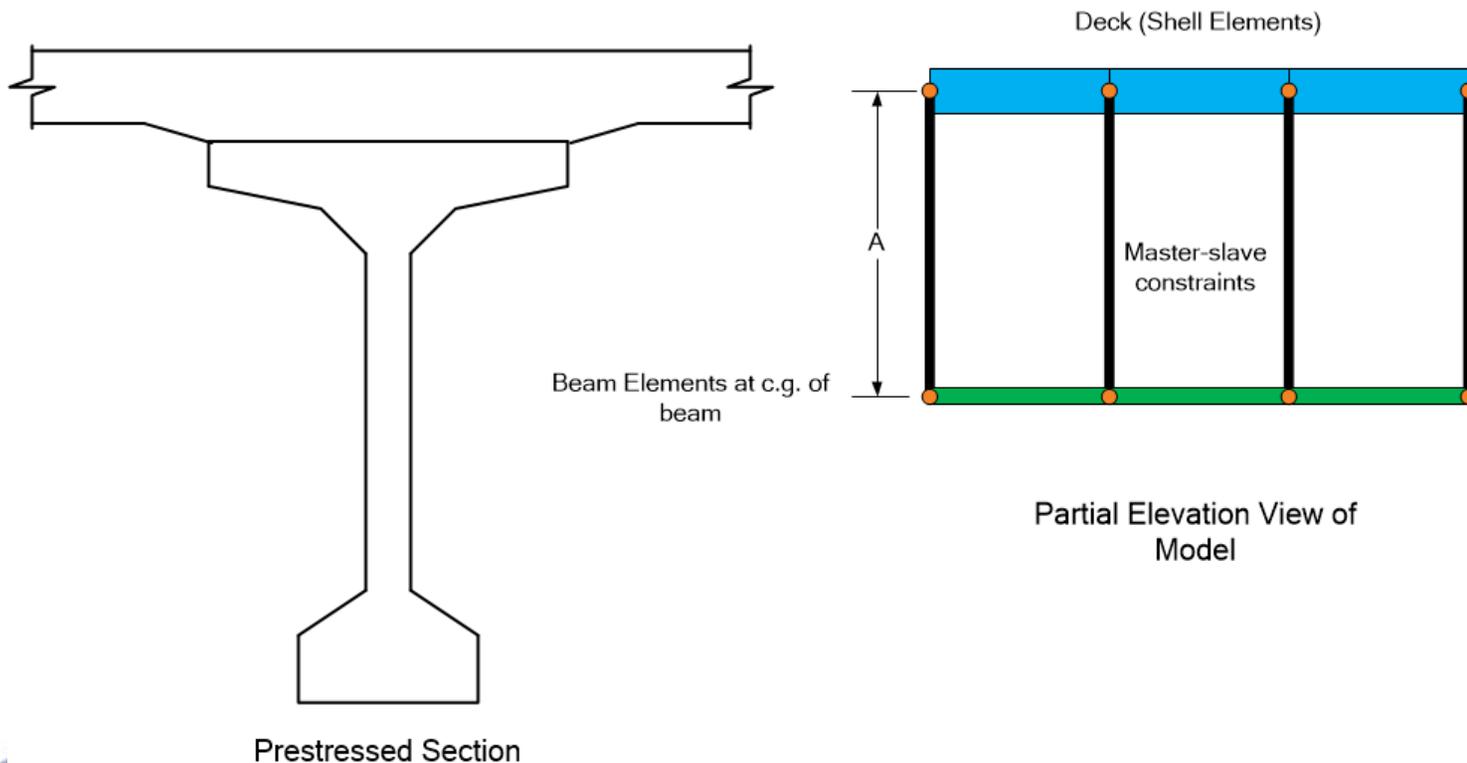


# 3D Model Generation



## Modeling of prestressed concrete sections:

- Beam elements used for prestressed concrete beam
- Shell elements used for deck/top flange
- Master-Slave constraints used for connection

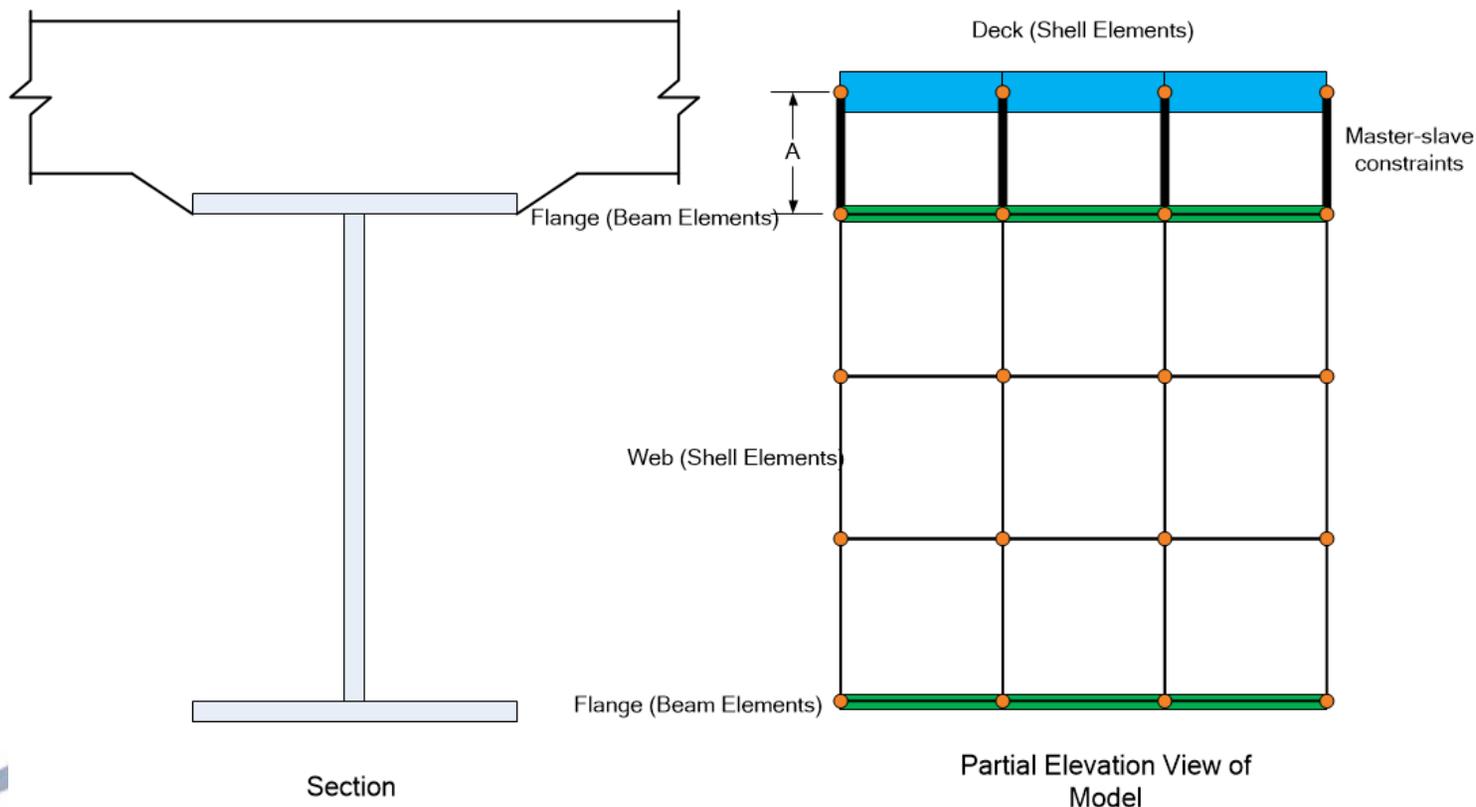


# 3D Model Generation



## Modeling of steel beam with concrete deck:

- Beam elements used for steel girder flanges
- Shell elements used for deck and steel girder web
- Master-Slave constraints used for connection

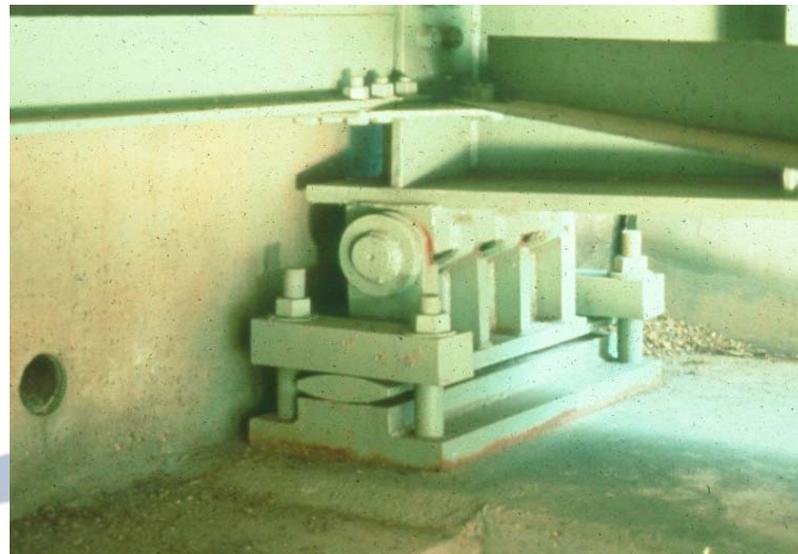


# 3D Model Generation



## Support conditions:

- Free bearings – permit translation in all directions
- Guided bearings – permit translation in only one direction, usually either longitudinal or transverse
- Fixed bearings – do not permit translation in any direction



# 3D Model Generation



## Analysis controls:

Specify mesh generation parameters

Girder System Superstructure Definition

Definition Analysis Specs Engine

Structural Slab Thickness

- Consider structural slab thickness for rating
- Consider structural slab thickness for design

Wearing Surface

- Consider wearing surface for rating
- Consider wearing surface for design
- Consider striped lanes for rating

Default Analysis Type: Line Girder

Longitudinal Loading

Vehicle increment: 1.000 ft

Transverse Loading

Vehicle increment in lane: 2.000 ft

Lane increment: 4.000 ft

Analysis Control Options

- LFD: Model non-composite regions as non-composite
- LRFD: Model non-composite regions as non-composite
- LRFR: Model non-composite regions as non-composite

Number of shell elements

- In the deck between girders
- In the web between flanges

Slower More accurate Faster Less accurate

10 9 8 7 6 5 4 3 2 1

Target aspect ratio for shell elements

Slower More accurate Faster Less accurate

1.0 1.5 2.0 2.5 3.0 3.5 4.0



# 3D Model Generation



## Analysis controls:

Girder System Superstructure Definition

Definition Analysis Specs Engine

Structural Slab Thickness

- Consider structural slab thickness for rating
- Consider structural slab thickness for design

Wearing Surface

- Consider wearing surface for rating
- Consider wearing surface for design

Consider striped lanes for rating

Default Analysis Type: Line Girder

Longitudinal Loading

Vehicle increment: 1.000 ft

Transverse Loading

Vehicle increment in lane: 2.000 ft

Lane increment: 4.000 ft

Analysis Control Options

- LFD: Model non-composite regions as non-composite
- LRFD: Model non-composite regions as non-composite
- LRFR: Model non-composite regions as non-composite

Number of shell elements

- In the deck between girders
- In the web between flanges

Slower More accurate Faster Less accurate

10 9 8 7 6 5 4 3 2 1

Target aspect ratio for shell elements

Slower More accurate Faster Less accurate

1.0 1.5 2.0 2.5 3.0 3.5 4.0

Define Longitudinal Loading and Transverse Loading



# 3D Features and Capabilities



## Analysis Controls:

- Select the diaphragms for which diaphragm forces are to be computed

Diaph

Select diaphragms for influence surface loading in a 3D

Select All Clear All

Bay 1	Bay 2	Bay 3
<input checked="" type="checkbox"/> 1-1	<input checked="" type="checkbox"/> 2-1	<input checked="" type="checkbox"/> 3-1
<input checked="" type="checkbox"/> 1-2	<input checked="" type="checkbox"/> 2-2	<input checked="" type="checkbox"/> 3-2
<input checked="" type="checkbox"/> 1-3	<input checked="" type="checkbox"/> 2-3	<input checked="" type="checkbox"/> 3-3
<input checked="" type="checkbox"/> 1-4	<input checked="" type="checkbox"/> 2-4	<input checked="" type="checkbox"/> 3-4
<input checked="" type="checkbox"/> 1-5	<input checked="" type="checkbox"/> 2-5	<input checked="" type="checkbox"/> 3-5
<input checked="" type="checkbox"/> 1-6	<input checked="" type="checkbox"/> 2-6	<input checked="" type="checkbox"/> 3-6
<input checked="" type="checkbox"/> 1-7	<input checked="" type="checkbox"/> 2-7	<input checked="" type="checkbox"/> 3-7
	<input checked="" type="checkbox"/> 2-8	

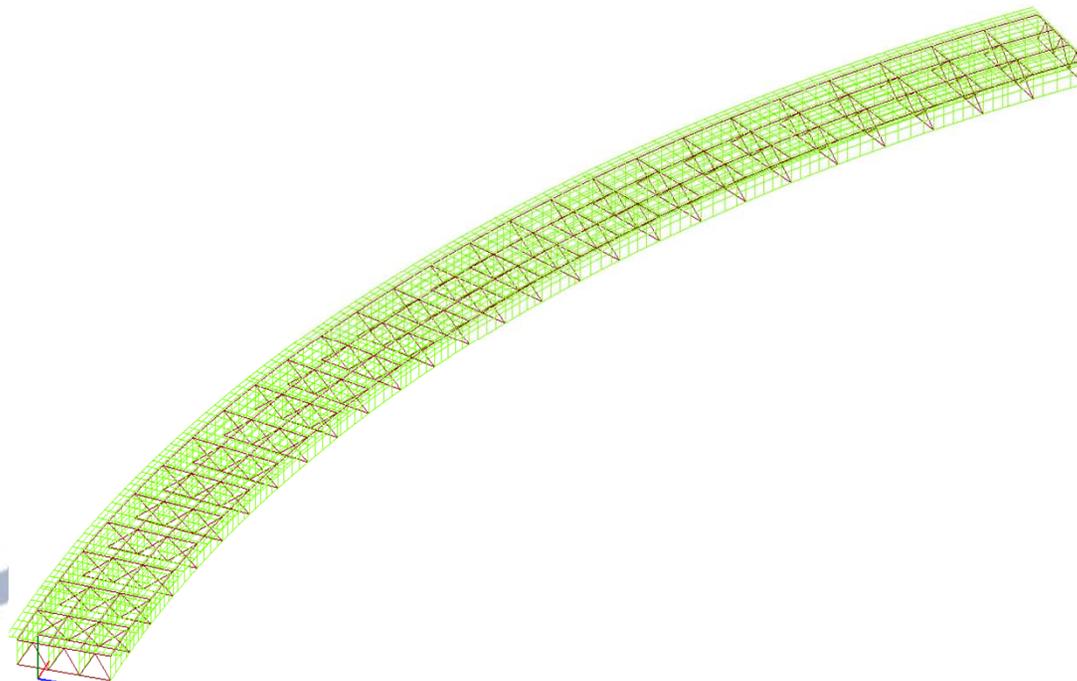


# 3D Features and Capabilities



## Model Viewer:

- Model can be viewed graphically
- Model Viewer permits view from many different vantages
- Ability to select what portions of the model are viewed
- Ability to view influence surfaces and load paths



# 3D Features and Capabilities



- 3D Finite element analysis based on an investigative study to identify best practices



# Awards



## American Council of Engineering Companies

The poster features a central 3D wireframe model of a bridge structure. Surrounding this model are several inset screenshots of the software interface, each with a caption: 'Using the Bridge Workspace', 'Reinforced Concrete Culvert Analysis', 'Post-Tensioned Box Girders (Future Release)', 'Pier Analysis', 'Working with the Bridge Explorer', and 'Detailed Specification Checking'. The top left corner displays the ACEC logo (American Council of Engineering Companies of Pennsylvania). The top center features the 'AASHTOWare Bridge Design & Rating' logo with 'BrD' and 'BrR' icons, and the tagline '(WITH A NEW TWIST)'. Below the logo, it lists 'Client/Owner: AASHTO' and 'Entering Firm: Michael Baker Jr., Inc. Moon Township, Pennsylvania'. The AASHTO logo is also present, along with the 'Baker' logo.

2014 National Recognition Award Winner



# Summary



1. One user interface handles most bridge types and is used for both design review and rating
  - Improved productivity by learning one user interface
  - Consistency across many bridge types
2. Database for storing bridge descriptions
  - Security
  - Backups
3. Simplified administration of one product



4. General 3D description not specific to:
  - A particular edition of the AASHTO specification
  - An analysis method (Line or 3D)
  - An analysis engine
  
5. As specifications and methods change the data does not have to be re-input
  
6. Enter data once and evaluate with different AASHTO specifications (ASR, LFR, LRFR), or different editions of a specification, or different models

7. Research – Evaluate specification changes before they are adopted for production use
8. System allows for 3<sup>rd</sup> party analysis engines
  - Wyoming BRASS
  - Bentley (LARS and former Leap products)
9. Opportunity for agency customization (Service Units)
  - Agencies can request features
  - Users vote on features
  - Technical Advisory Groups – advise how features should be implemented

# Thank you