The case for moving to 3D

Raoul Karp, PE, SE
VP, Structural and Bridge

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Motivations for 3D

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Motivations for 3D

- Internal Efficiencies
  - Conceptual Alternatives, Analysis-Drawing, Model-Analysis, Parametric Changes, QA-QC

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Motivations for 3D

- Internal Efficiencies
  - Conceptual Alternatives, Analysis-Drawing, Parametric Changes, QA-QC
- Reduce Cost of Built Structure
  - Risk and time of model recreation, Multi discipline clash etc
  - Staged Visualization
  - Are we reducing risk by not sharing 3D context of our 2D drawings?

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Is it more or less risk to only produce 2D drawings?

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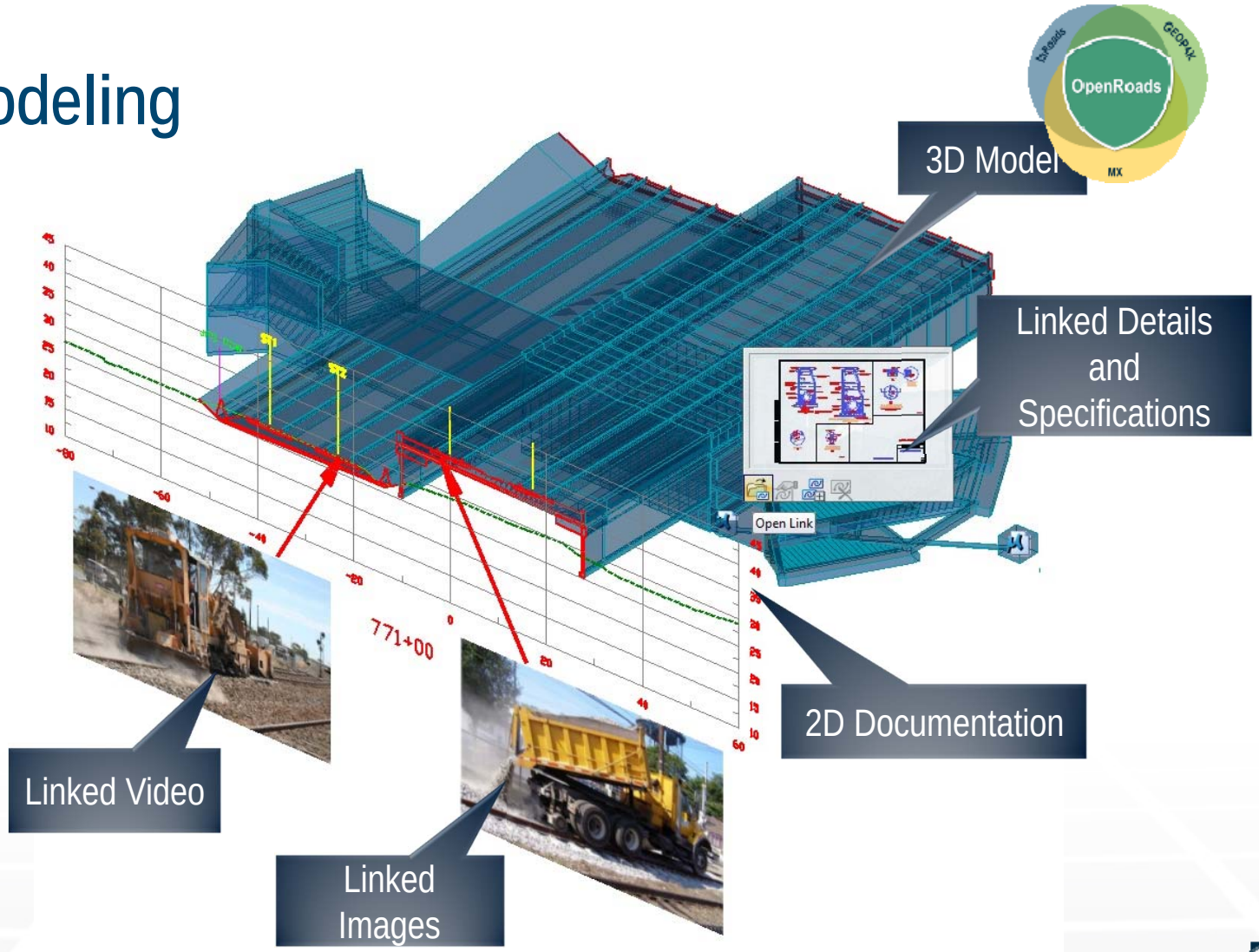
Hypermodeling



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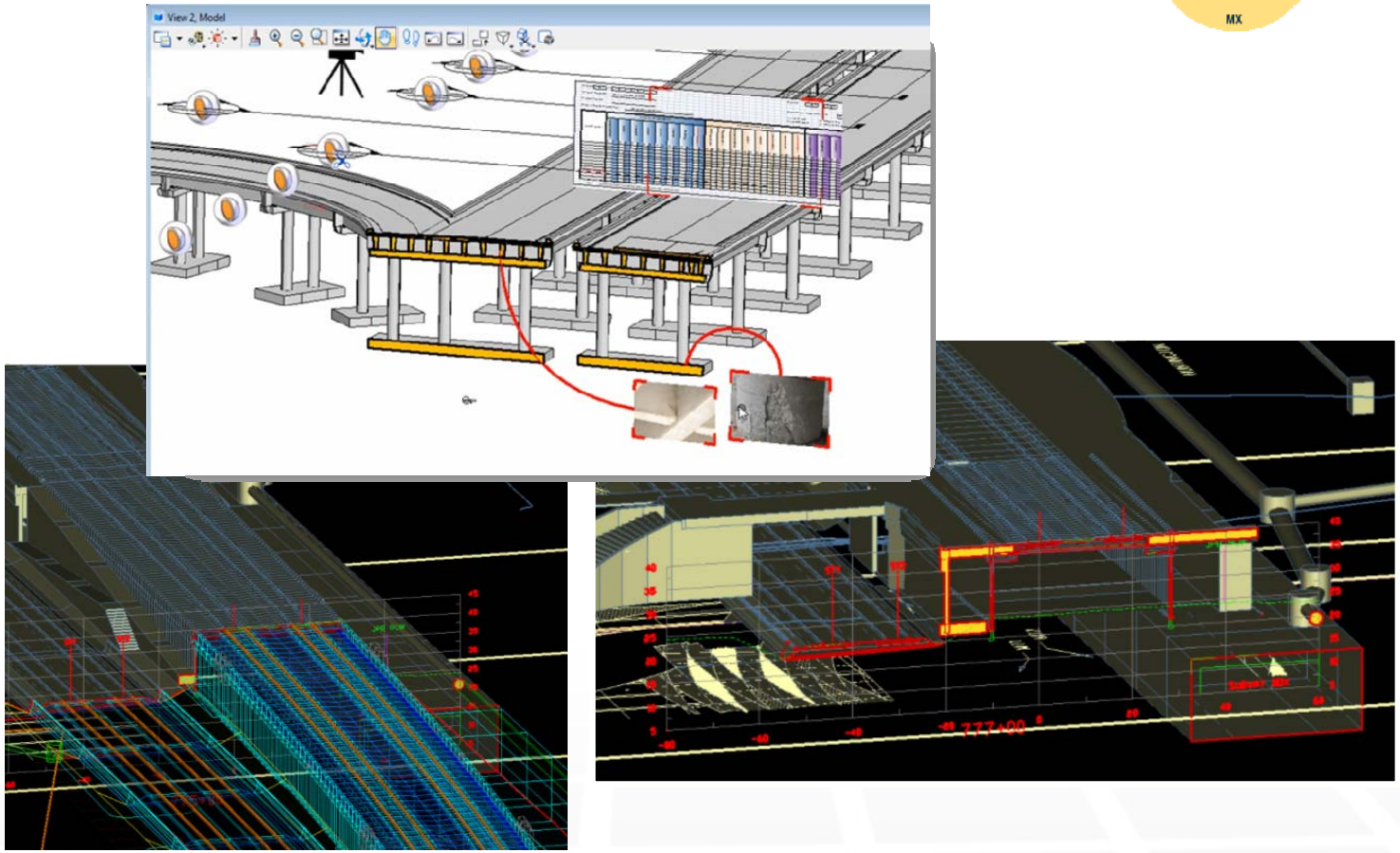
Hypermodeling



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Immersive Modeling and Design-Time Visualization

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Motivations for 3D

- Internal Efficiencies
  - Conceptual Alternatives, Analysis-Drawing, Parametric Changes
- Reduce Cost of Built Structure
  - Risk and time of model recreation, Multi discipline clash etc
  - Staged Visualization
  - Are we reducing risk by not sharing 3D context of our 2D drawings?
- Reduce Risk and Cost of O&M
  - What is the cost of bridge closure?
  - Develop a true As-Built…
  - What about existing inventory?

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Bye-Bye LIDAR?

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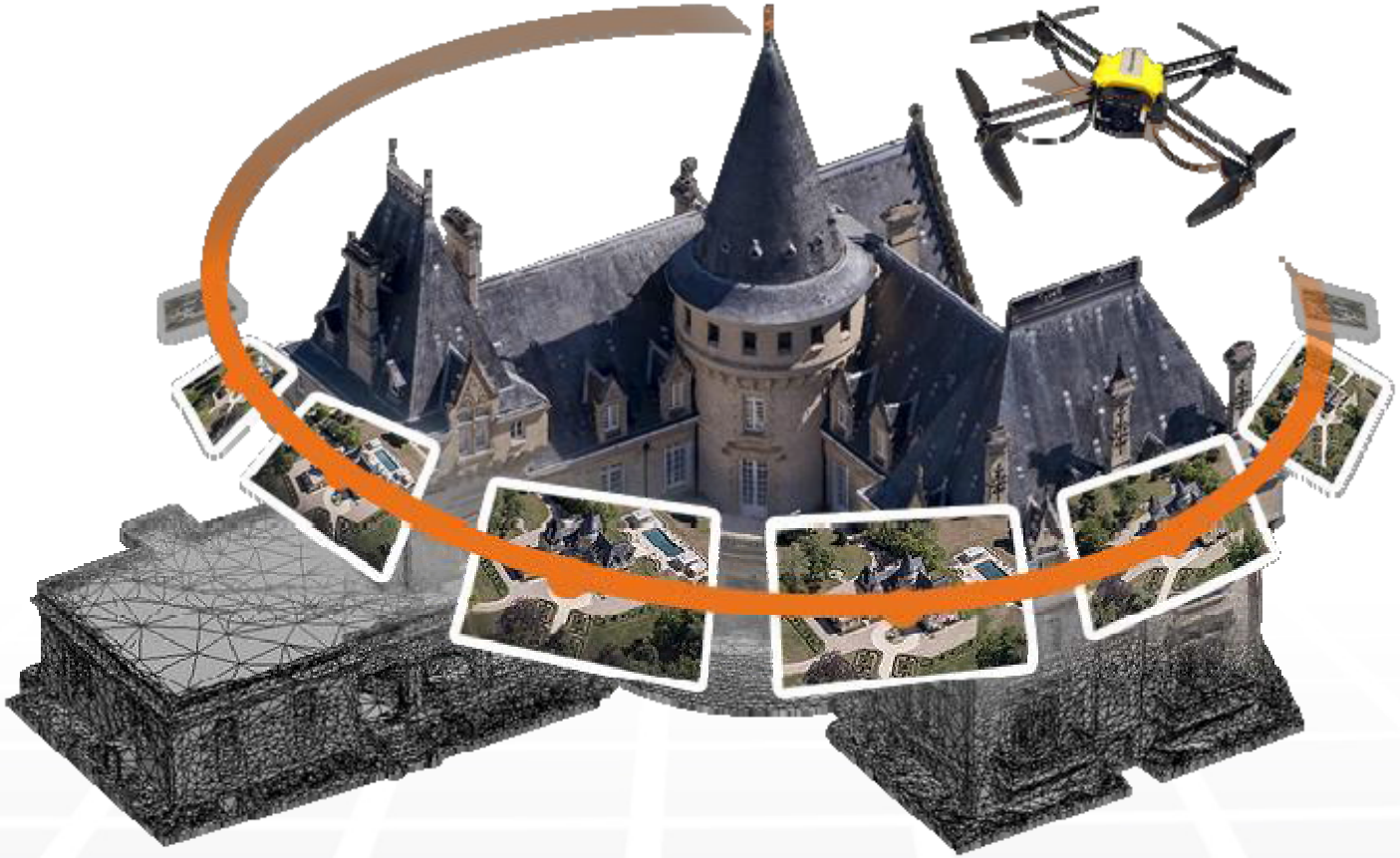
Acute3D: 3D modeling from photos



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Unlimited scalability | From Sites

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From photos to 3D | Infrastructure

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As-built structures

Automatic 3D modelization of transportation infrastructures (Asia Air Survey)

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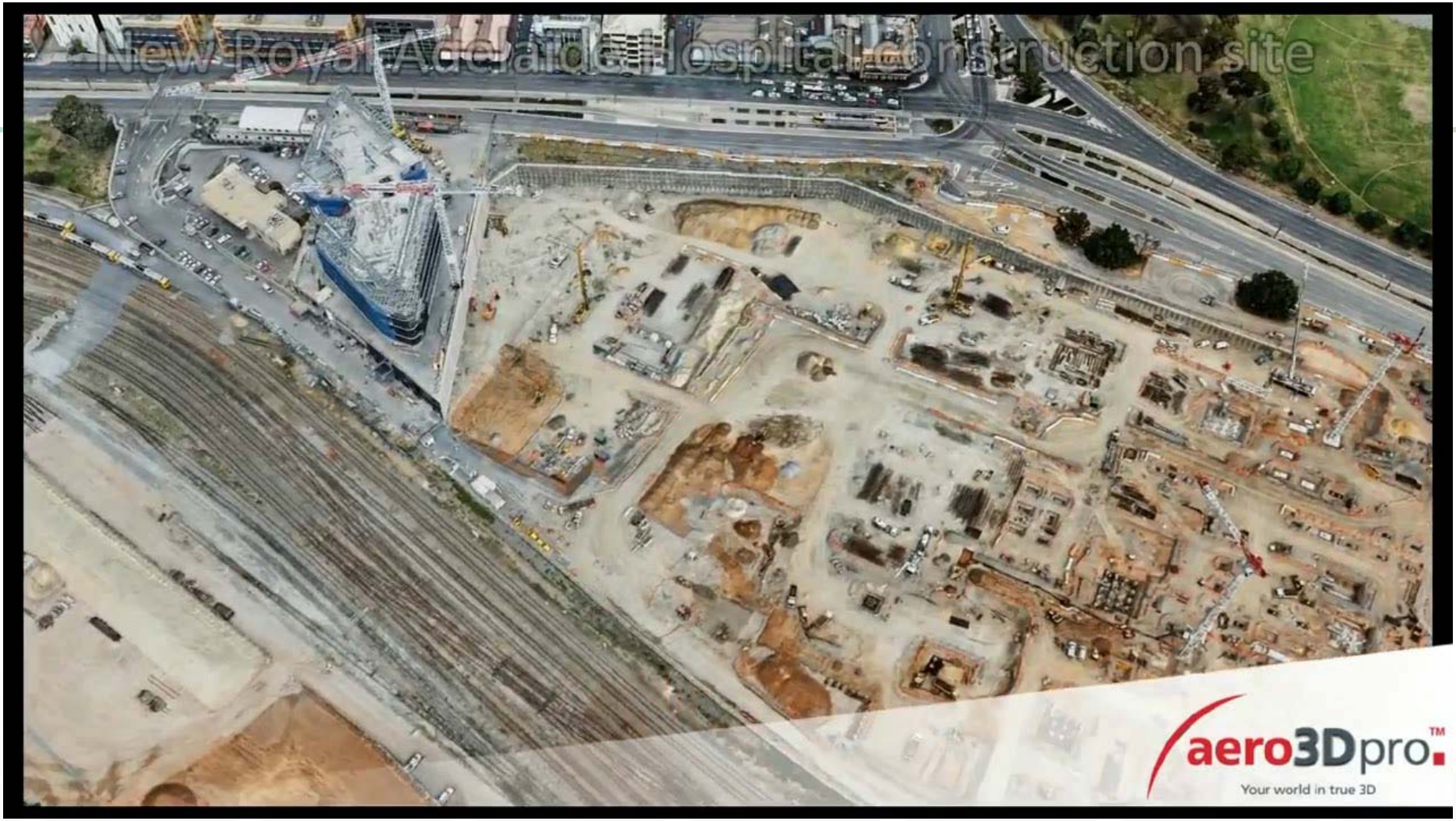

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Motivations for 3D

- Single biggest Impediment?
  - Interoperability – Standards
  - Do we have the right contractual structure in place?
    - Design – Bid – Build
    - Design – Build
    - P3

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Join the (R)Evolution

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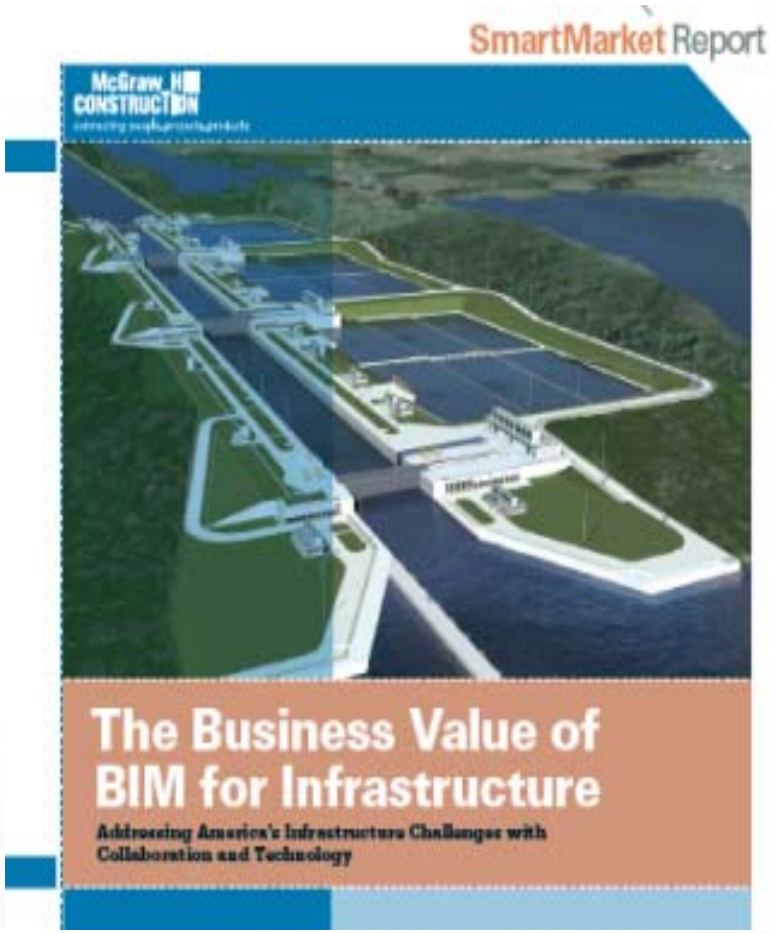
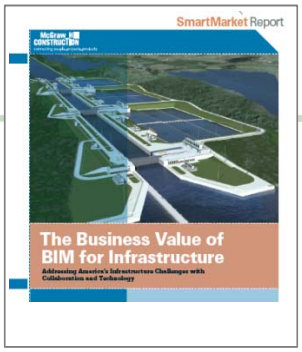
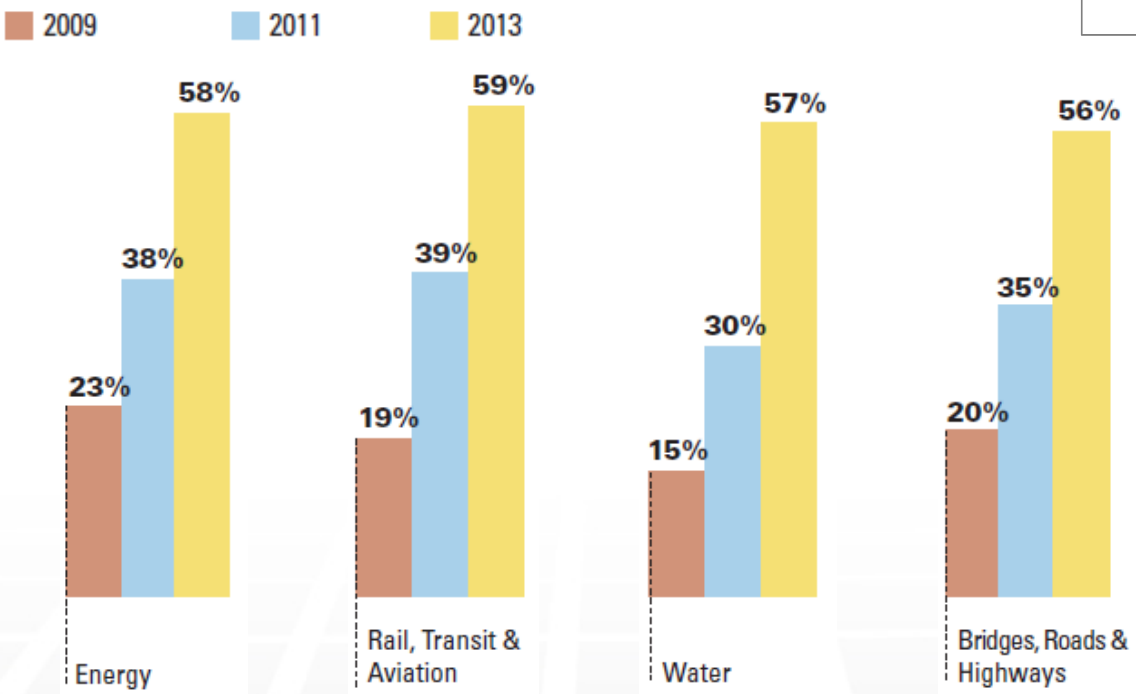

SmartMarket Report
McGraw-Hill CONSTRUCTION
The Business Value of BIM for Infrastructure
Addressing America's Infrastructure Challenges with Collaboration and Technology

Business Value of BIM…



BIM Implementation on More than 50% of Infrastructure Projects by Project Type

Source: McGraw-Hill Construction, 2012



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Parametric and Integrated Bridge Design
LEAP Bridge Steel

Shri Bhide, PhD, PE, SE, F.ACI, F.ASCE
Director, Product Management

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Bentley BrIM Products

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BrIM Products

	Routine CIP RC, PT Box, CIP Slab Precast/ Pre-Tensioned, Steel			Complex Segmental, Arch, Cable-Stayed, Suspension
Inspection, Maintenance and Asset Management	InspectTech, Exor, eB, Optram			
Construction Engineering, Erection Control				RM Bridge
Bridge Load Rating	LARS	LBS	LBE	
Drawings Plans Production	LEAP Bridge / MicroStation			RM Bridge / MicroStation
Detailing	Rebar / PowerRebar / ProStructures			
Special Technologies & Analysis: Cantilever, ILM, Pre-Cast Segmental	RM Bridge			
Steel Analysis & Design	LEAP Bridge Steel (LBS)			RM Bridge
Concrete Analysis & Design	LEAP Bridge Enterprise (LBE)			RM Bridge
Solid Bridge Geometry Modeling	OpenBridge Modeler (Q3 2015)			
Geotechnical Data Management	gINT			
Civil Planning & Design	GEOPAK	InRoads	MXROAD	OpenRoads

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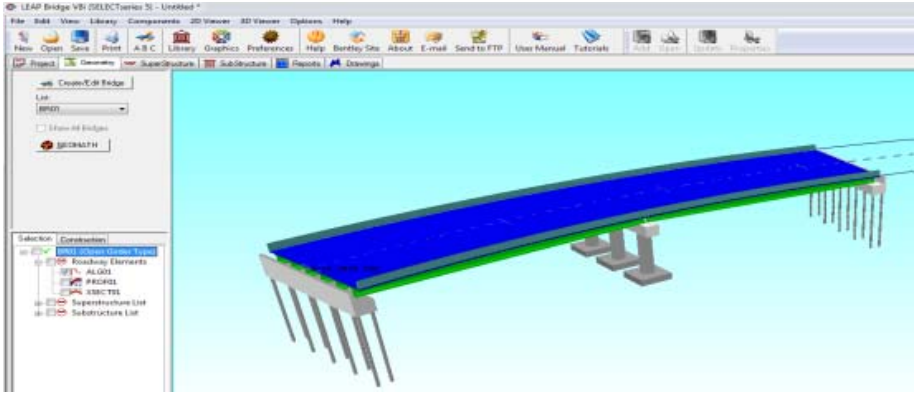
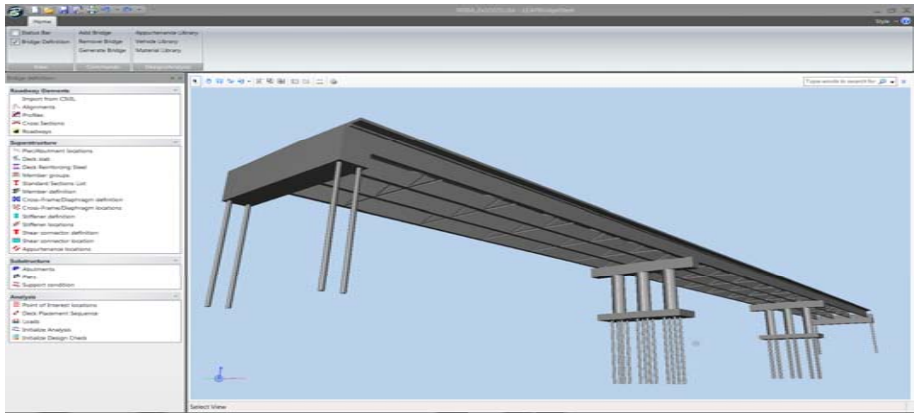
LEAP Bridge for Everyday Bridges

LEAP Bridge Enterprise
for Concrete Bridges



LEAP Bridge Steel
for Steel Bridges



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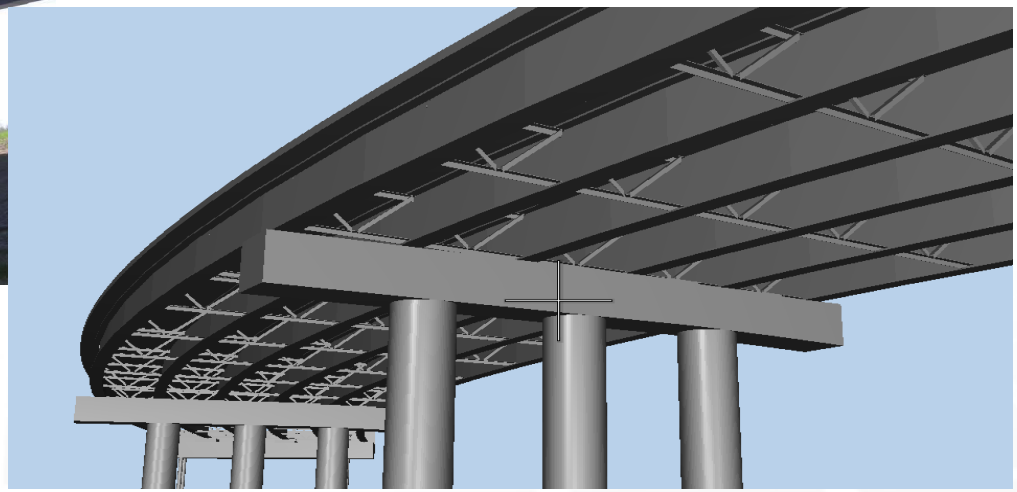
LEAP Bridge Steel

Design and Rating of Steel Bridges



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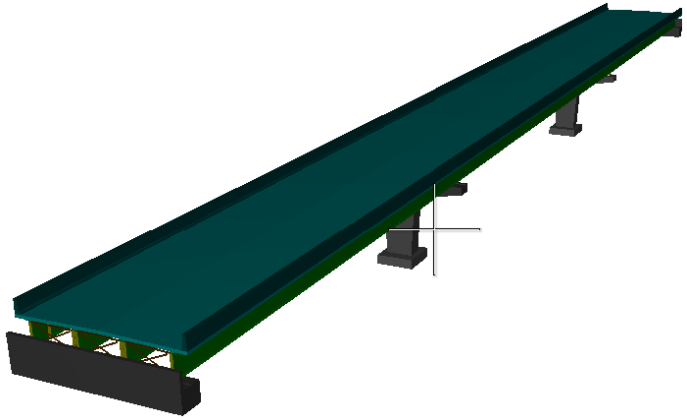
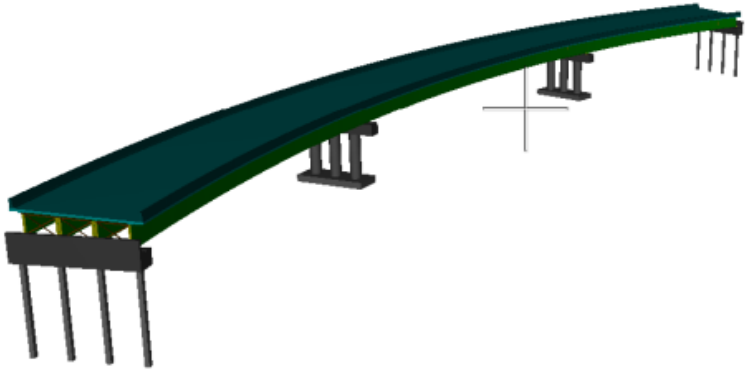
LEAP Bridge Steel Overview

- Supported bridge configurations
  - Simple and continuous spans
  - Straight and curved bridges
  - Standard rolled shapes and welded I girders
  - 6th Edition (7th coming soon) of the AASHTO LRFD Bridge Design Specification, and
  - 2nd Edition of the AASHTO Manual for Bridge Evaluation



- Provides:
  - Parametric modeling
  - Streamlined analysis
  - Design code checking
  - Load Rating
  - Transparent dead and live load analysis by STAAD.Pro



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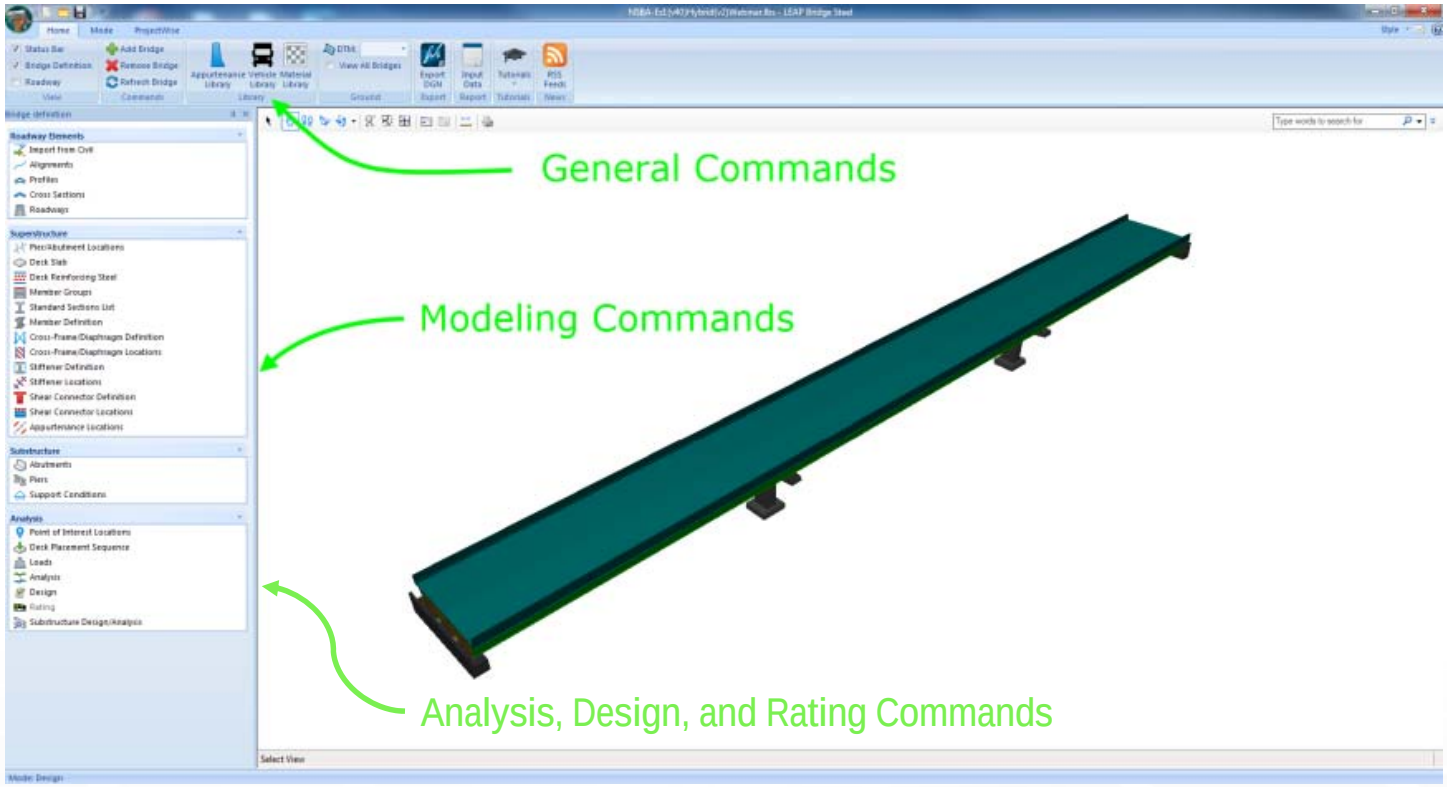
LEAP Bridge Steel Overview

- General Commands
  - Libraries
  - Tutorials
  - MS export …
- Modeling Commands
  - Roadway
  - Superstructure
  - Substructure
- Analysis, Design, and Rating Commands



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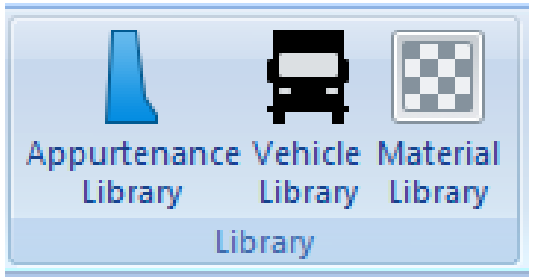
General Commands - Libraries

- Libraries store…
  - Appurtenances
  - Vehicles/live load information
  - Material tables
- Users can add and share library data
- Library elements are selected during the modeling process



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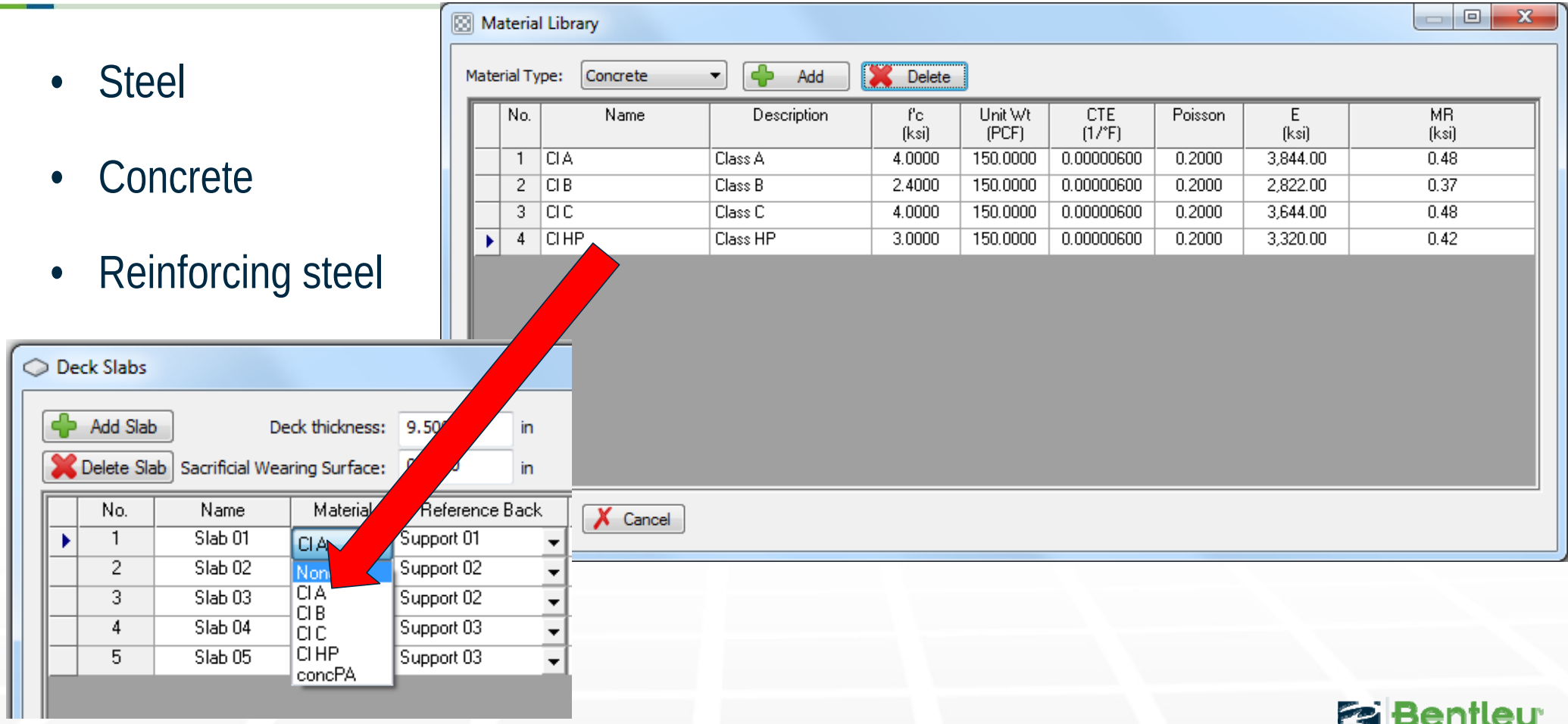
General Commands – Material Library

- Steel
- Concrete
- Reinforcing steel



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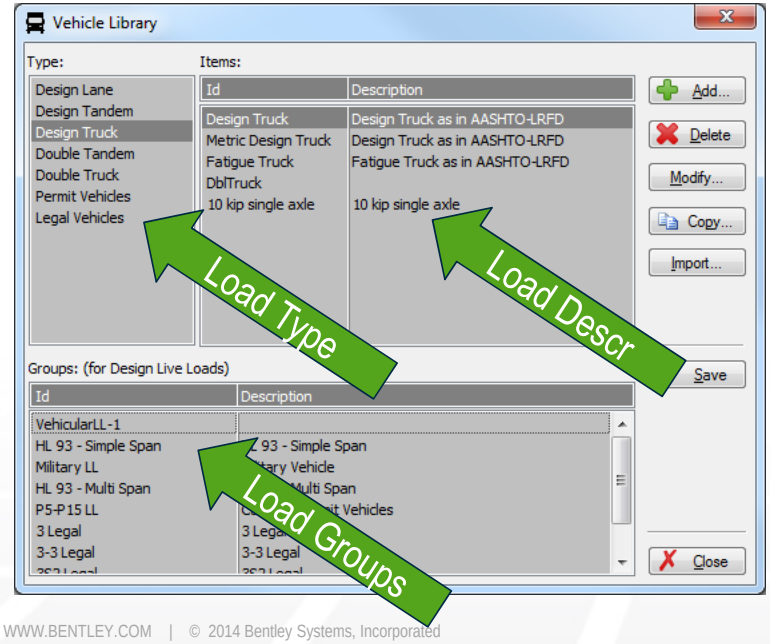
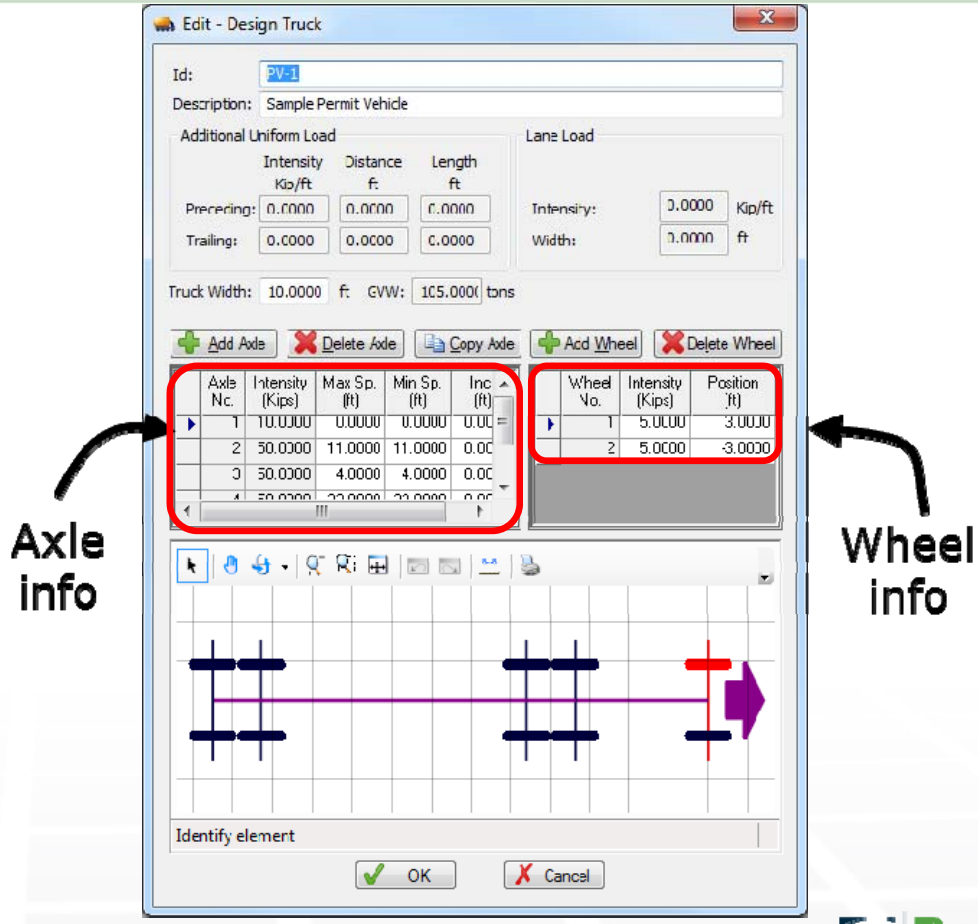
General Commands – Vehicle Library

- Define
  - Truck loads
  - Lane loads
  - Live load groups





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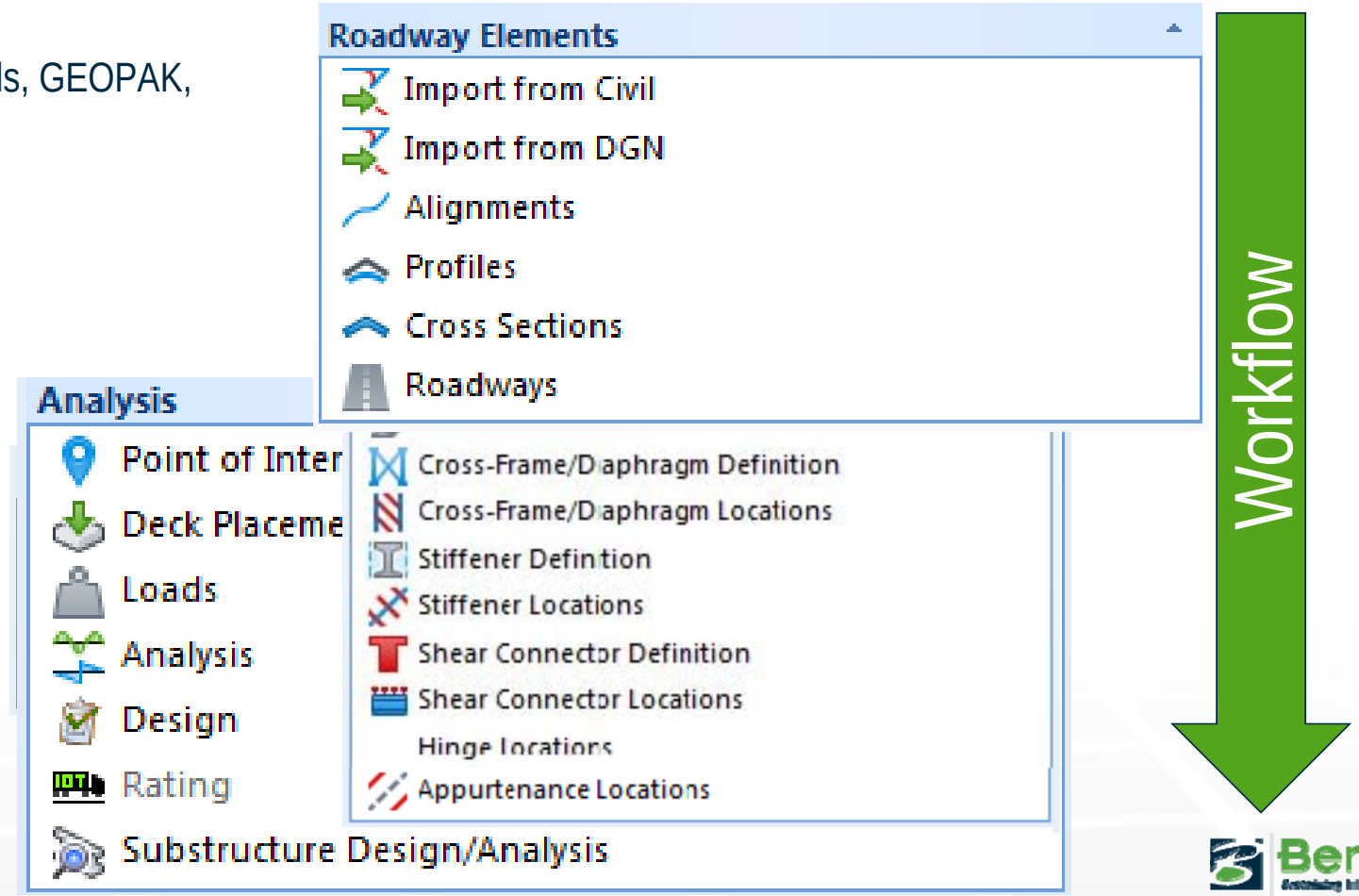
Bridge Modeling Workflow

- Roadway Elements
  - Import from Civil InRoads, GEOPAK, MXROAD
  - Enter in LBS
- Superstructure
- Substructure
- Analysis
- Design
- Load Rating



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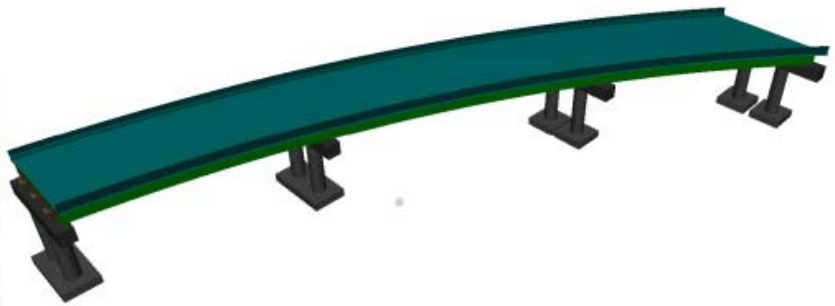
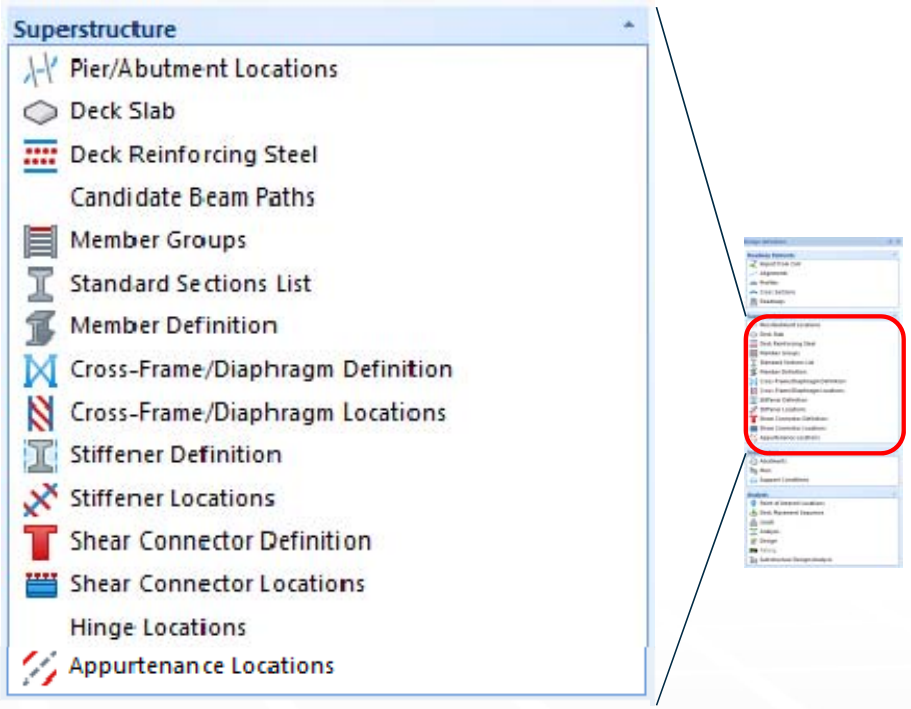
Superstructure Commands

- Define the components of the superstructure
- 3D bridge model automatically updated geometrically and for loading
- 3D Model can be visualized at every stage of model definition





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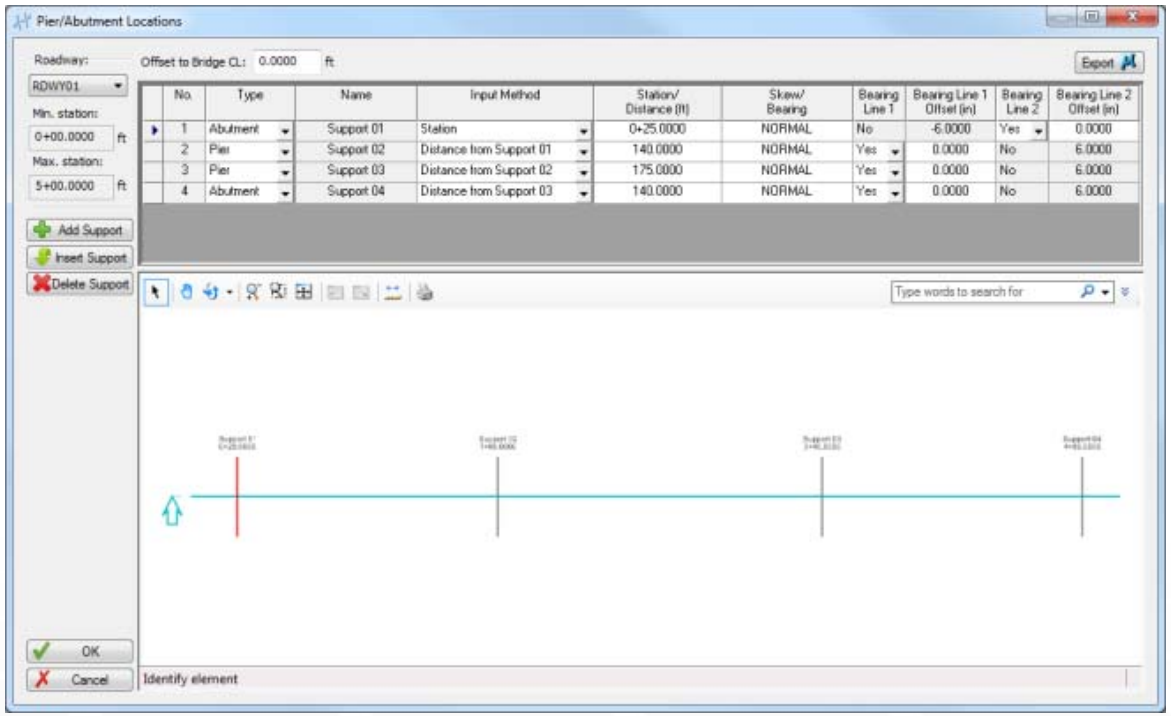
Superstructure – Pier & Abutment Locations

- Locate bridge support centerlines
- Define as pier or abutment
- Assign skew, if any
- Can be offset to alignment
- Define bearing locations
- Changes are automatically reflected in the overall model



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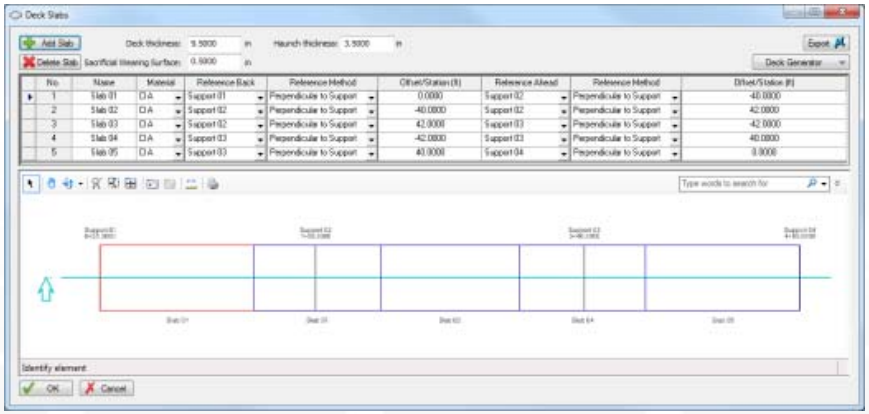
Superstructure – Deck Slab

- Define concrete deck longitudinal bounds
- When the deck is defined as multiple slab units, these can be used in the Deck Placement Sequence Command
- Sacrificial wearing surface included for dead load calculation
- Slab is considered non-composite until shear connectors are added



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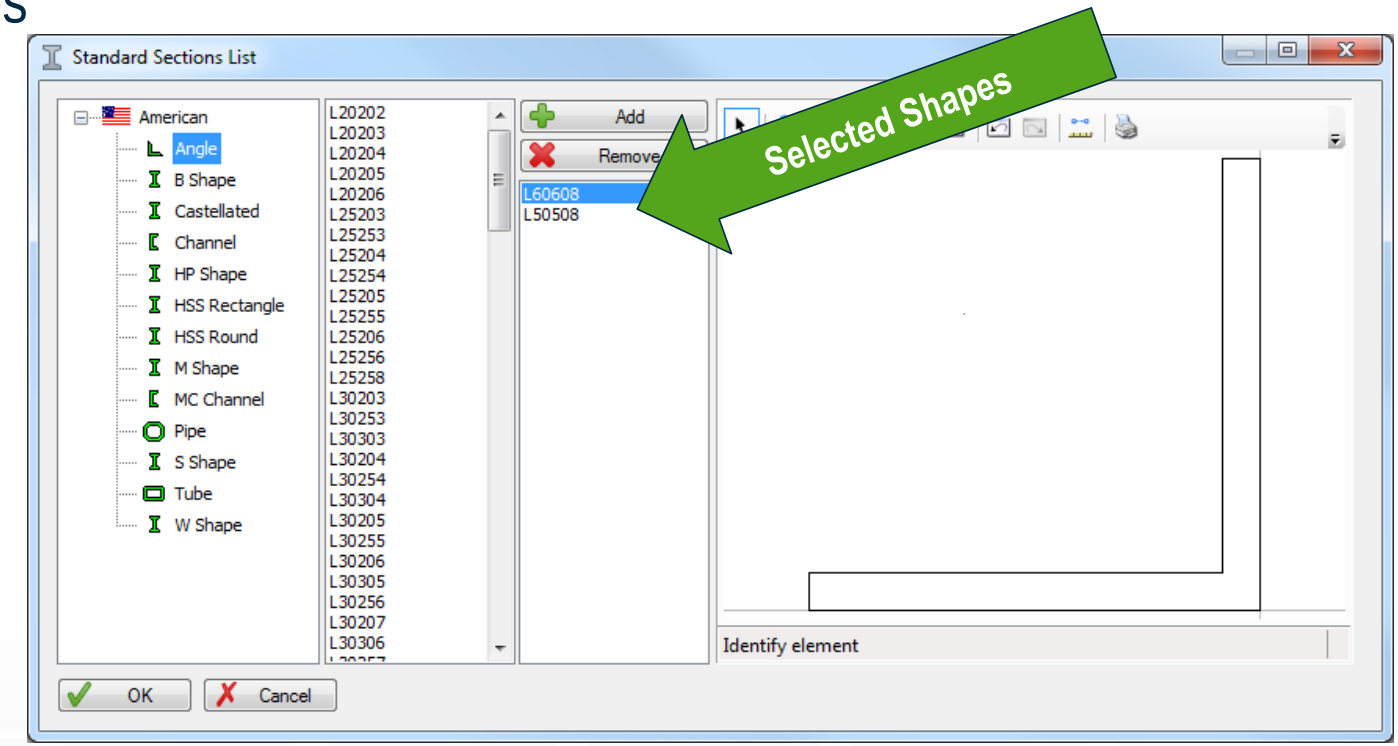
Superstructure – Standard Section List

- Select standard shapes for…
  - Cross frames
  - Main members



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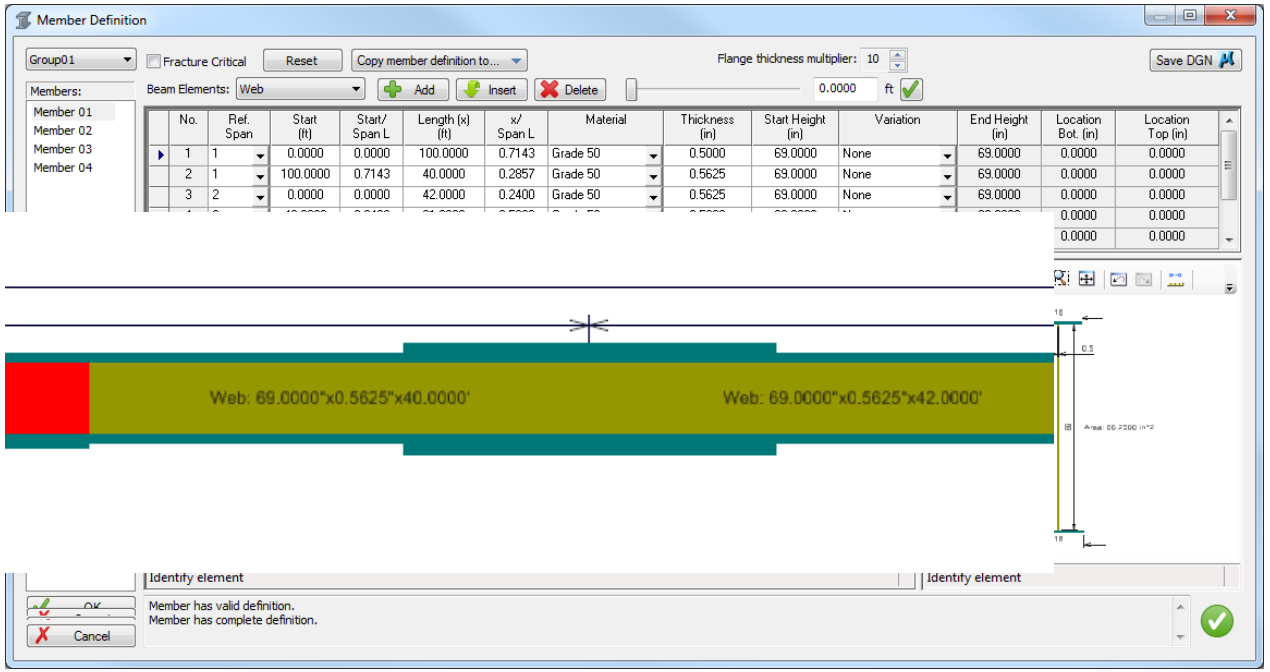
Superstructure – Member Definition

- Define member geometry using schedule based methodology
- Web transitions
- Copy members
- Hybrid girders
- Welded plate or standard section



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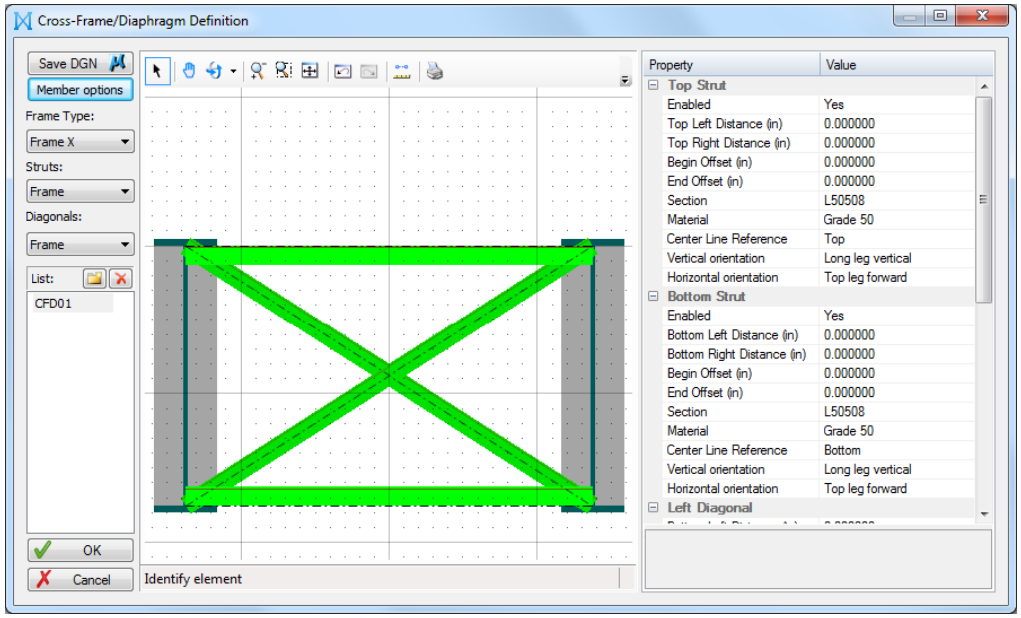
Superstructure – Cross-Frame / Diaphragm Definition

- Struts, X, V, inverted V
- Build from standard shapes
- Control orientation of members
- Analyze as frame or truss
- Used in grillage model as equivalent beam using methods from NCHRP Report 725
- Individual member forces computed



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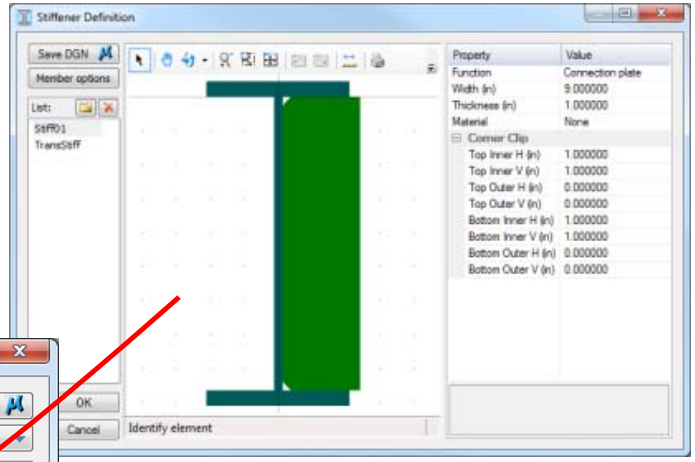
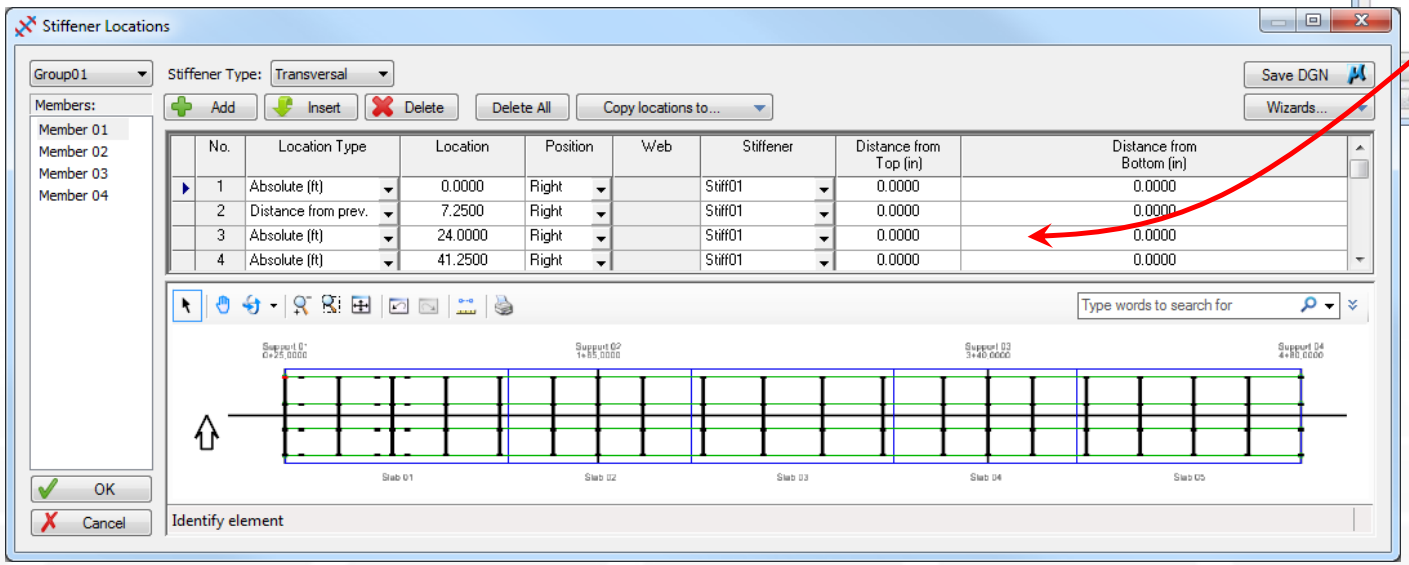
Superstructure – Stiffener Definition and Location

- Define bearing, connection plates or shear stiffeners
- Wizards available to assist locating stiffeners





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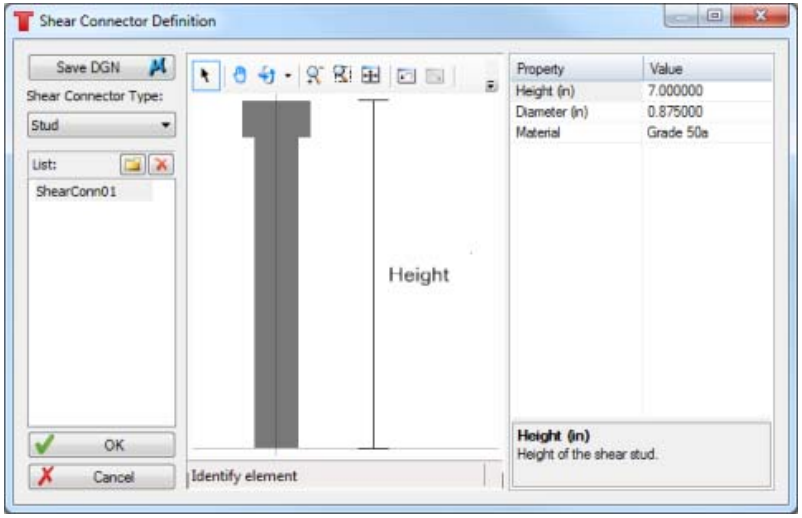
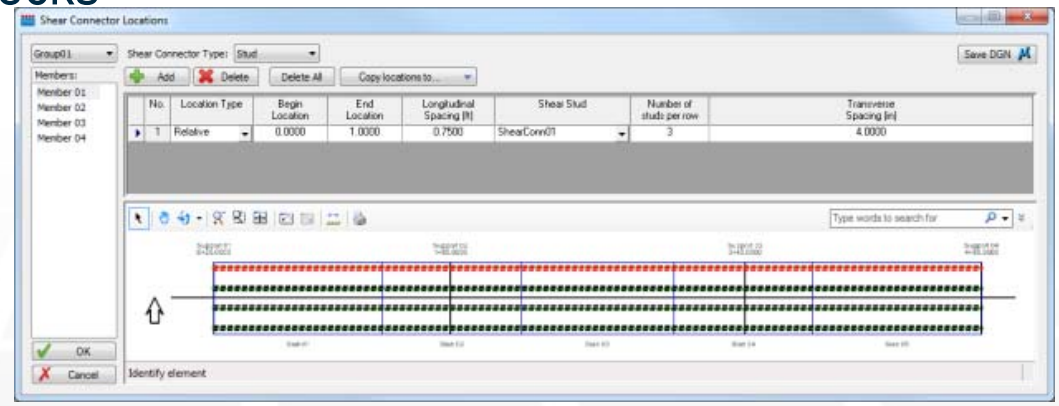
Superstructure – Shear Connector Definition and Location

- Define stud, channel or generic
- Locate along members by range with longitudinal and transverse spacing
- Define regions of composite action
- Fatigue and Strength checks





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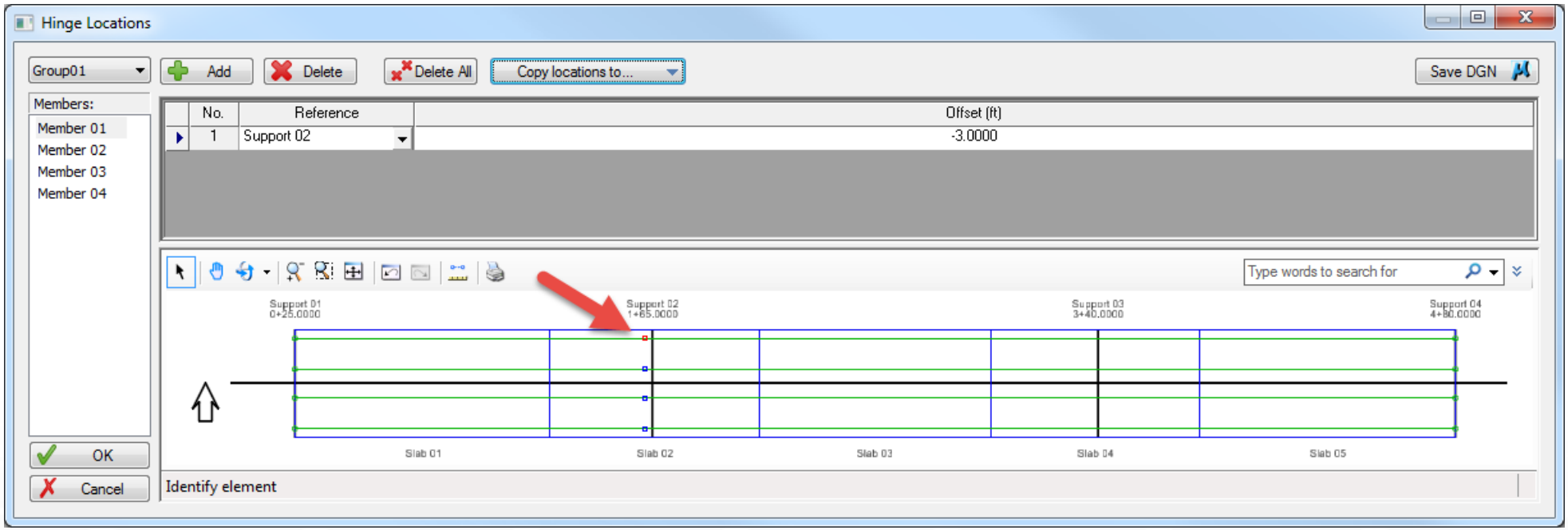
Hinge Locations

- Define locations of moment release along any member



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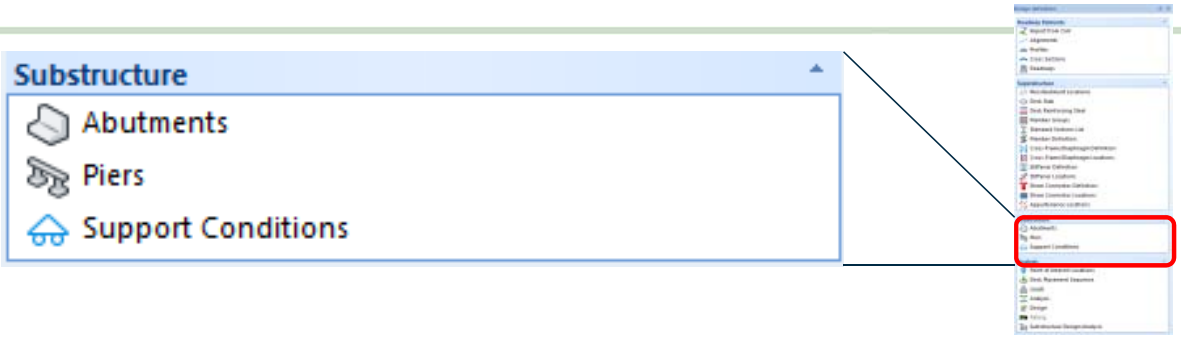
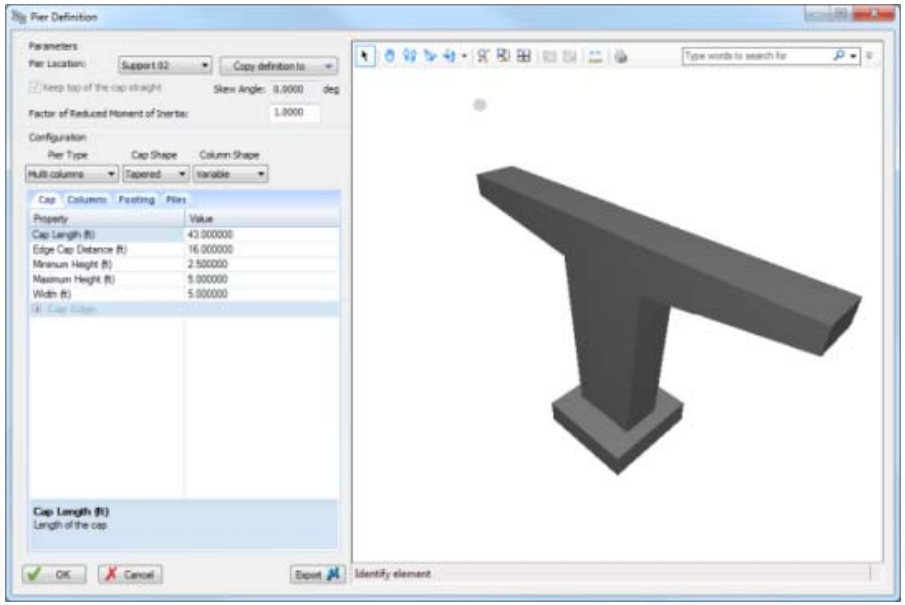
Substructure – Piers and Abutments

- Piers
  - Multi-column
  - Hammerhead
- Abutments
  - Pile cap
  - Stem wall
- All geometry defined in LBS and passed to RC-PIER for design





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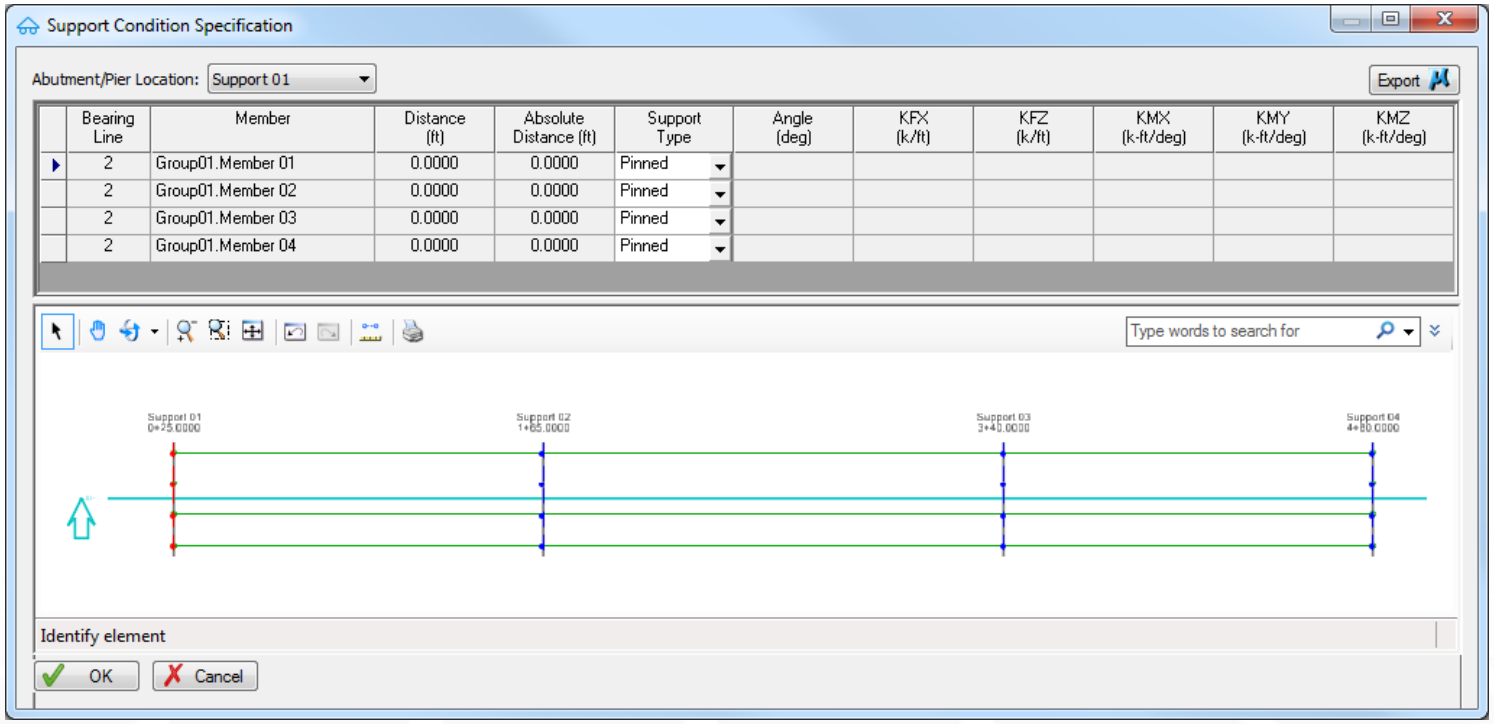
Substructure – Support Conditions

- Control movement at bearing locations
  - Pinned
  - Roller
  - Fixed
  - Float
  - Directional



Bearing Line	Member	Distance (ft)	Absolute Distance (ft)	Support Type	Angle (deg)	KFX (k/ft)	KFZ (k/ft)	KMX (k-ft/deg)	KMY (k-ft/deg)	KMZ (k-ft/deg)
2	Group01.Member 01	0.0000	0.0000	Pinned						
2	Group01.Member 02	0.0000	0.0000	Pinned						
2	Group01.Member 03	0.0000	0.0000	Pinned						
2	Group01.Member 04	0.0000	0.0000	Pinned						

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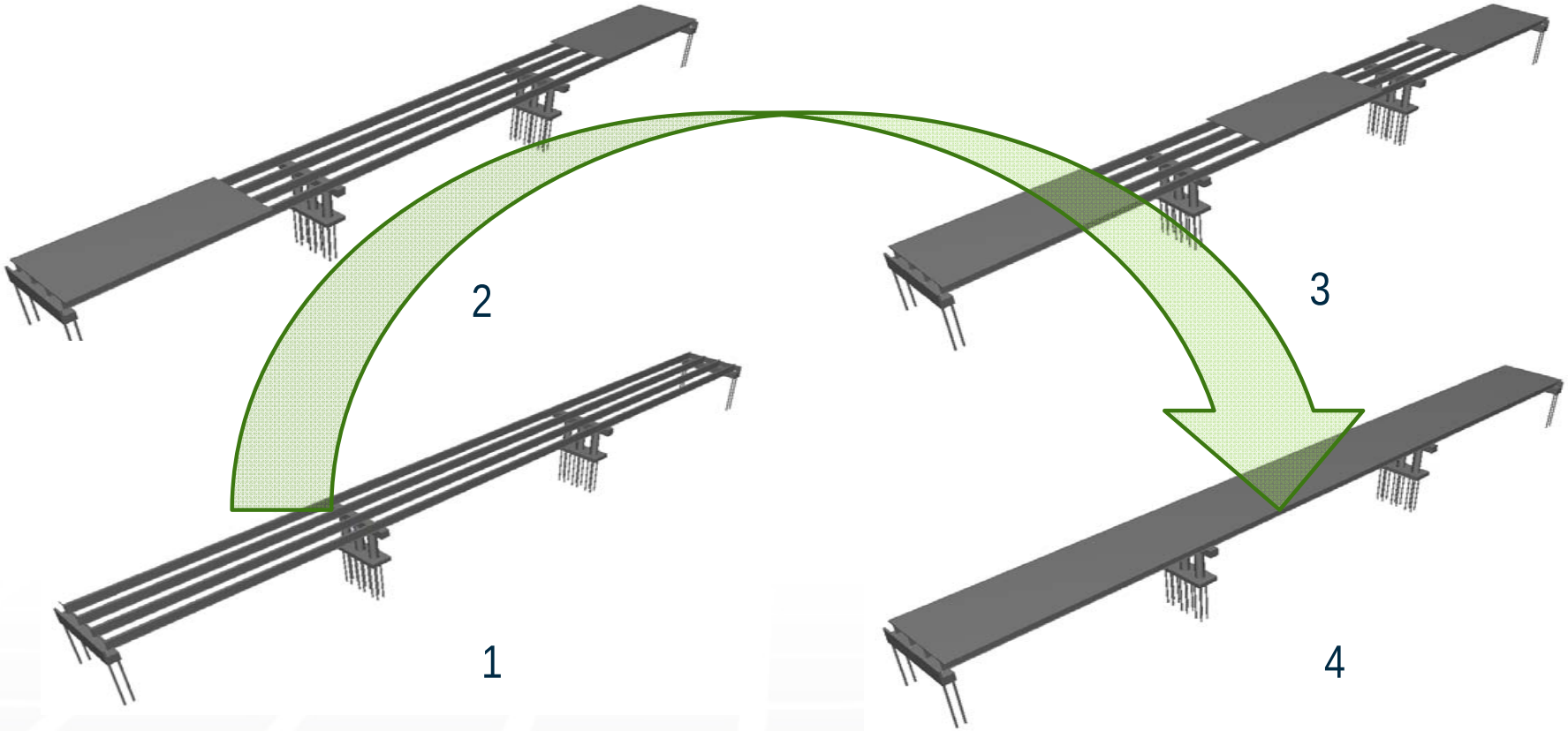
Analysis – Deck Placement Sequence



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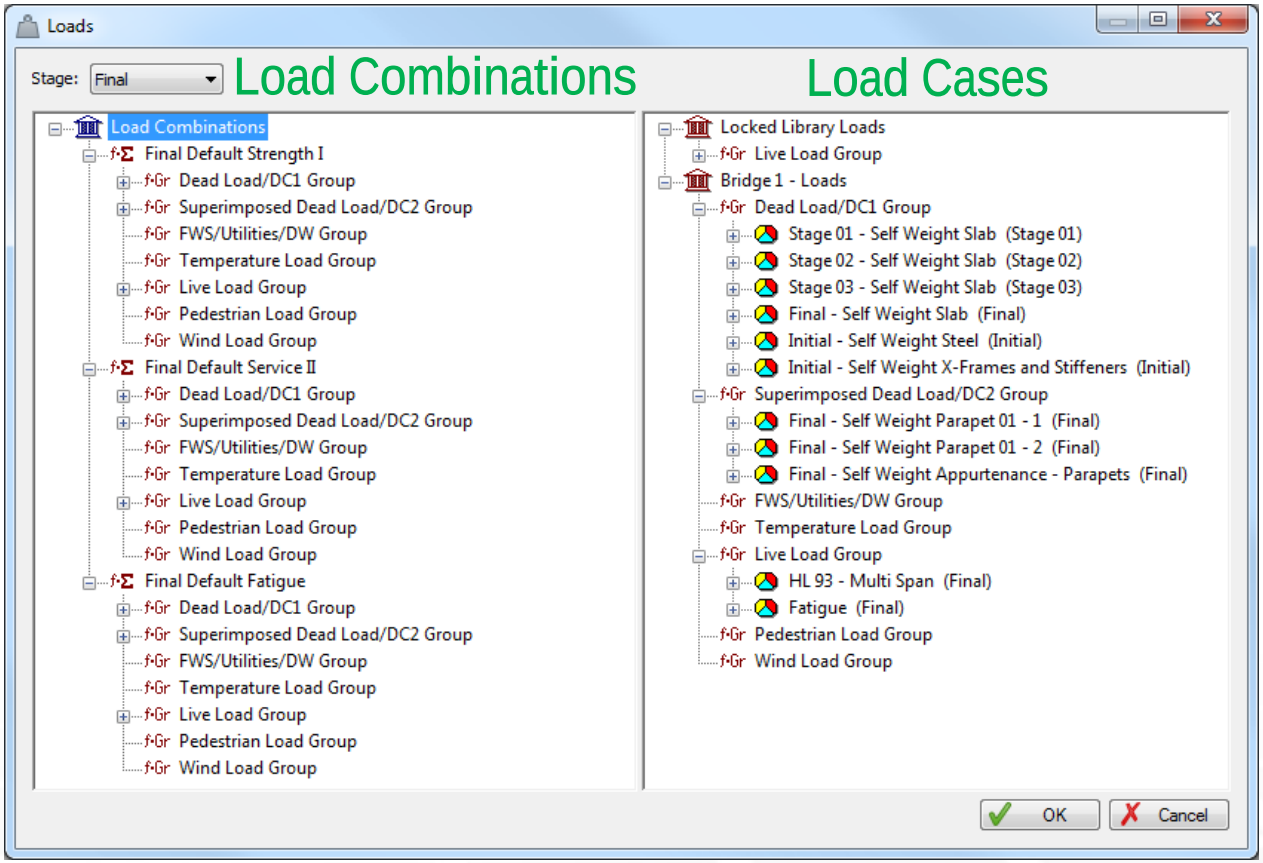
Analysis - Loads

- The Loads command allows entry of load cases (right) and Load combinations (left)
- Loads Cases can be:
  - Permanent DC1 dead load
  - Superimposed DC2 dead load
  - FWS/Utility DW dead load
  - Uniform temperature
  - Pedestrian
  - Wind
  - and Live load
- Load cases and combinations can be user defined for any stage.



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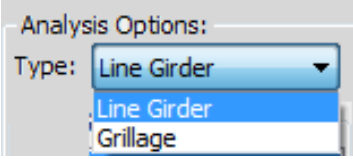
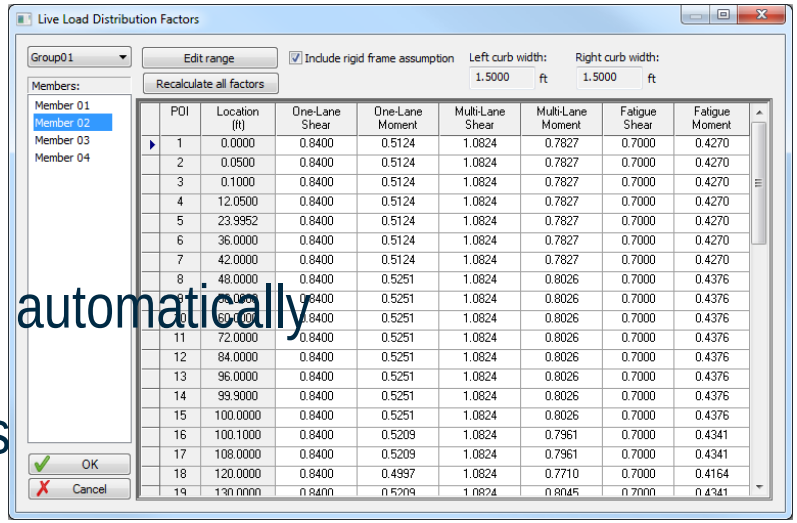
Analysis – Structural Analysis

- There currently are two analysis options
  - Line girder
  - Grillage



- Line Girder Live load distribution factors calculated automatically



POI	Location (ft)	One-Lane Shear	One-Lane Moment	Multi-Lane Shear	Multi-Lane Moment	Fatigue Shear	Fatigue Moment
1	0.0000	0.8400	0.5124	1.0824	0.7827	0.7000	0.4270
2	0.0500	0.8400	0.5124	1.0824	0.7827	0.7000	0.4270
3	0.1000	0.8400	0.5124	1.0824	0.7827	0.7000	0.4270
4	12.0500	0.8400	0.5124	1.0824	0.7827	0.7000	0.4270
5	23.9952	0.8400	0.5124	1.0824	0.7827	0.7000	0.4270
6	36.0000	0.8400	0.5124	1.0824	0.7827	0.7000	0.4270
7	42.0000	0.8400	0.5124	1.0824	0.7827	0.7000	0.4270
8	48.0000	0.8400	0.5251	1.0824	0.8026	0.7000	0.4376
9	[illegible]	0.8400	0.5251	1.0824	0.8026	0.7000	0.4376
10	60.0000	0.8400	0.5251	1.0824	0.8026	0.7000	0.4376
11	72.0000	0.8400	0.5251	1.0824	0.8026	0.7000	0.4376
12	84.0000	0.8400	0.5251	1.0824	0.8026	0.7000	0.4376
13	96.0000	0.8400	0.5251	1.0824	0.8026	0.7000	0.4376
14	99.9000	0.8400	0.5251	1.0824	0.8026	0.7000	0.4376
15	100.0000	0.8400	0.5251	1.0824	0.8026	0.7000	0.4376
16	100.1000	0.8400	0.5209	1.0824	0.7961	0.7000	0.4341
17	108.0000	0.8400	0.5209	1.0824	0.7961	0.7000	0.4341
18	120.0000	0.8400	0.4997	1.0824	0.7710	0.7000	0.4164
19	130.0000	0.8400	0.5209	1.0824	0.8045	0.7000	0.4341

- Analysis performed for all dead and live load cases
- Analysis takes into account structure stiffness variations in each stage
- Results displayed in report and graphic form
- Results exported to multiple formats: PDF, Excel, HTML, RTF, MHT, Text, JPG, PNG…..

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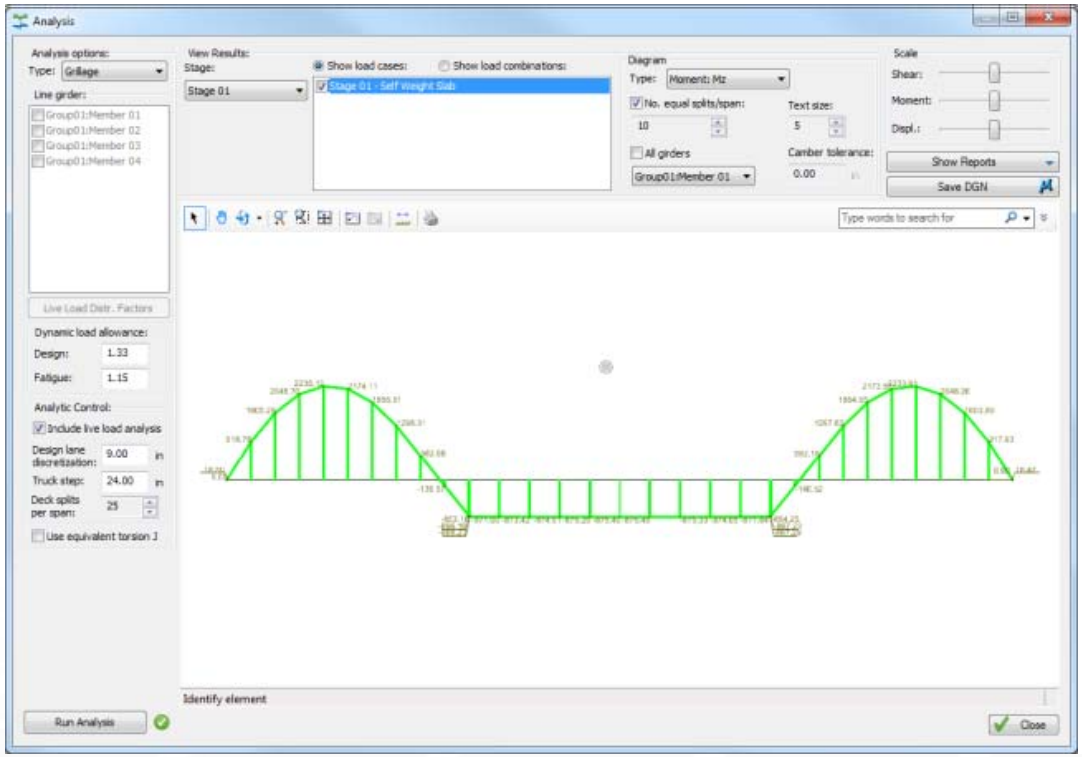
Analysis – Results



Member Forces

Group01 Member 01

Dead Load Stage 01 - Stage 01 - Self Weight Slab

POI Loc. (ft)	Span Fraction	Fx (kip)	Fy (kip)	Fz (kip)	Mx (kip-ft)	My (kip-ft)	Mz (kip-ft)
0.0000	1.0000	0.00	73.61	0.00	0.00	0.00	0.00
0.0750	1.0005	0.00	-73.52	0.00	0.00	0.00	6.12
0.1500	1.0011	0.00	-73.44	0.00	0.00	0.00	11.63
12.0750	1.0863	0.00	-59.92	0.00	0.01	0.00	807.92
24.0000	1.1714	0.00	-46.27	0.00	0.00	0.00	1442.60
36.0000	1.2571	0.00	-30.10	0.00	0.00	0.00	1887.41
42.0000	1.3000	0.00	-23.16	0.00	0.00	0.00	2047.19
48.0000	1.3429	0.00	-16.21	0.00	-0.03	0.00	2165.17
56.0000	1.4000	0.00	-3.92	0.00	0.00	0.00	2233.09
60.0000	1.4286	0.00	0.77	0.00	0.00	0.00	2239.05
72.0000	1.5143	0.00	14.65	0.00	-0.04	0.00	2145.95
84.0000	1.6000	0.00	31.32	0.00	-0.01	0.00	1852.47
96.0000	1.6857	0.00	45.10	0.00	-0.04	0.00	1392.90
99.9000	1.7136	0.00	51.27	0.00	0.01	0.00	1201.52
100.0000	1.7143	0.00	51.43	0.00	-0.01	0.00	1196.10

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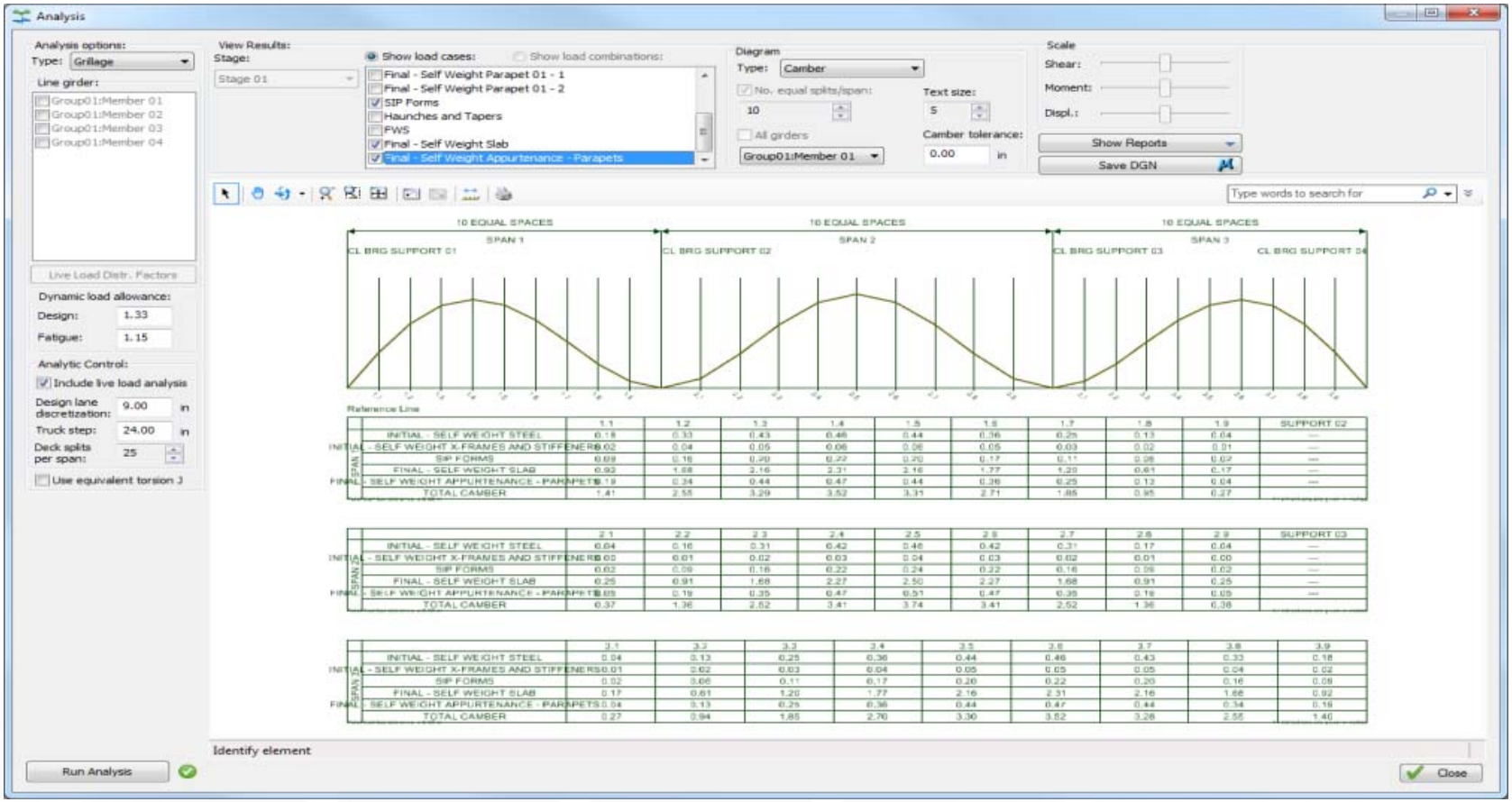
Analysis Results – Camber Diagrams



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Analysis – Design Reports

- Under / Over Design
- Section Properties
- Section Limits
- Factored Forces
- Factored Stresses
- Intermediate values
- Shear connectors
- Constructibility
- Service Limit State
- Strength Limit State
- Fatigue

Combination: Stage 02 Default Strength I

Eff. Slab Width (in): 114.000 Modular Ratio n: 7.544

	Steel	Composite (n=n)	Composite (n=3n)	Steel + Long. Reinf (n=n)
Overall Section Height (in)	---	82.375	---	---
Steel Area (in^2)	66.250	---	---	---
MOI - strong axis - X (in^4)	52513.688	133342.194	101100.017	65006.206
NA to Bottom of Section (in)	35.522	64.001	52.729	39.802
NA to Top of Section (in)	35.353	6.874	18.146	31.073
S - strong axis top (in^3)	1485.407	19399.432	5571.388	2092.073
S - strong axis bottom (in^3)	1478.345	2083.423	1917.362	1633.225
S - strong axis T/slab (in^3)	---	7257.307	3410.208	---
MOI - weak axis - Y (in^4)	767.302	---	---	---
S - weak axis top (in^3)	95.913	---	---	---
S - weak axis bottom (in^3)	85.256	---	---	---
Iy - top flange (in^4)	341.333	---	---	---
Iy - bottom flange (in^4)	425.250	---	---	---

Factored Forces

	Combination Name	Combination Type *	Factor	Mx (kip-ft)	My (kip-ft)	Mz (kip-ft)	Fx (kip)	Fy (kip)	Fz (kip)
DC1	Final Default Strength I	Strength I	1.250	0.053	0.000	2009.972	0.000	45.413	0.000
DC2	Final Default Strength I	Strength I	1.250	-0.087	0.000	339.845	0.000	6.673	0.000
DW	Final Default Strength I	Strength I	1.500	0.000	0.000	0.000	0.000	0.000	0.000
TEMP	Final Default Strength I	Strength I	1.200	0.000	0.000	0.000	0.000	0.000	0.000
WIND	Final Default Strength I	Strength I	1.000	0.000	0.000	0.000	0.000	0.000	0.000
PED	Final Default Strength I	Strength I	1.750	0.000	0.000	0.000	0.000	0.000	0.000
LL+I (+)	Final Default Strength I	Strength I	1.750	0.000	0.000	5616.917	0.000	-114.765	0.000
LL+I (-)	Final Default Strength I	Strength I	1.750	0.000	0.000	-2236.063	0.000	65.518	0.000

* Fatigue forces and moments are not factored

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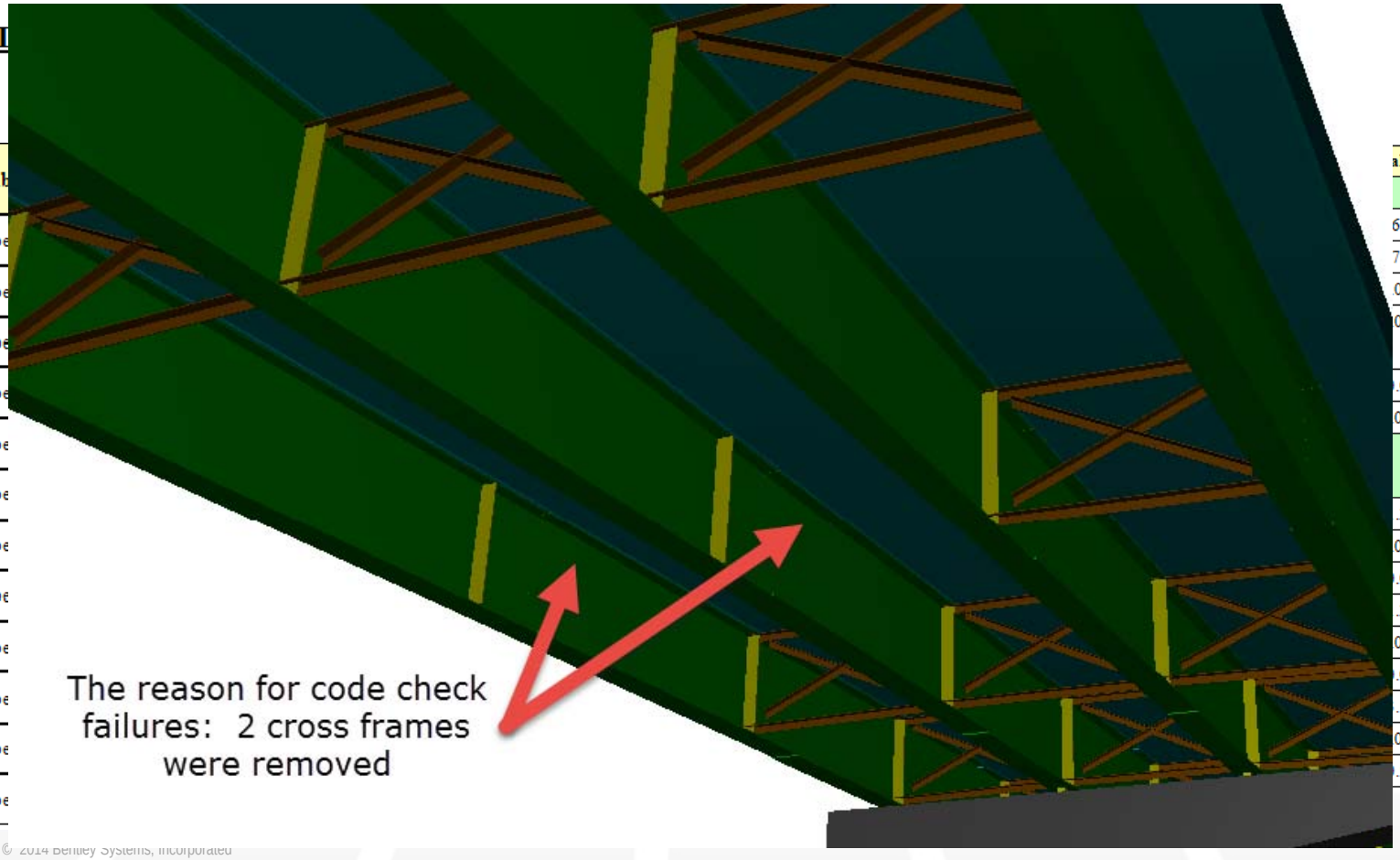
Analysis – Design Reports



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Group01	Membe

alue	Perf. Ratio	Result
6.000		
7.550		
.002		
002		
.000	0.0001	Passed
002		
.351	0.2271	Passed
002		
.000		
.351	0.2270	Passed
002		
.000		
.115	1.1238	Failed
002		
.570		

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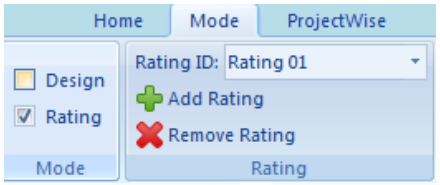
Analysis - Rating

- LBS 1.0 performs design Inventory and Operating rating
- Rating models are copied from the design model or other rating models – multiple rating models possible
- User defined combinations



Load Rating

Group01 Member 01

Design Inventory (Strength I) Design Inventory

POI Loc. (ft)	Moment Rating Factor	Moment/Stress Resistance (kip-ft / ksi)	Controlling Equation	Shear Rating Factor	Shear Resistance (kip)	Controlling Equation
0.000	---	11285.209	Equation 6.10.7.1.1-1	4.372	1000.500	Equation 6.10.9.1-1
0.075	530.558	46.442	Equation 6.10.8.1.1-1 local buckling	2.312	575.406	Equation 6.10.9.1-1
0.150	408.991	11277.049	Equation 6.10.7.1.1-1	3.724	858.103	Equation 6.10.9.1-1
12.075	4.450	10728.203	Equation 6.10.7.1.1-1	2.691	559.678	Equation 6.10.9.1-1
24.000	2.179	10313.365	Equation 6.10.7.1.1-1	1.170	239.197	Equation 6.10.9.1-1
36.000	1.519	10055.495	Equation 6.10.7.1.1-1	1.652	239.197	Equation 6.10.9.1-1
42.000	1.358	9978.162	Equation 6.10.7.1.1-1	1.926	239.197	Equation 6.10.9.1-1
48.000	1.902	13541.622	Equation 6.10.7.1.1-1	2.330	239.197	Equation 6.10.9.1-1
56.000	1.880	13558.251	Equation 6.10.7.1.1-1	2.601	239.197	Equation 6.10.9.1-1
60.000	1.892	13588.735	Equation 6.10.7.1.1-1	2.480	239.197	Equation 6.10.9.1-1
72.000	2.032	13768.350	Equation 6.10.7.1.1-1	1.631	239.197	Equation 6.10.9.1-1
			Equation 6.10.8.1.1-1			Equation

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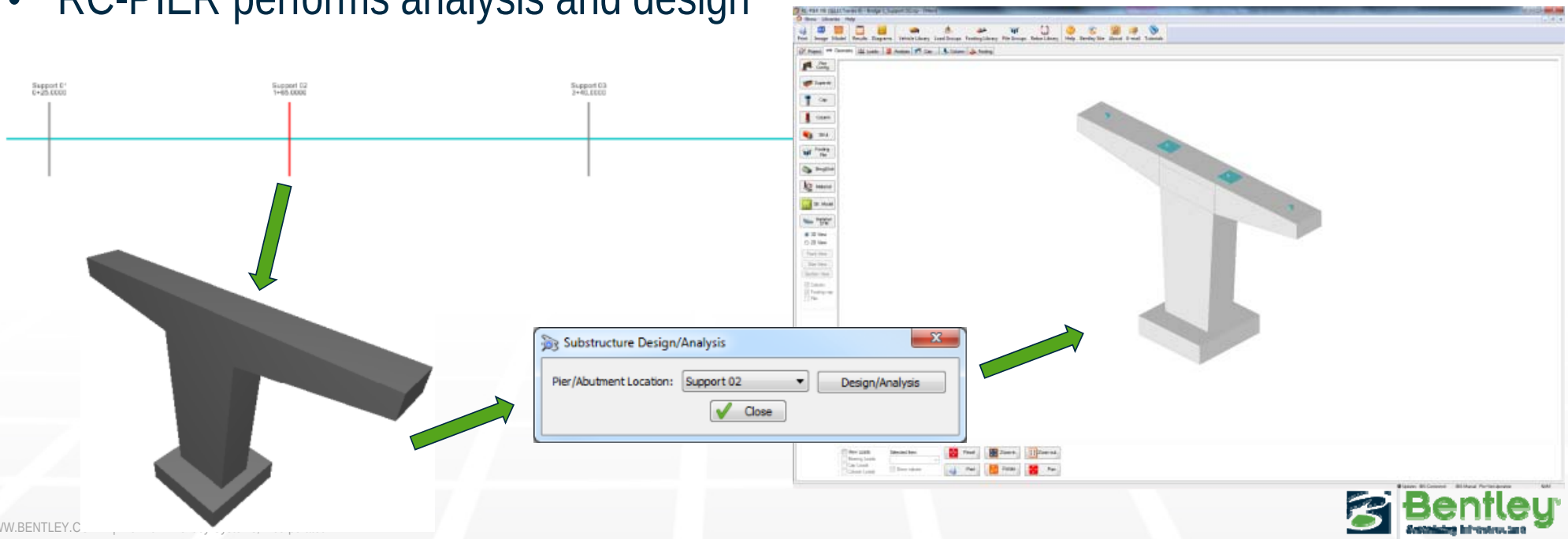
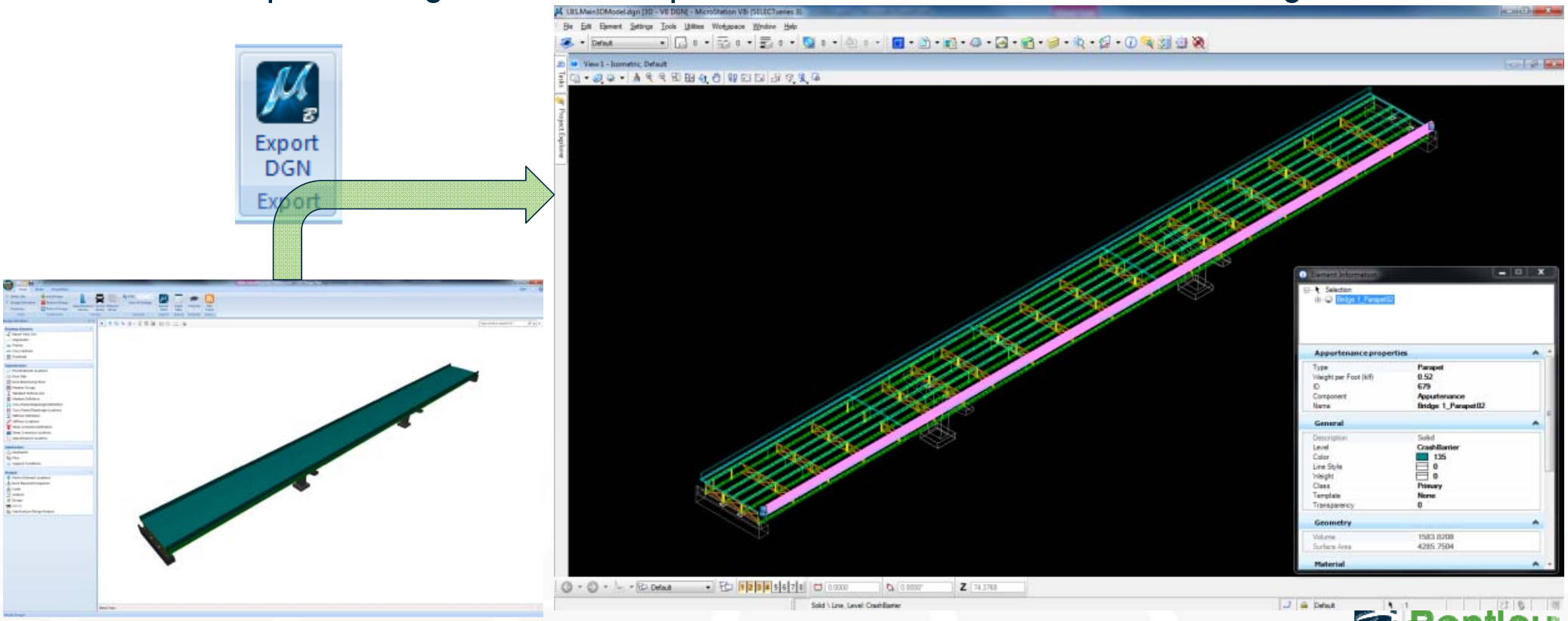
Analysis – Substructure Design/Analysis

- Substructure geometry and superstructure description are seamlessly passed to RC-PIER
- RC-PIER performs analysis and design



Export to MicroStation

- The complete bridge model is exported to MicroStation as a 3D intelligent model



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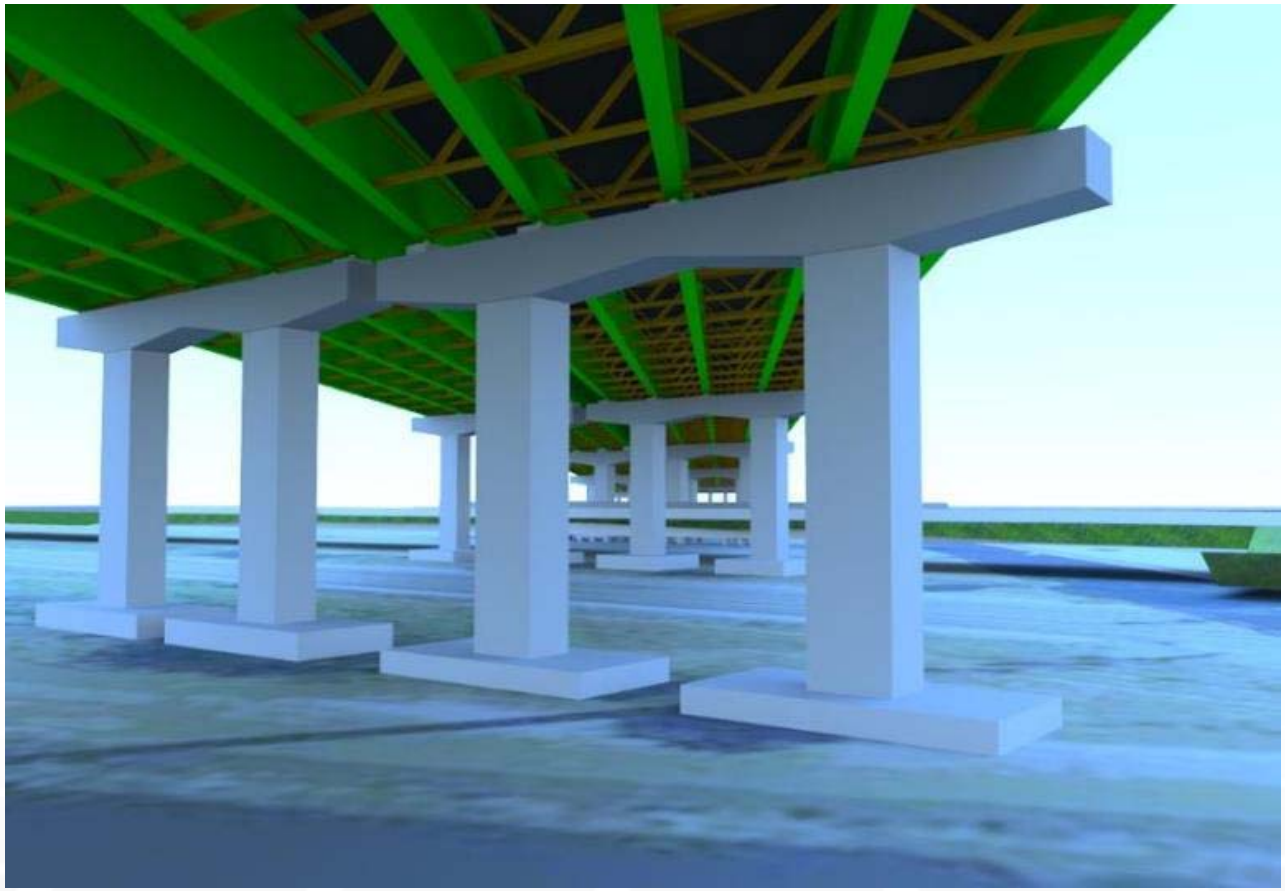
Steel Bridge designed by LEAP Bridge Steel



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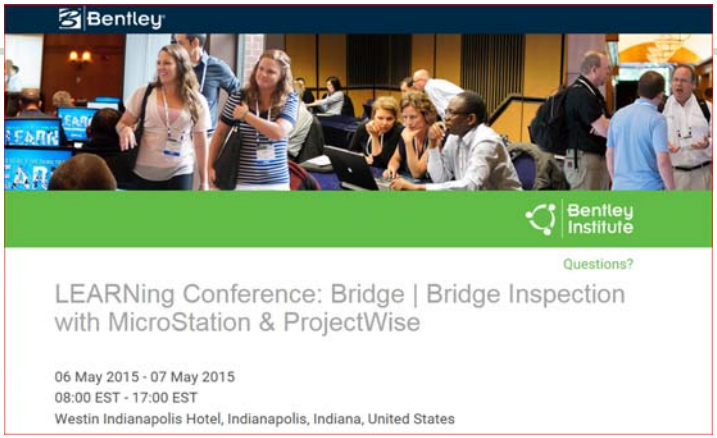
Upcoming Events – Important Dates



- Next Bridge SIG Meeting
  - Bentley LEARNing conference
    - May 6-7, 2015 – Indianapolis, Indiana
    - Bentley Bridge SIG Meeting – Day 2
  - Thursday, June 11, 2015 2pm EDT
    - 3D Bridge Modeling with LEAP Products
      - Guest Presenter: Steve Willoughby, Bentley
  - Thursday, July 9, 2015 2pm EDT
    - Reinforced Concrete Detailing for Bridges using ProConcrete (powered by Bentley Rebar)
      - Guest Presenter: Raul Amaya, PE, Bentley

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