

# AASHTOWare Bridge Substructure Overview



AASHTOWare Bridge Rating/Design  
User Group Meeting  
Kansas City, Kansas – August 2017

# BrD Substructure Capabilities

- Describe/spec check 4 types of piers
- LRFD Specifications
  - 4<sup>th</sup> Edition, 2008 interims through 8<sup>th</sup> Edition
- Integrated with BrD Superstructure or stand-alone pier
- Load transfer from BrD Superstructure
- Computed loads or user defined loads
- User control of loads and FE model



# BrD Substructure Capabilities

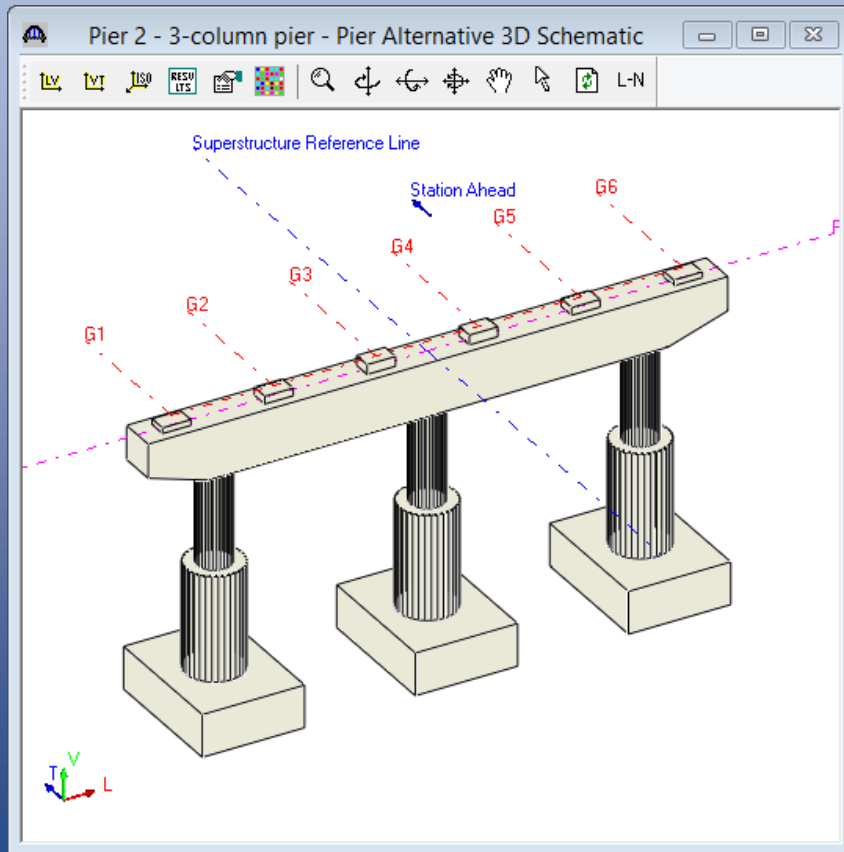
- Schedule-based reinforcement with development length calculations
- Pier: Linear finite element analysis, moment magnification
- Drilled Shaft: Nonlinear finite element analysis
- Load combination generation
- Tabular and graphical FE results



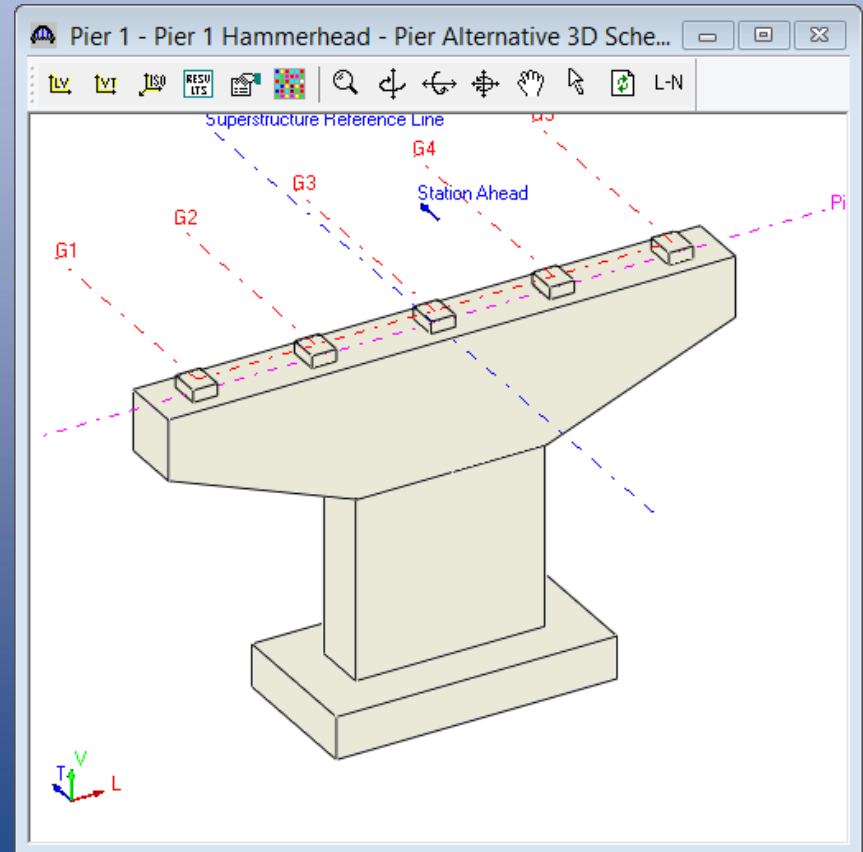
# BrD Substructure Capabilities

- Four types of piers can be analyzed

Frame

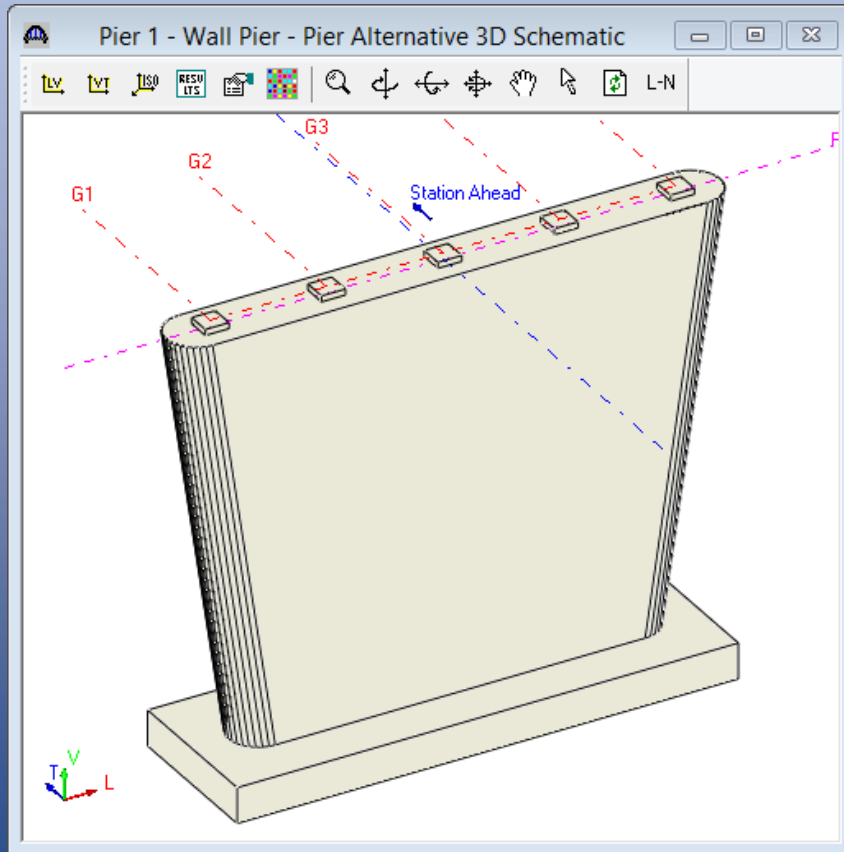


Solid Shaft

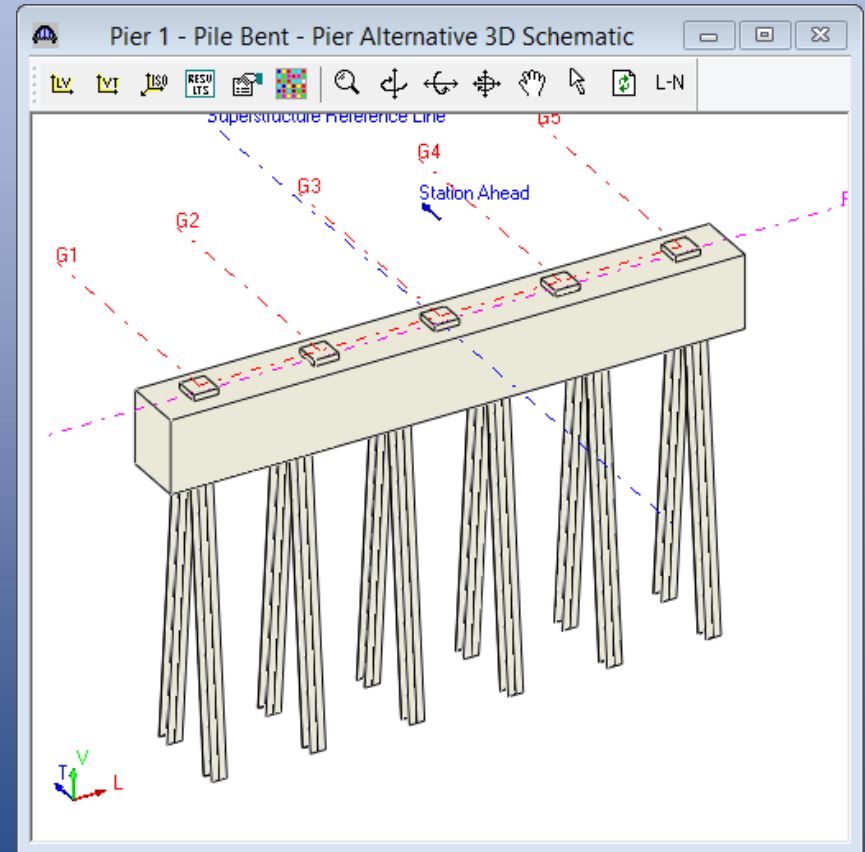


# BrD Substructure Capabilities

Wall

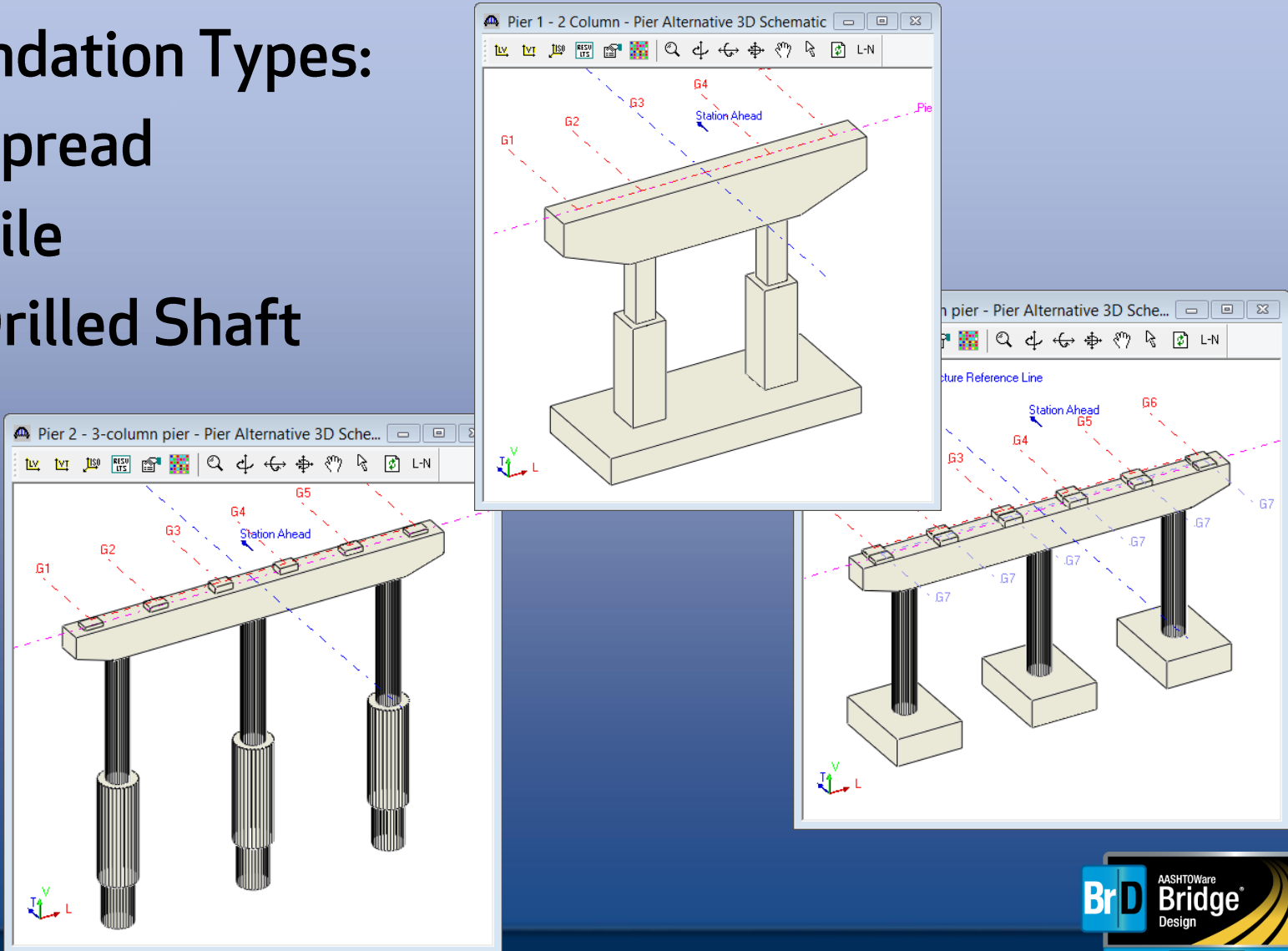


Pile Bent



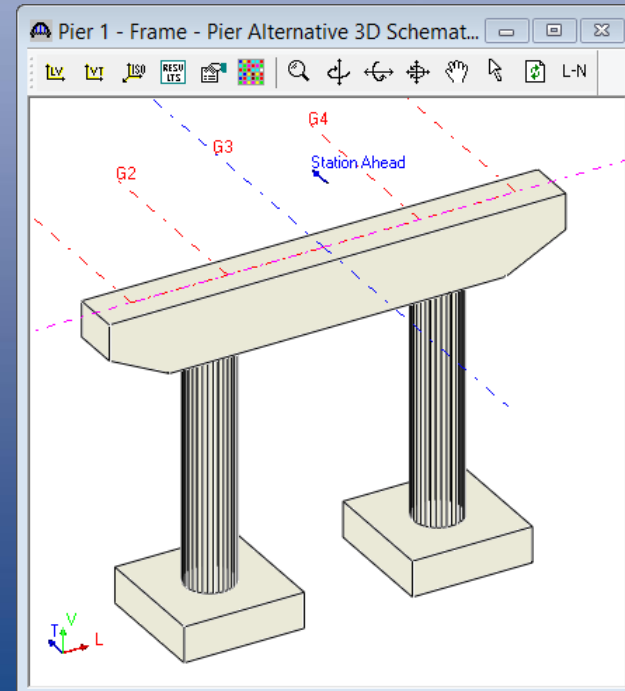
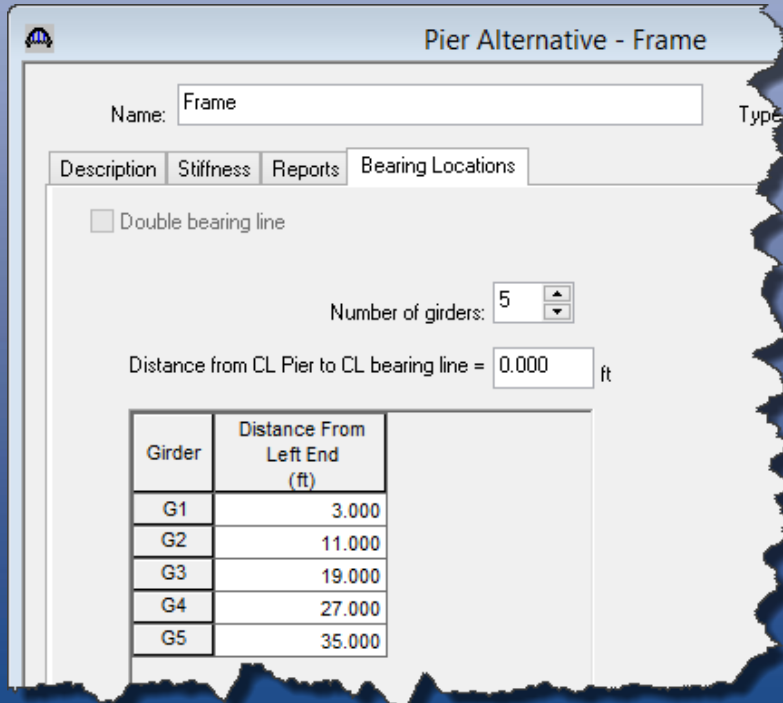
# BrD Substructure Capabilities

- Foundation Types:
  - Spread
  - Pile
  - Drilled Shaft



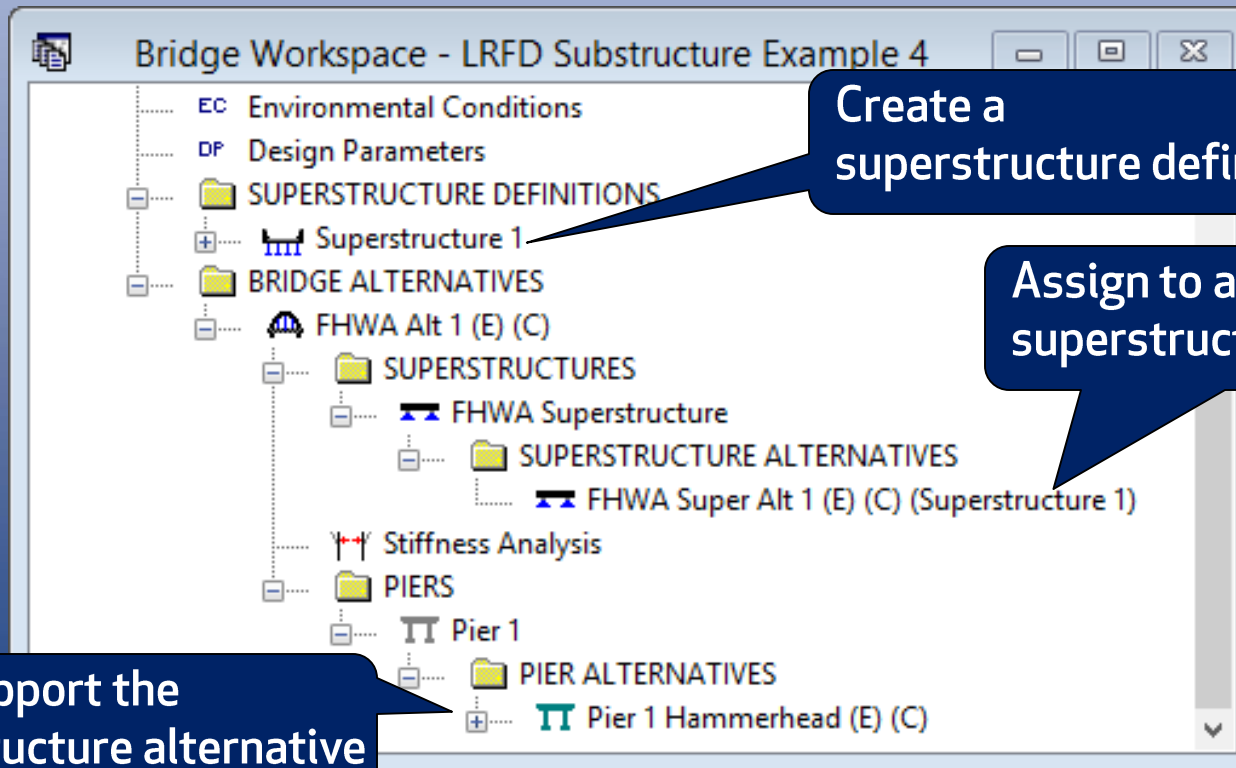
# Stand-Alone Pier

- User defines girder locations
- User enters dead load reactions & superstructure loads
- User enters live load pier reactions
- BrD distributes user defined LL lanes to the girders



# Integration with BrD Superstructure

- Automated dead and live load computations
- Dead load and live load transfer from BrD Superstructure



Create a superstructure definition

Assign to a superstructure alternative

Piers support the superstructure alternative



# Live Load Generation

- Longitudinal live load analysis
  - 2-D “line” analysis of superstructure to generate influence line
  - Single lane reaction without distribution factors
  - Piers supporting 2 independent superstructures are handled

# Live Load Generation

- Transverse live load analysis
  - User controls lane application

The screenshot displays the 'Superstructure Loads - Pier 1 - Pier 1 Hammer' software interface. The window title is 'Superstructure Loads - Pier 1 - Pier 1 Hammer'. The interface is divided into several sections:

- Back Span:** Span No.: 1, Superstructure Definition: Superstructure 1
- Ahead Span:** Span No.: 2, Superstructure Definition: Superstructure 2
- Navigation Tabs:** DL, FR, LL Settings (selected), LL-Reaction, LL-Distribution, BR
- Live Loading Type:**  User defined lanes,  Automated
- Scan for controlling load positions:**
- Transverse Loading:**
  - Vehicle increment in lane: 2.000 ft
  - Lane increment: 4.000 ft
  - Move vehicles right to left across travelway:

# Live Load Generation

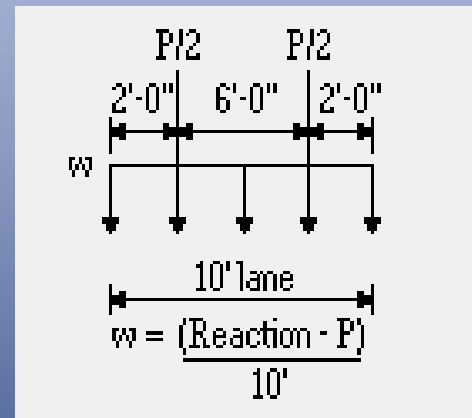
- Transverse live load analysis
  - User controls distribution of single lane reaction

Distribution Method

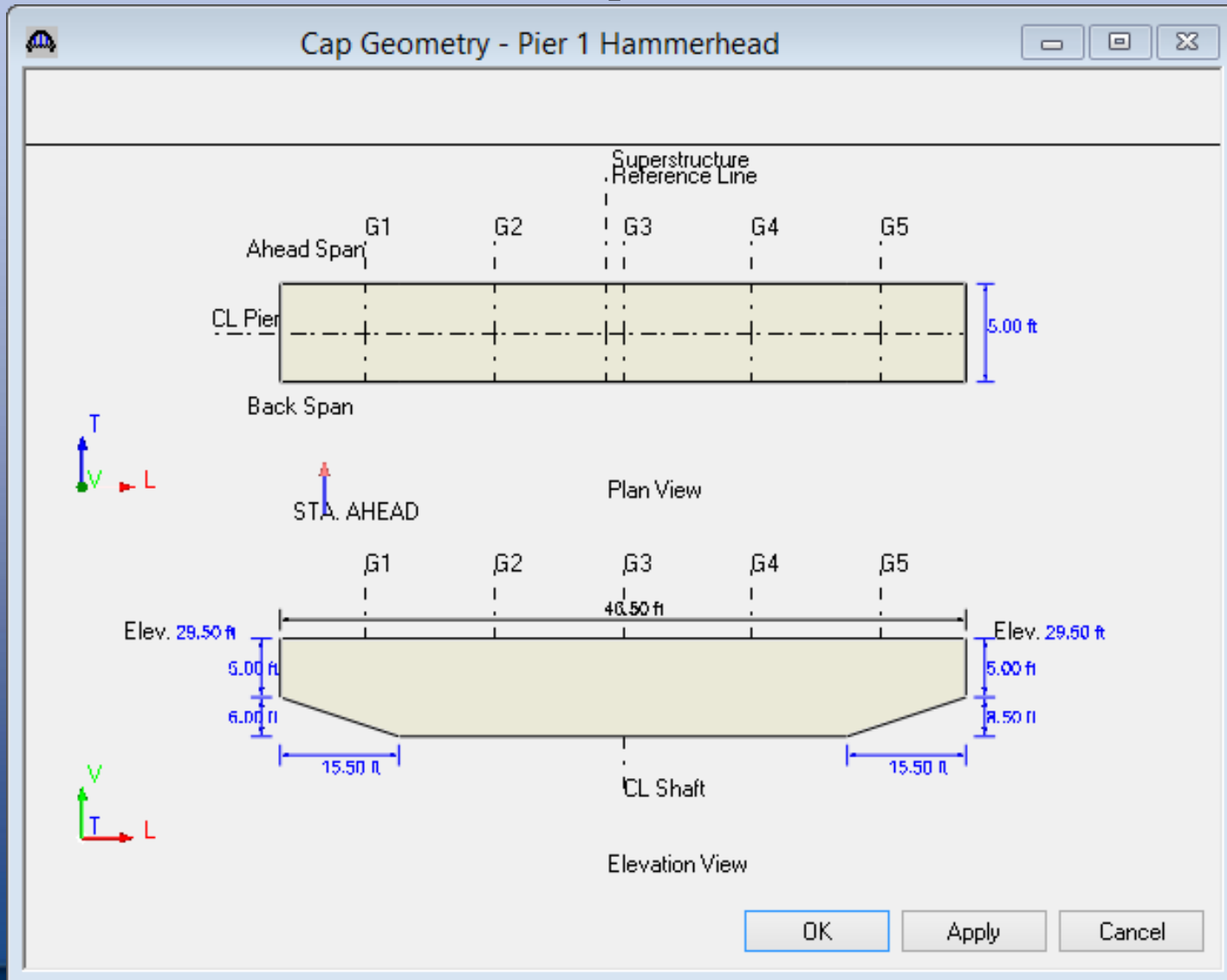
Tributary area

Lever rule

Rigid deck action



# Graphical Data Entry



# Text Data Entry

Cap Properties - Pier 1 - Pier 1 Hammerhead

Description Additional Loads

Cap Type: Beam Shape Cap Cap Top Configuration: Sloped Cap Material: Class A (US) v

Pedestals Exposure factor: 1.000

Member	CL Bearing Station (ft)	Angle Between CL Member and CL Support (Degrees)	Bearing Seat Elevation (ft)
G1	120.00	90.00	29.50
G2	120.00	90.00	29.50
G3	120.00	90.00	29.50
G4	120.00	90.00	29.50
G5	120.00	90.00	29.50

OK Apply Cancel

# Schedule Based Reinforcement

- BrD computes the development length and takes it into consideration in the spec checks

Cap Reinforcement - Pier 1 - Pier 1 Hammerhead

Flexural Shear

Longitudinal Skin

Bar size: 8 Bar spacing: 8.000 in Bar material: Grade 60 Stirrup clear cover: 2.5000 in

Primary Flexural

Reinforcement Input Method  Reinforcement follows cap profile

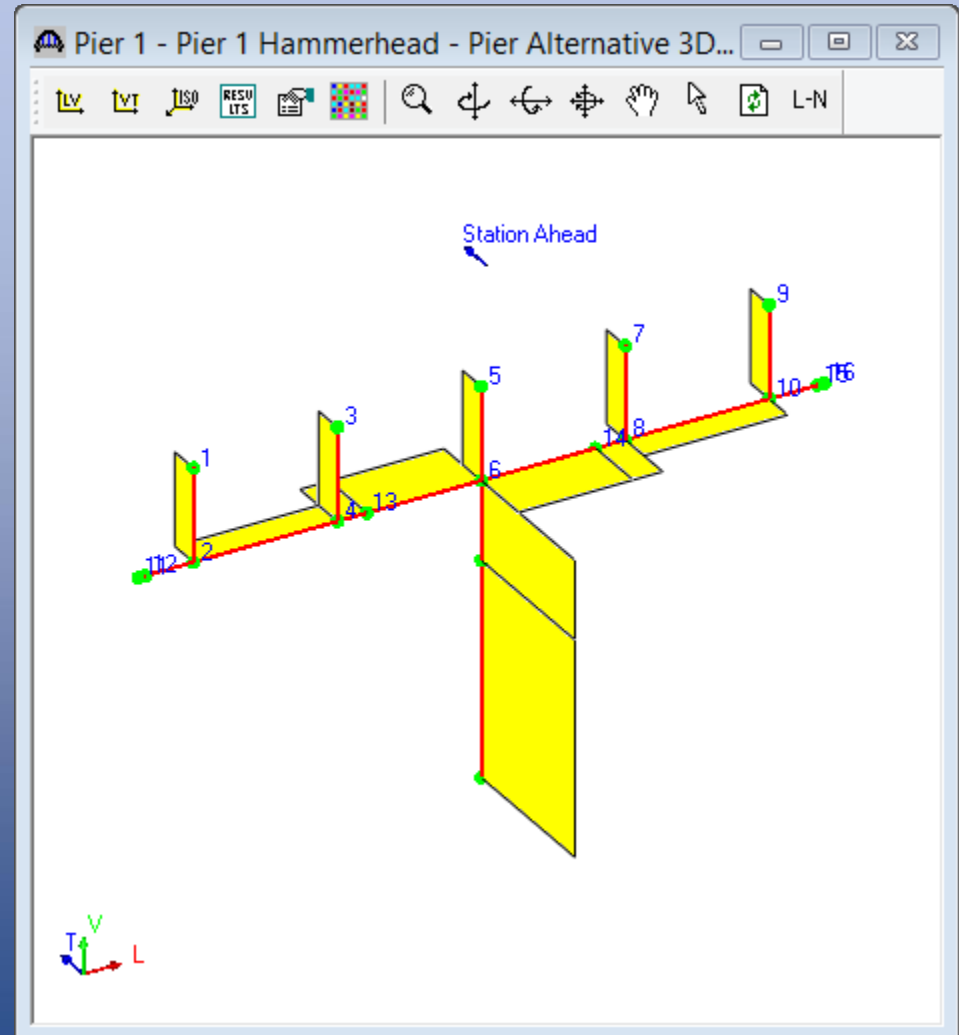
Simplified  Advanced

Set	Measure From Cap	Vertical Distance (in)	Bar Size	Number	Material	Start Distance (ft)	Straight Length (ft)	End Distance (ft)	Hook at Start	Hook at End	Developed at Start	Developed at End
1	Top	3.830	11	10.000	Grade 60	0.500	45.500	46.000	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2	Top	8.240	11	10.000	Grade 60	0.500	45.500	46.000	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3	Bottom	3.625	8	5.000	Grade 60	0.500	45.500	46.000	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

New Duplicate Delete

# Pier Schematic

- Dimensions
- Zoom
- Rotate
- View FE model
- View FE results



# Pier Loads

- Computed for you or enter your own

Superstructure Environmental Loads - Pier 1 - Pier 1 Hammerhead

Back Span Span No.: 1 Ahead Span Span No.: 2 Pier skew: 0.00 Degrees

Superstructure Definition: Superstructure 1 Superstructure Definition: Superstructure 1

Wind Load Basis  Gust speed  Fastest-mile speed

WS-Super WS-Over WL TU SH

Input

AASHTO LRFD Spec Article 3.8.1.2.2 Loads from Superstructure

Transverse load distribution option: Fixed & Expansion Bearings Friction velocity, V0: 12.00 mph

Transverse superstructure length: 120.000 ft Friction length, Z0: 8.20 ft

Superstructure design elevation: 34.594 ft Base design wind velocity, VB: 100.00 mph

Design height, Z: 29.094 ft V30: 100.00 mph

Override design height, Z: ft

Loads for Wind from Left to Right

Display  Computed  Override  Use override values

Wind Skew Angle (deg)	Superstructure Longitudinal Force (kip)			
	G1	G2	G3	G4
0	12.188	12.188	12.188	12.188
15	10.725	10.725	10.725	10.725

Wind Skew Angle (deg)	Superstructure Transverse Force (kip)			
	G1	G2	G3	G4
0	-0.000	-0.000	-0.000	-0.000
15	-1.462	-1.462	-1.462	-1.462

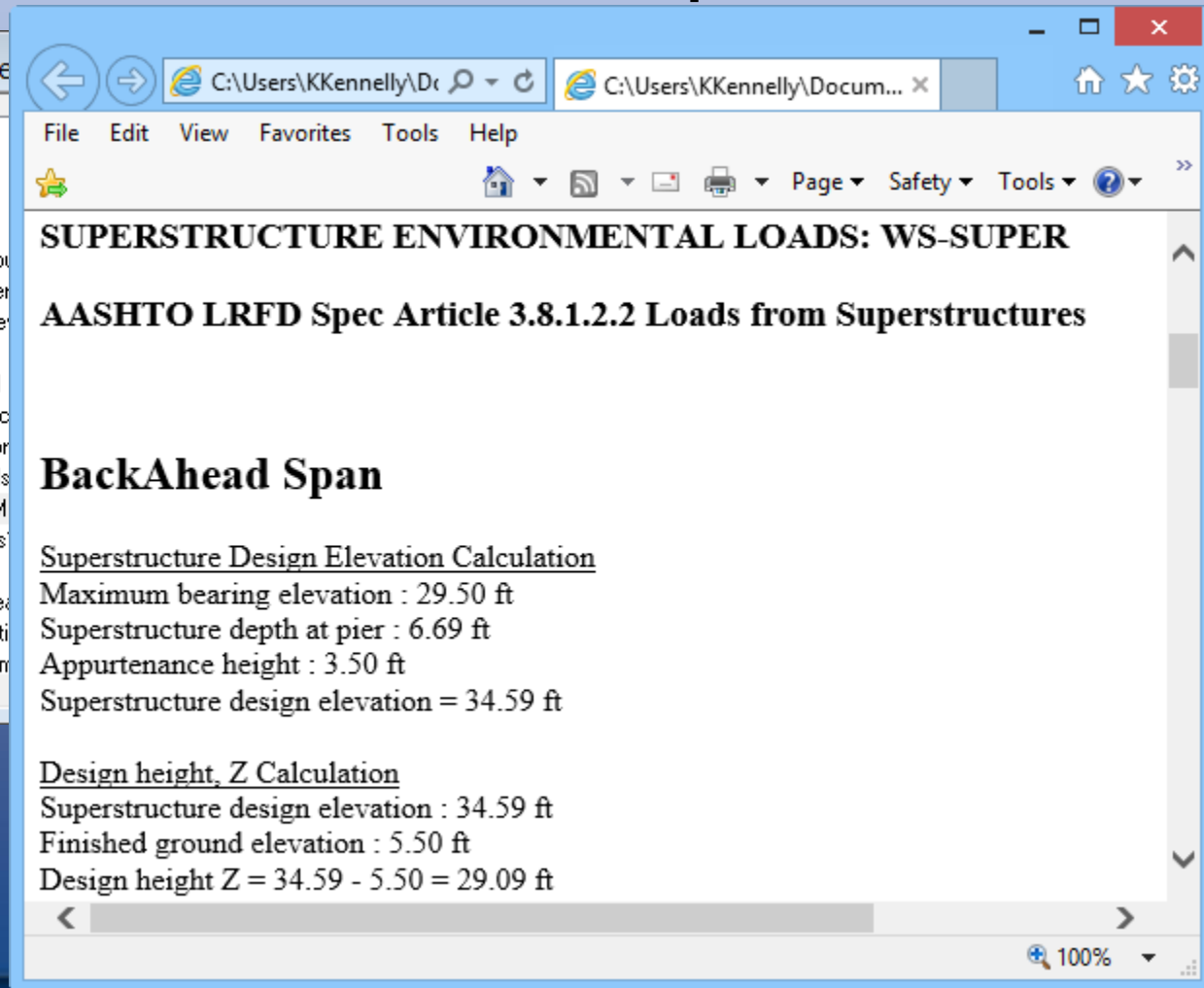
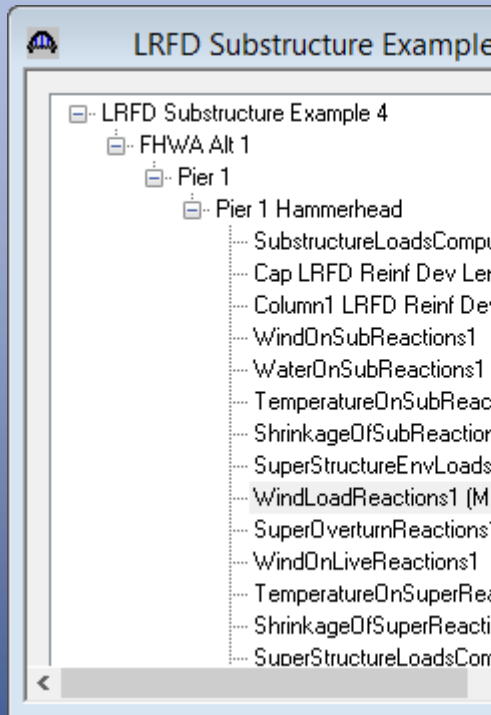
Wind Skew Angle (deg)	Vertical Reaction due to Transverse Force (kip)			
	G1	G2	G3	G4
0	6.367	3.184	0.000	0.000
15	5.603	2.802	0.000	0.000

Compute



# Pier Loads

- Reports are available for all computed loads



# User Control of Loads

- Load palette controls usage of load types

Load Palette

Use	Input Defined	Override	Use	Input Defined	Override
DC <input checked="" type="checkbox"/>	✓	<input checked="" type="checkbox"/>	EH Active <input type="checkbox"/>	NA	
DW <input checked="" type="checkbox"/>	✓	<input checked="" type="checkbox"/>	EH At-Rest <input type="checkbox"/>	NA	
LL <input checked="" type="checkbox"/>	✓	<input type="checkbox"/>			
PL <input checked="" type="checkbox"/>	✗	<input type="checkbox"/>			
BR <input checked="" type="checkbox"/>	✓	<input type="checkbox"/>	TU <input checked="" type="checkbox"/>	✗	<input type="checkbox"/>
CT <input type="checkbox"/>	NA		TG <input type="checkbox"/>	NA	
WA <input checked="" type="checkbox"/>	✓	<input type="checkbox"/>	SH <input checked="" type="checkbox"/>	✗	<input type="checkbox"/>
WS <input checked="" type="checkbox"/>	✓	<input type="checkbox"/>	CR <input checked="" type="checkbox"/>	NA	
WL <input checked="" type="checkbox"/>	✓	<input type="checkbox"/>	SE <input type="checkbox"/>	NA	
			FR <input checked="" type="checkbox"/>	✗	<input type="checkbox"/>
			CV <input type="checkbox"/>	NA	

Select All   Clear All   Open Template   Save Template   OK   Cancel

# User Control of Loads

- Load combinations can be controlled

Load Combination Settings - Pier 1 Hammerhead

LRFD Substructure Design Settings: Final Design Setting (US)      LRFD Factors: 2014 (2016 interim) AASHTO LRFD 9

Chosen limit states:

- STRENGTH-I
- STRENGTH-II
- STRENGTH-III
- STRENGTH-IV
- STRENGTH-V
- SERVICE-I
- SERVICE-II
- SERVICE-III
- SERVICE-IV
- FATIGUE-I
- FATIGUE-II
- EXTREME EVENT-I
- EXTREME EVENT-II

Settings

Water Levels

- Low
- Mean
- Design flood
- Check flood

Wind Direction

- Left to right
- Right to left

Wind Angles

- 0 Degrees
- 15 Degrees
- 30 Degrees
- 45 Degrees
- 60 Degrees

Temperature Change

- Rise
- Fall

Consider simplified wind loading

Additional Combinations

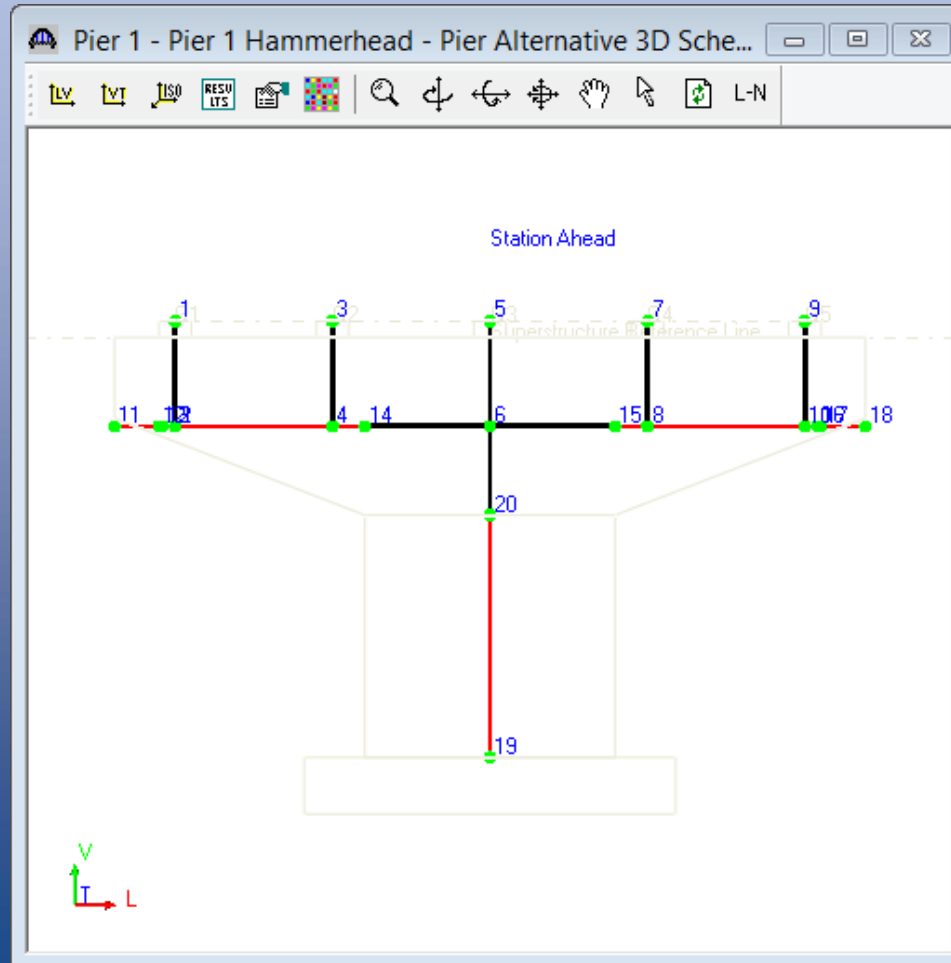
- Check overall stability
- Check for deformations

Open Template...      Save Template...

OK      Apply      Cancel

# Finite Element Model

- Generate and view the FE model before analysis



# Finite Element Analysis

- First order elastic analysis
- First order elastic analysis with moment magnification
- Non-linear analysis – only piers with drilled shafts
- Load combination generation
- Force envelope generation

# Tabular Results

Report

New Open Save

Model Loads Reactions Displacements F

Include in report

Display

FX  FY  FZ

MX  MY  MZ

File Edit View Favorites Tools Help

Find: limit stte Previous Next Options No matches found

## Limit State Nodal Reactions

**Limit State: STRENGTH-I**

**Load Combination ID: 1**  
**Load Combination Equation: LC 1 = 1.000 ( 1.25DC(1) + 1.50DW(2) + 1.25DC(3) + 1.75LL(4) + 1.75BR(404) + 1.20TU(414) )**  
**Load Combination: DLmax,LL1 T DV:1,BR 1 Lane(Back),TU Sub - Fall**

Node	X Force (kip)	Y Force (kip)	Z Force (kip)	X Moment (kip-ft)	Y Moment (kip-ft)	Z Moment (kip-ft)
19	37.800	2943.241	-0.001	6890.057	0.000	-1020.600

**Load Combination ID: 2**  
**Load Combination Equation: LC 2 = 1.000 ( 1.25DC(1) + 1.50DW(2) + 1.25DC(3) + 1.75LL(4) + 1.75BR(404) + 1.20TU(415) )**  
**Load Combination: DLmax,LL1 T DV:1,BR 1 Lane(Back),TU Sub - Rise**

Node	X Force (kip)	Y Force (kip)	Z Force (kip)	X Moment (kip-ft)	Y Moment (kip-ft)	Z Moment (kip-ft)
19	37.800	2943.241	-0.001	6890.057	0.000	-1020.600

100%

# Graphical Results

×
View Results

**Display**

Limit State Envelope

Load Case

Load Combination

**Action**

Axial

Compression ■

Tension ■

Shear yy ■

Shear zz ■

Bending yy ■

Bending zz ■

Torsion ■

Deflection

Auto Apply

Name

Superstructure DC

Superstructure DW

Substructure Self V

LL1 T DV:1

LL2 T DV:2

LL3 T DV:3

LL4 T DV:4

LL5 T DV:5

LL6 T DV:6

LL7 T DV:7

LL8 T DV:8

LL9 T DV:9

LL10 T DV:10

LL11 T DV:11

LL12 T DV:12

LL13 T DV:13

LL14 T DV:14

Auto Apply

×
Pier 1 - Pier 1 Hammerhead - Pier Alternative 3D Sche...

LV VT ISO RESU LTS L-N

# Specification Checks

Specification Checks for Pier 1 Hammerhead - 11 of 239

- Pier Component
  - Cap
    - 0.00 ft.
    - 0.50 ft.
    - 3.75 ft.
    - 5.34 ft.
    - 13.50 ft.
    - 15.50 ft.
    - 23.25 ft.
    - 31.
    - 33.
    - 41.
    - 42.
    - 46.
    - 46.
    - Column
    - 0.0
    - 15.
    - Column
    - Pile
    - Footing Longitudinal Moment Sect
    - Footing Transverse Moment Sectic
    - Footing Longitudinal Shear Sectio
    - Footing Transverse Shear Section
    - Column Punching Shear Section
    - Pile Punching Shear Section

Specification Reference	Limit State	Flex. Sense
5.8.3.4 Procedures for Determining Shear Resistan...		N/A
✓ 5.8.3.3 Nominal Shear Resistance		N/A
✓ 5.8.2.7 Maximum Spacing of Transverse Reinforce...		N/A
✓ 5.8.2.5 Minimum Transverse Reinforcement		N/A
✓ 5.8.2.1 Torsion		N/A
✓ 5.7.4.5 Biaxial Flexure		N/A
✓ 5.7.4.2 Limits for Reinforcement		N/A

Spec Check Detail for 5.7.4.5 Biaxial Flexure

Analysis of the full cross section (Does not meet minimum reinforcement requirements of Article 5.7.4.2 Limits for Reinforcement).

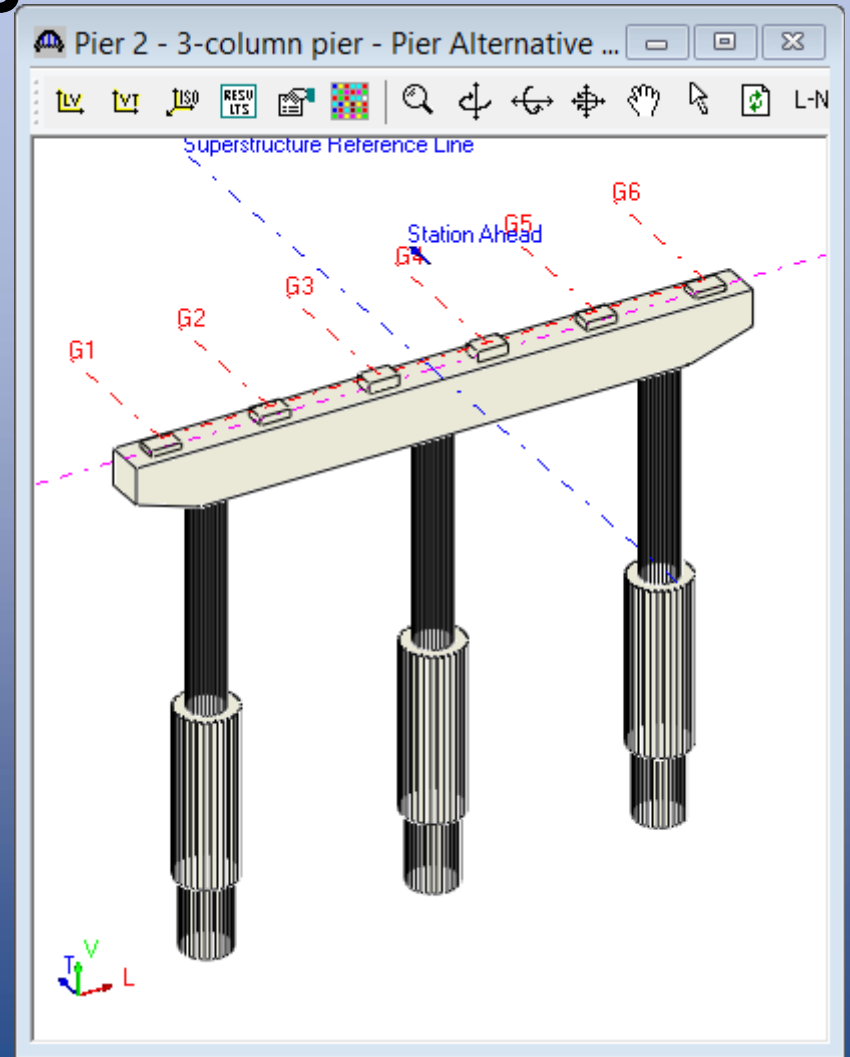
Limit State	Load Combination	Pu kip	Mux kip-ft	Muy kip-ft	Mur kip-ft	Alpha Deg	Phi	Phi * Pn kip	Phi * Mnr kip-ft	Mnr/Mur
STR-I	209	3569.89	-2168.77	-5091.43	5534.10	246.93	0.90	3570.03	34758.31	6.28
STR-I	177	3569.89	-2168.77	4398.56	4904.17	116.25	0.90	3570.05	32303.47	6.59
STR-I	177	3569.89	-2168.77	4398.56	4904.17	116.25	0.90	3570.05	32303.47	6.59
STR-I	177	3569.89	-2168.77	4398.56	4904.17	116.25	0.90	3570.05	32303.47	6.59
STR-I	385	2226.82	-1020.60	-8166.06	8229.59	262.88	0.90	2227.04	44965.61	5.46
STR-I	153	3019.66	-1020.60	-8166.06	8229.59	262.88	0.90	3019.37	48232.51	5.86
STR-I	345	2226.82	-1020.60	8166.06	8229.59	97.12	0.90	2226.81	44963.70	5.46

OK



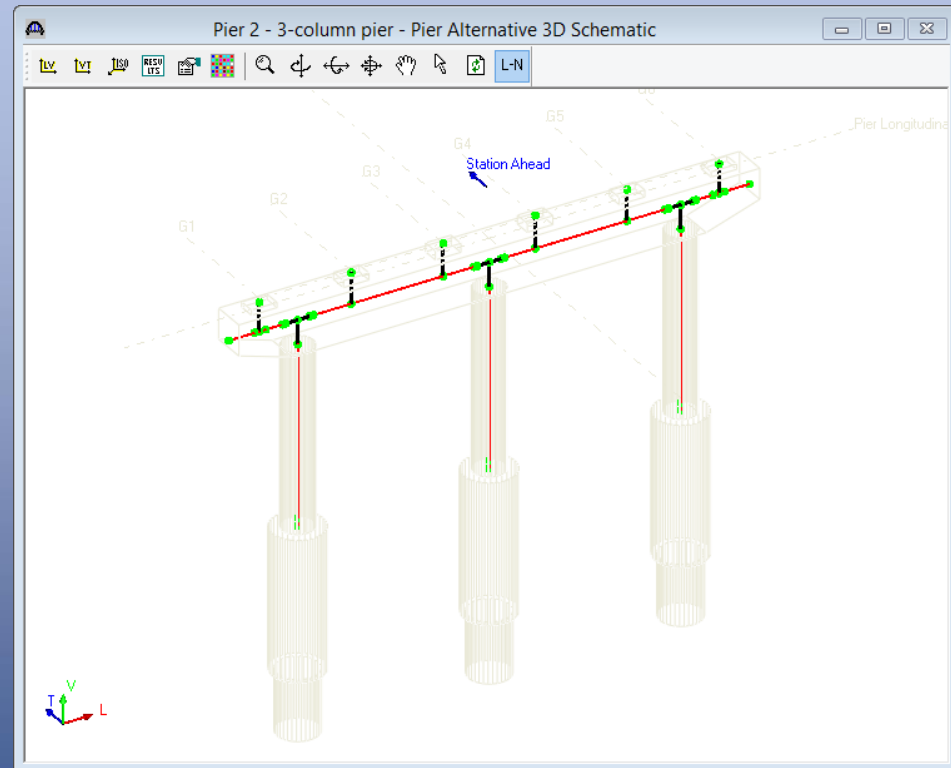
# Drilled Shaft Analysis

- Only for piers with drilled shafts



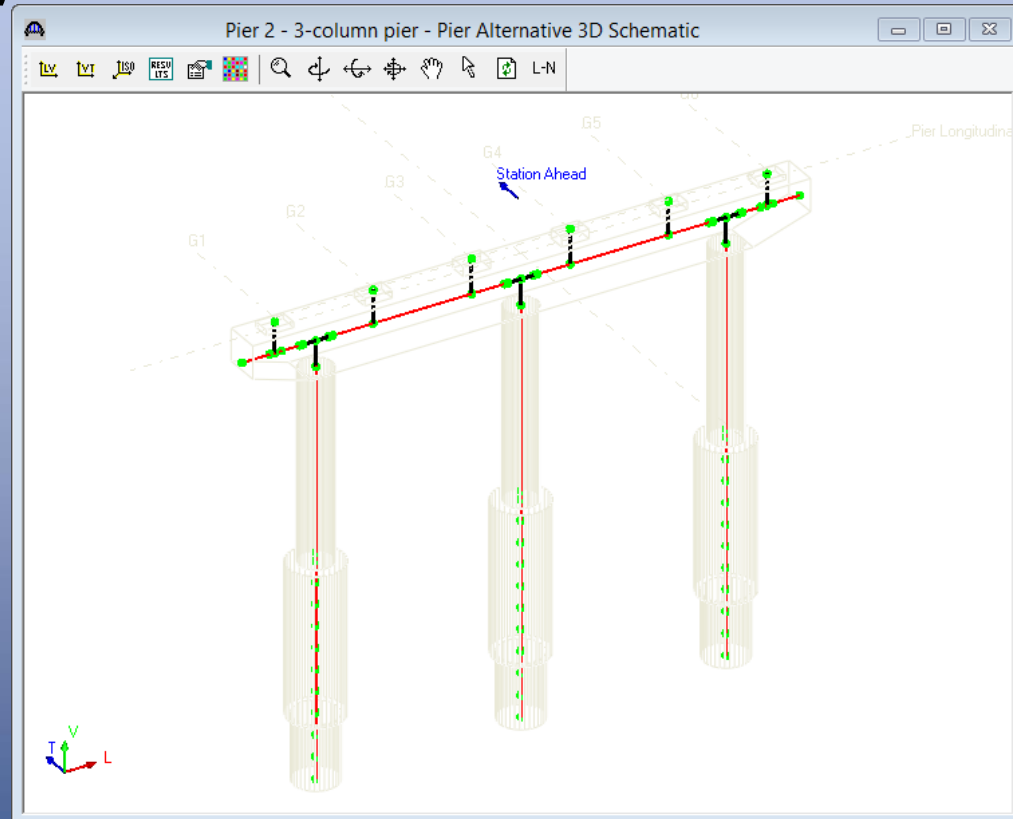
# Drilled Shaft Analysis

- Linear analysis
- FE model stops at the base of the columns
- Unfactored load cases applied to the pier
- Superposition and load factors used to combine into factored loads to find critical load combinations



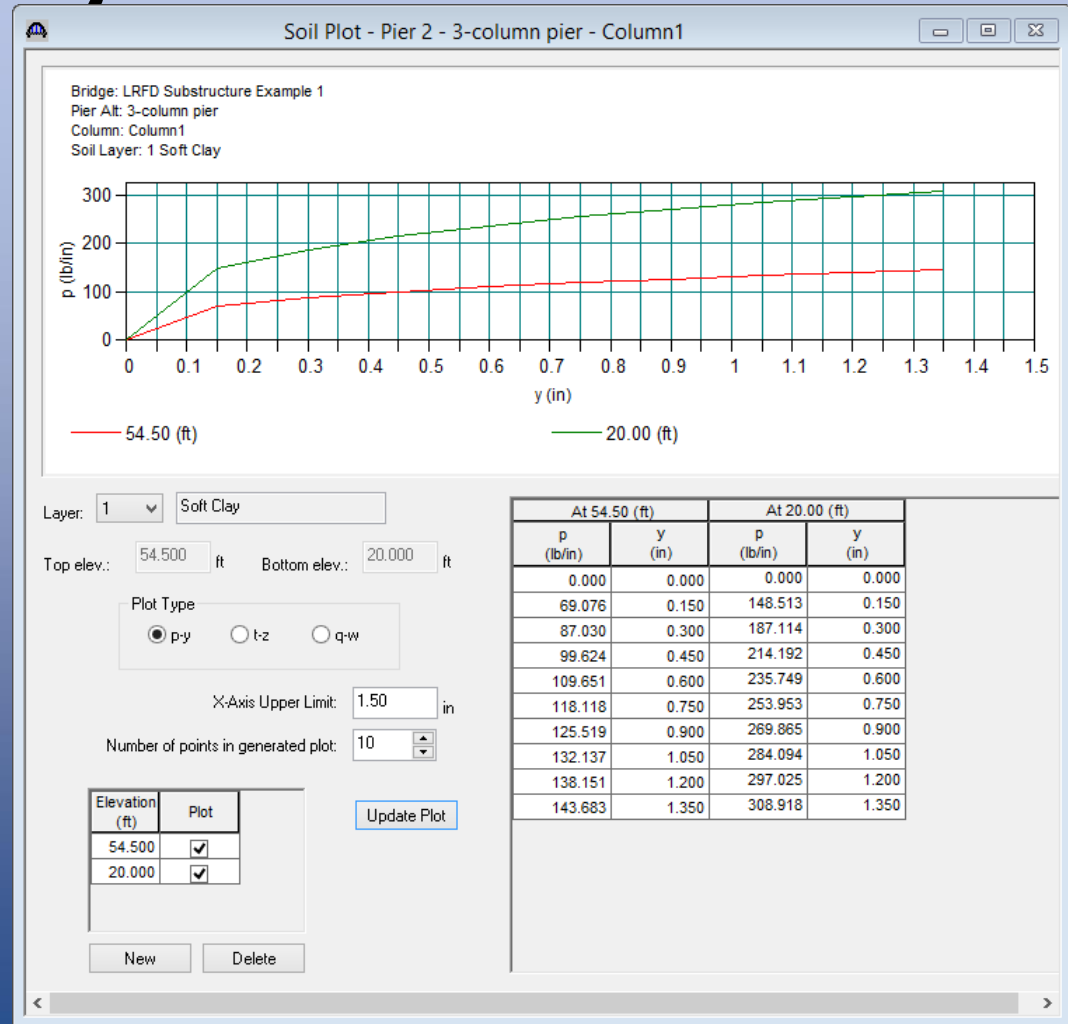
# Drilled Shaft Analysis

- Factored and combined loads applied to the pier as load cases
- Soil layers are described
- FE model includes the drilled shaft and rock sockets
- Non-linear analysis of this model



# Drilled Shaft Analysis

- Graphic results of p-y curves



# Superstructure Integral with Pier

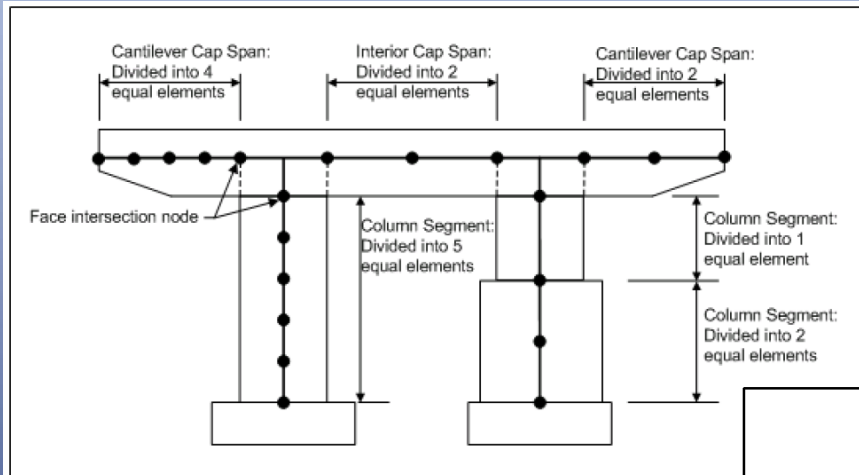
- Only available for RC Slab System and Concrete MCB
- Pier stiffness is included in the FE model for the superstructure
- Pier itself is not analyzed or spec-checked

## Slab Structure Type

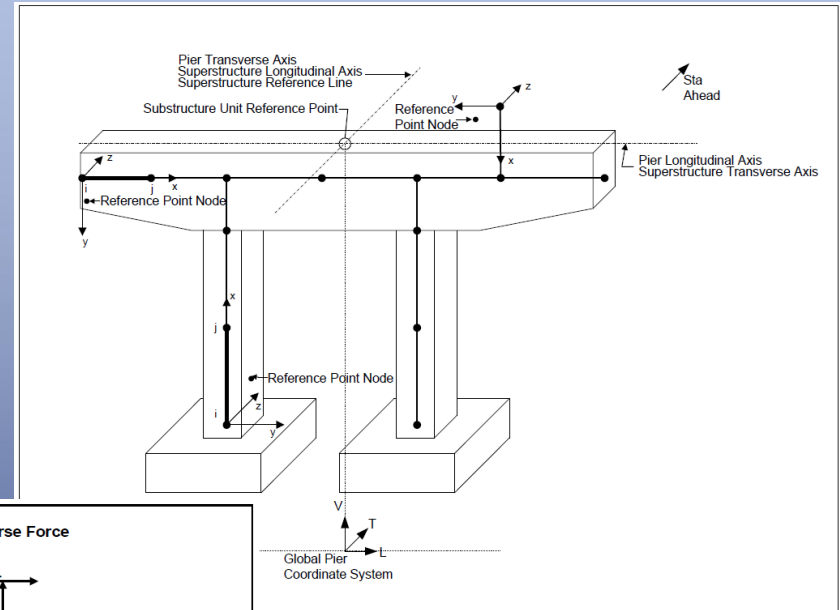
- Frame structure simplified definition
- Slab integral with pier
  - Consider pier skew in FE section properties
- Slab not integral with pier

# Help

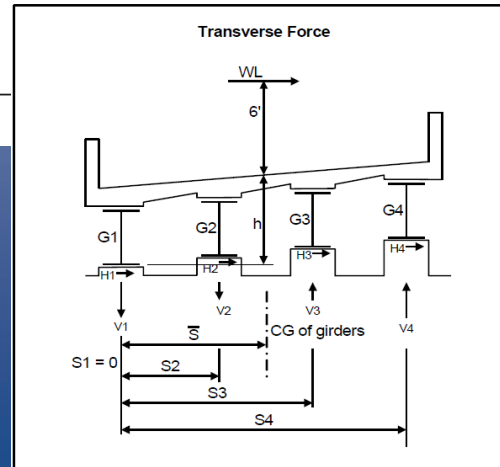
- AASHTO LRFD Substructure Method of Solution Manual



User-defined cap and column elements



Relationship between global and local coordinate systems



# Thank You

