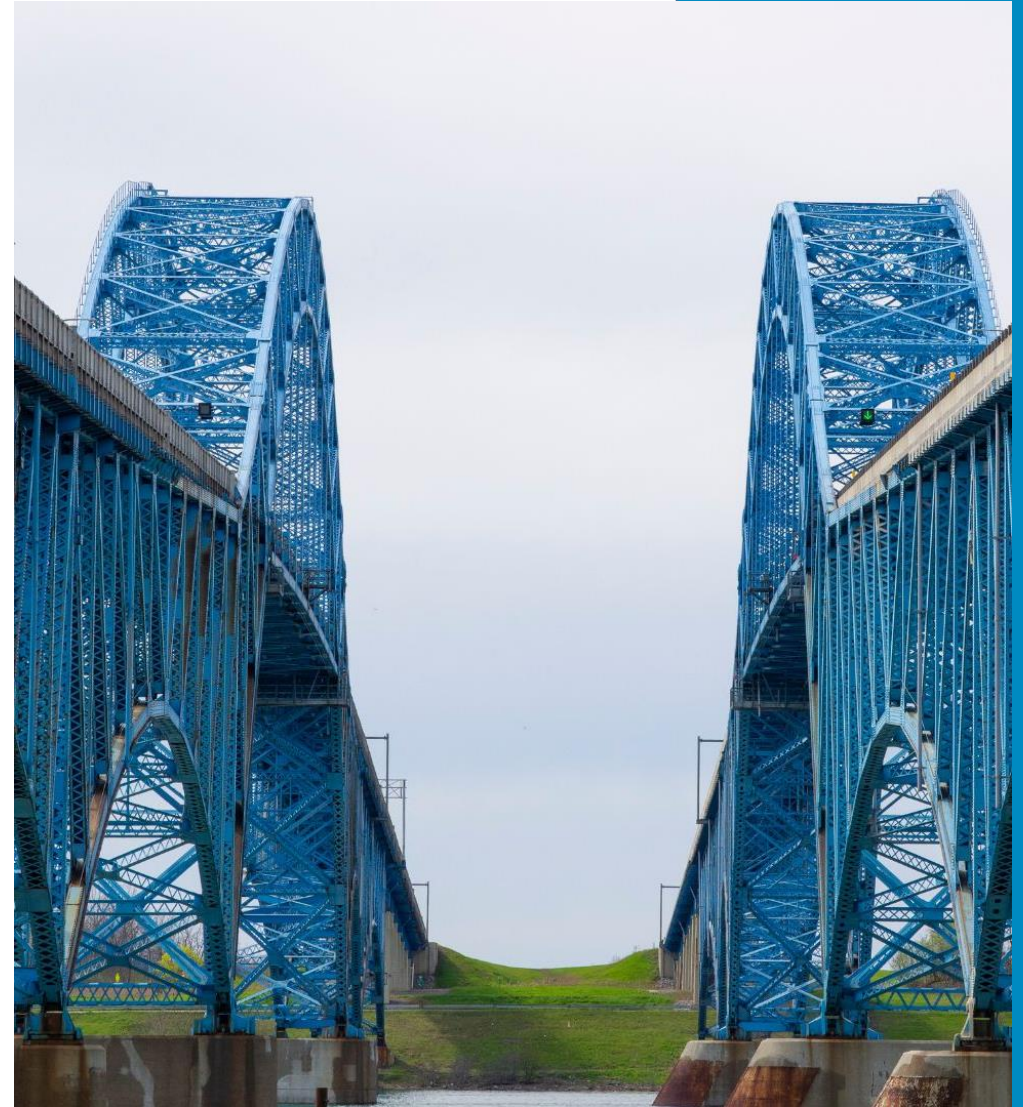


BrD Substructure Capabilities & What's Coming in BrDR 7.7

Herman Lee, P.E.

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RADBUG 2024 | August 6-7 | Buffalo, NY



BrD Substructure Capabilities

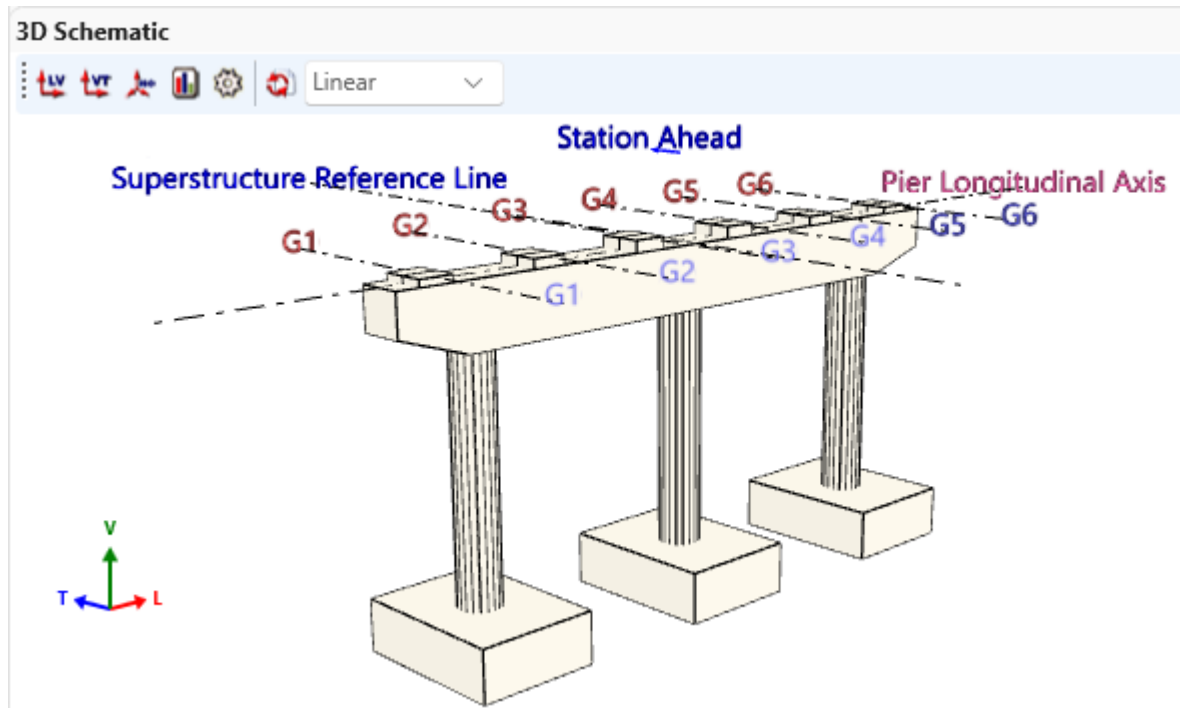
- Describe/spec check 4 types of piers
- LRFD Specifications
 - 4th Edition, 2008 interims through 9th Edition
- Integrated with BrD Superstructure or stand-alone pier
- Load transfer from BrD Superstructure
- Computed loads or user defined loads
- User control of loads and FE model

BrD Substructure Capabilities

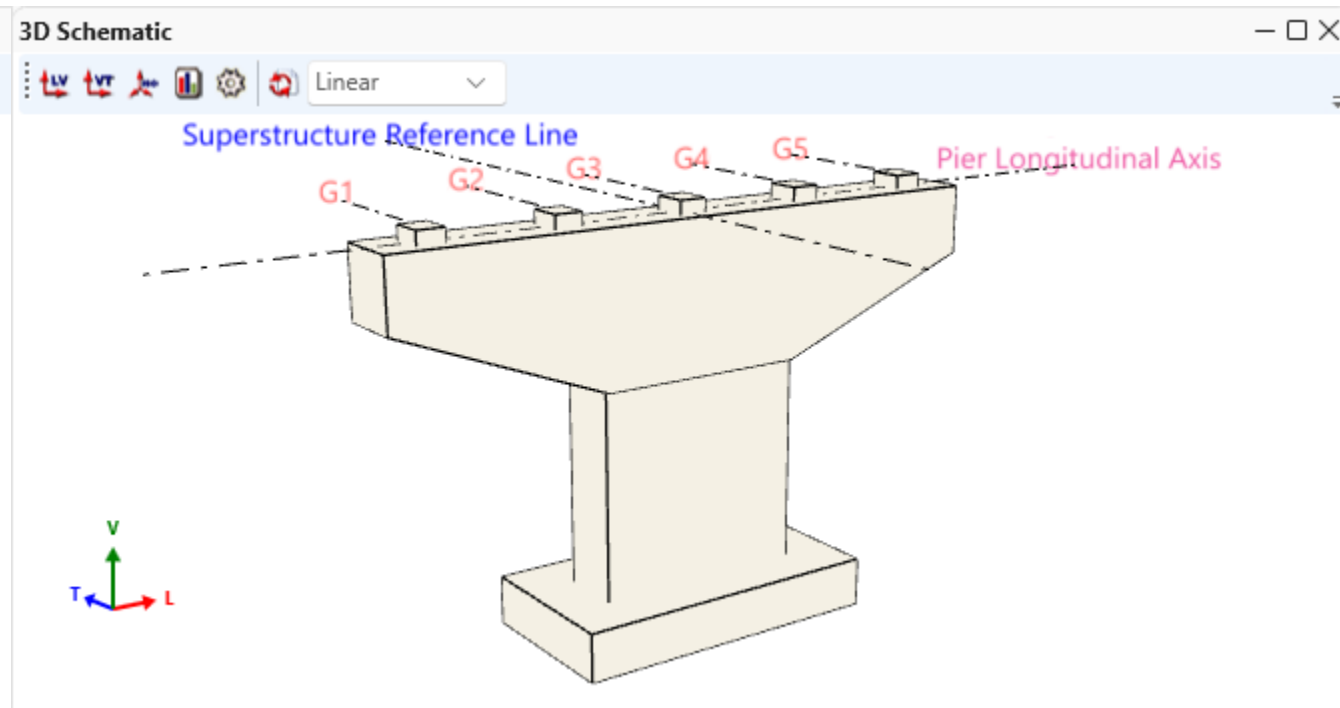
- Schedule-based reinforcement with development length calculations
- Pier – Linear finite element analysis, moment magnification
- Drilled Shaft – Nonlinear finite element analysis
- Load combination generation
- Tabular and graphical FE results

Four Types of Piers

Frame

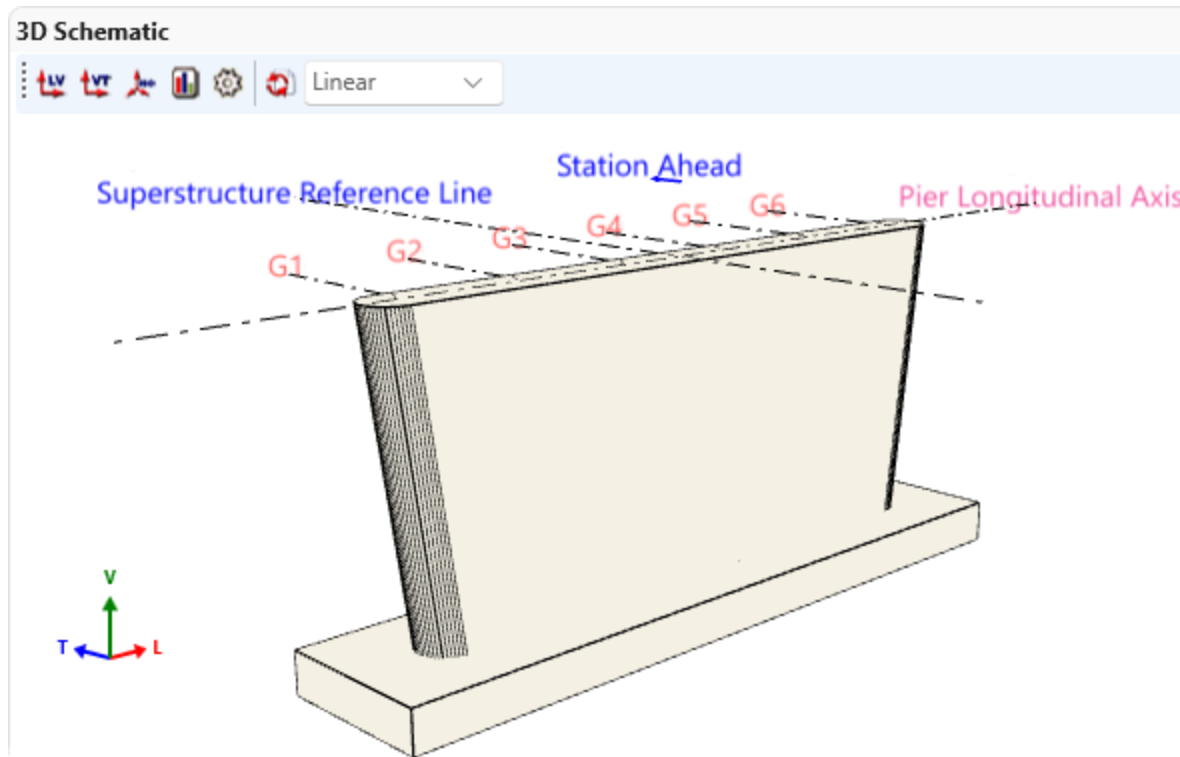


Solid Shaft

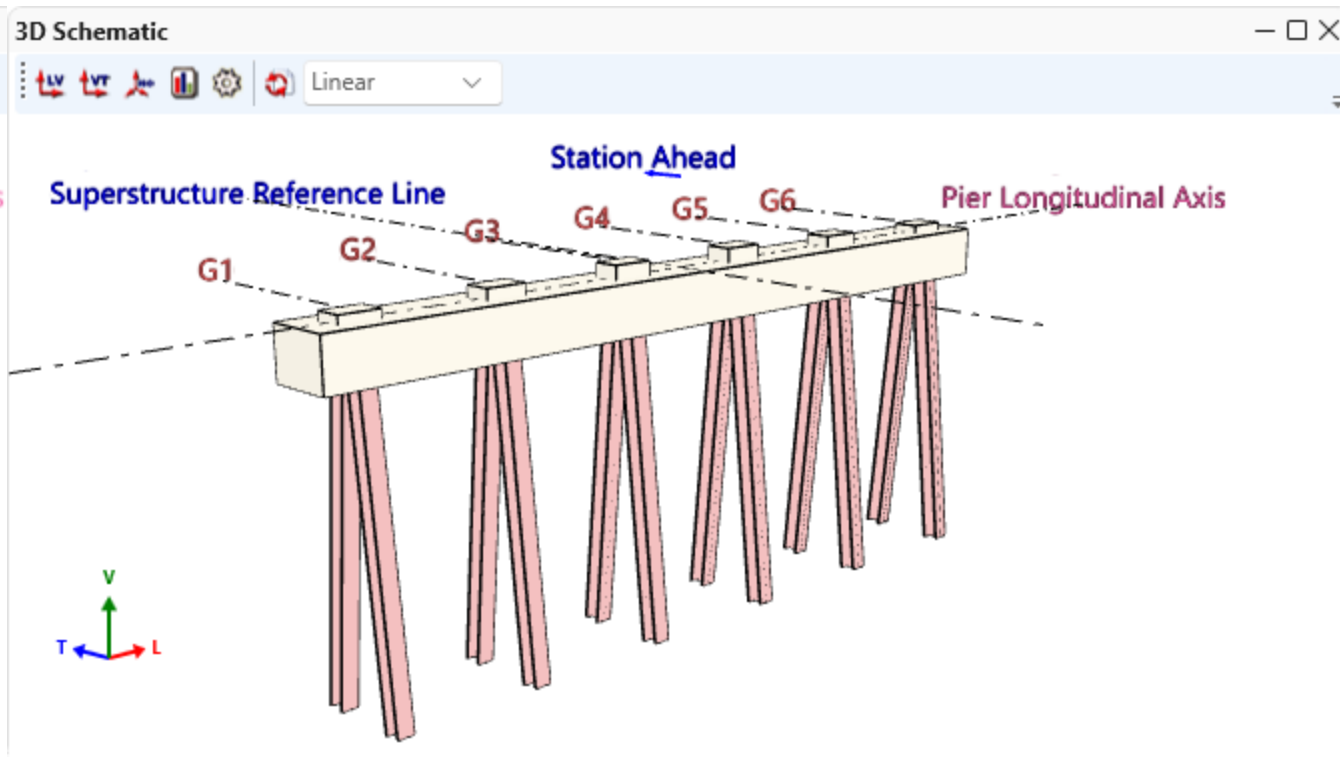


Four Types of Piers

Wall

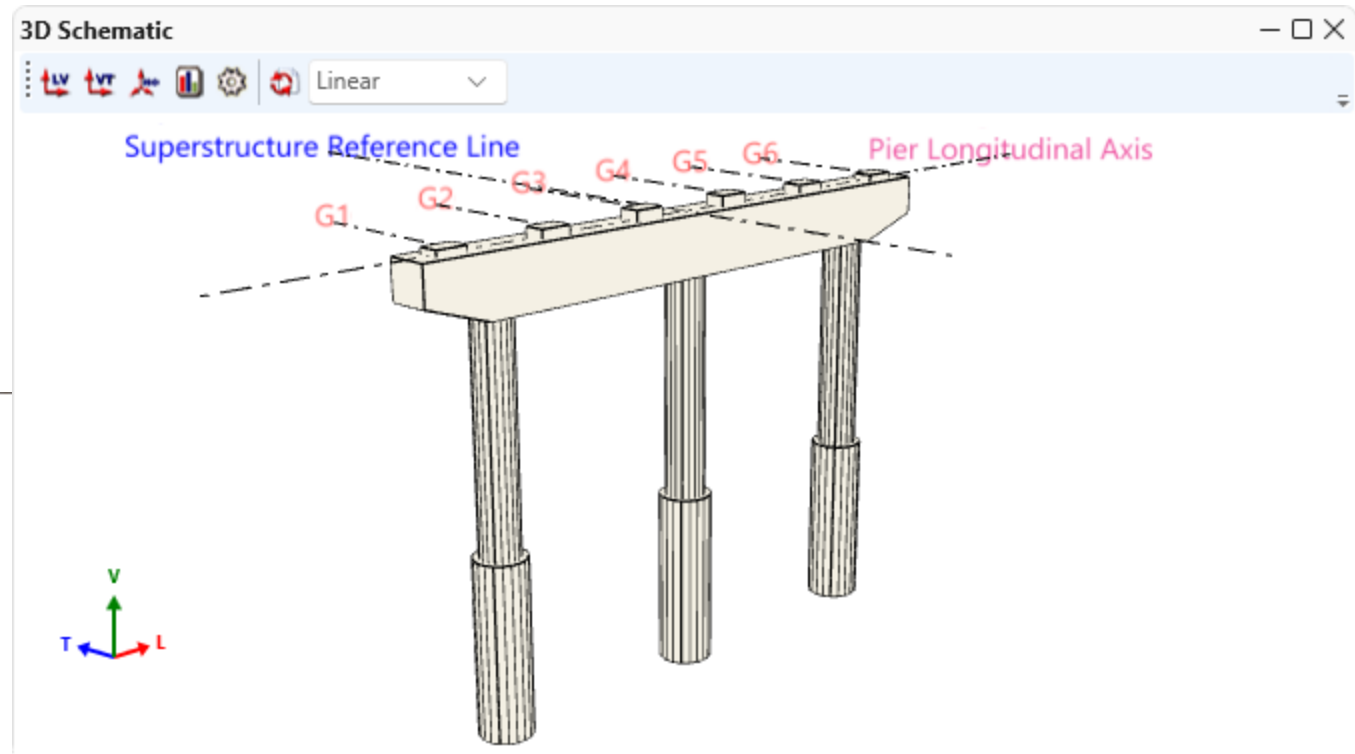
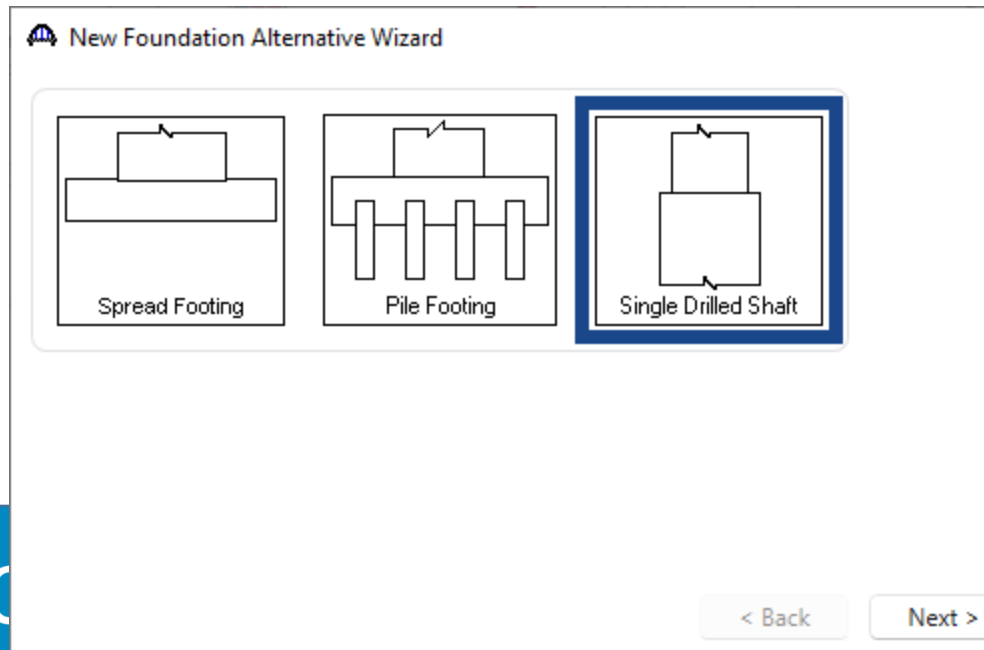


Pile Bent



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

Pier Alternative - NORTH PIER WALL

Name: NORTH PIER WALL Type: RC Wall Pier

Description Stiffness Reports **Bearing location**

Double bearing line

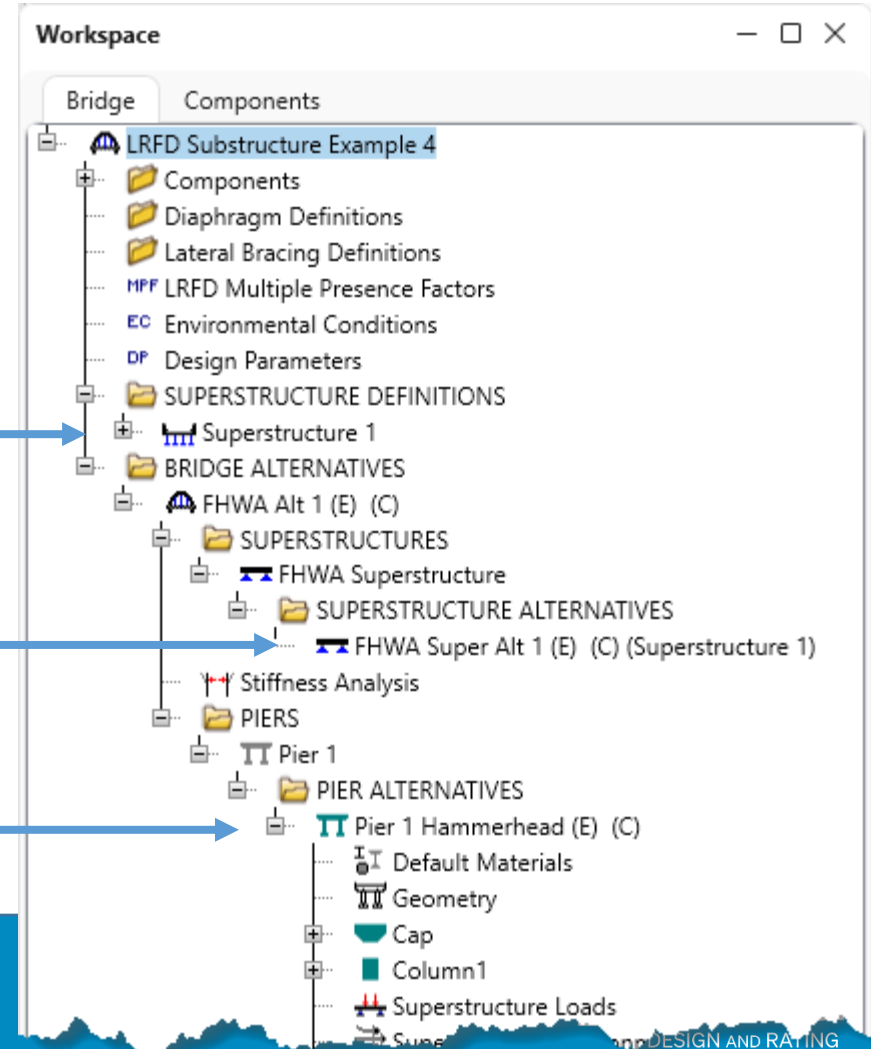
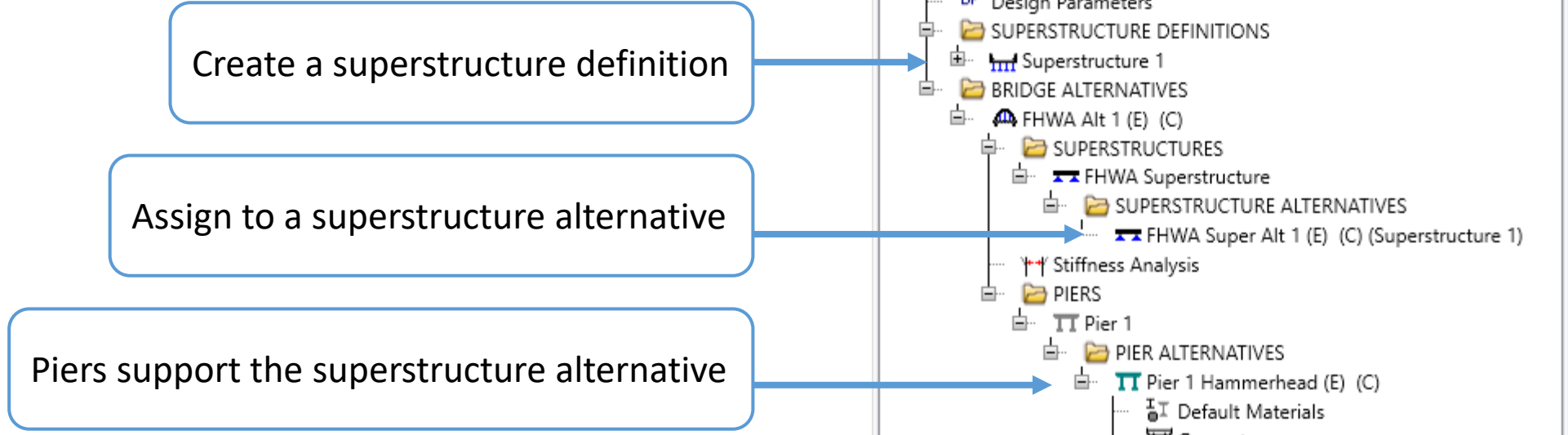
Number of girders: 7

Distance from CL pier to CL bearing line: 0.000 ft

	Girder	Distance from left end (ft)
>	G1	2.616
	G2	13.105
	G3	23.594
	G4	34.083
	G5	44.572
	G6	55.062
	G7	65.551

Integration with BrD Superstructure

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



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

Superstructure Loads-Pier 1-Pier 1 Hammerhead

Back span
Span no.: 1
Superstructure definition: Superstructure 1

Ahead span
Span no.: 2
Superstructure definition: Superstructure 1

DL FR **LL settings** 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 vehicle right to left across travelway:

Load pattern description

Load pattern	Description
--------------	-------------

Live load positions
Load pattern:
Number of vehicles: 0
Distance from edge:
SIGN ANGLE

Live Load Generation

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

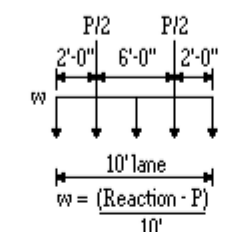
Superstructure Loads-Pier 1-Pier 1 Hammerhead

Back span
Span no.: 1
Superstructure definition: Superstructure 1

Ahead span
Span no.: 2
Superstructure definition: Superstructure 1

DL FR LL settings LL-reaction **LL-distribution** BR

Distribution method
 Tributary area
 Lever rule
 Rigid deck action



Loads

Display
 Computed Override Use override values

Without dynamic load allowance

Vehicle	Vehicle type	Single lane reaction (kip)	Axle load P (kip)	Uniform load w (kip/ft)
> HL-93 (US)	Truck + Lane	0.000	32.000	13.497
HL-93 (US)	Tandem + Lane	0.000	25.000	12.069

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

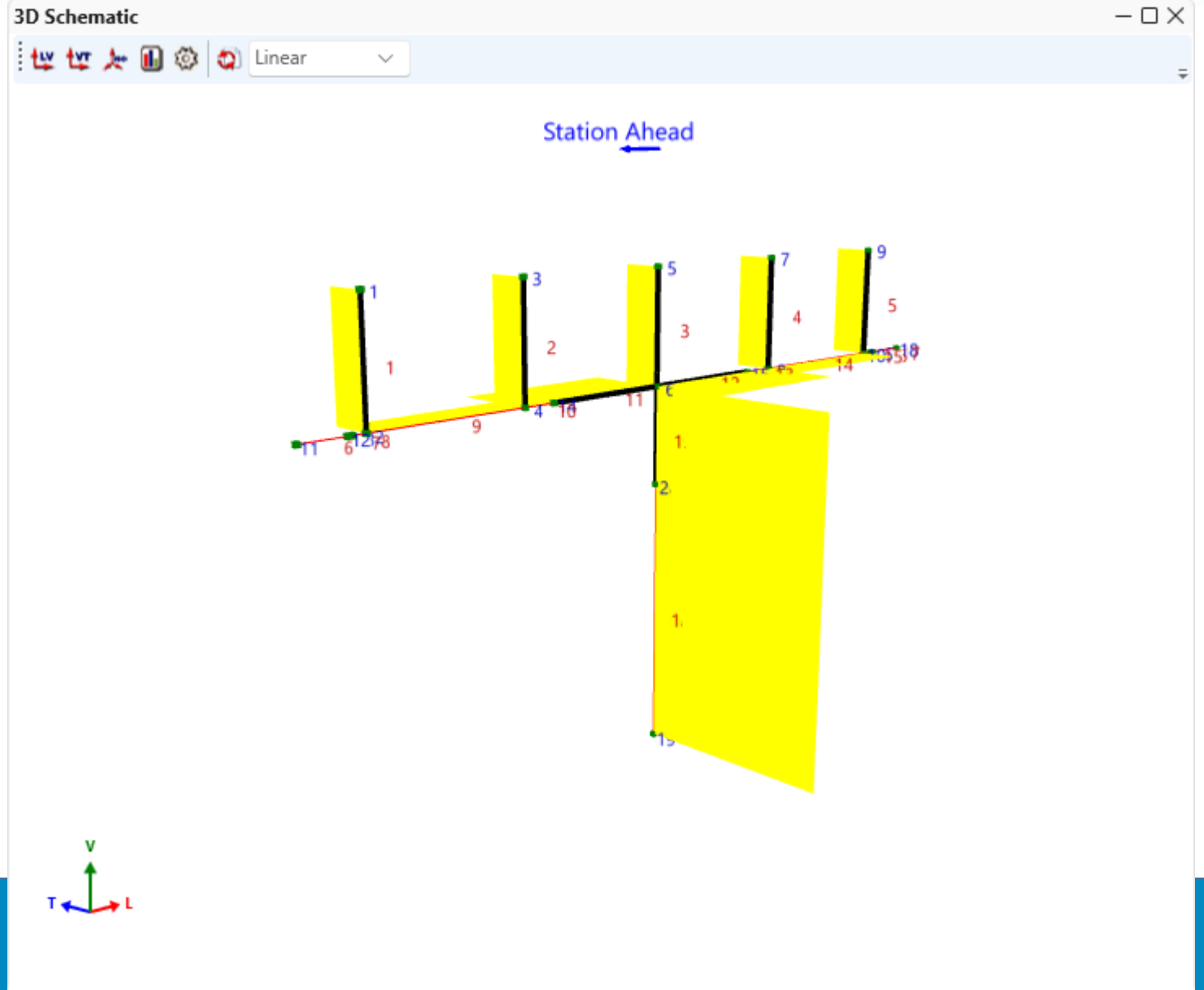
Primary flexural

Reinforcement input method: Simplified Advanced Reinforcement follows cap profile

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"/>

Pier Schematic

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



Pier Loads

- Computed for you or enter your own

Superstructure environmental load generation progress

Info: Getting computation event...
Info: Using created model domain...
Computing forces for Wind on Superstructure...
Computing forces due to wind acting on the superstructure...
Info: Wind on superstructure forces computed successfully!
Info: Getting computation event...
Info: Using created model domain...
Generating model loads for Wind on Superstructure...
Computing forces due to overturning wind acting on superstructure...
Info: Overturning wind on superstructure forces computed successfully!
Info: Getting computation event...
Info: Using created model domain...
Computing forces for Wind on Live...
Computing forces due to wind acting on the live load...
Info: Wind on live forces computed successfully!
Info: Getting computation event...
Info: Using created model domain...
Generating model loads for Temperature on Superstructure...
Generation of model loads will use User-Defined forces due to tempera
Skipping computation of forces due to temperature effects on the supe
Temperature effects on the superstructure are user-defined

Superstructure Environmental Loads - Pier 1 - Pier 1 Hammerhead

Back span

Span no.:

1

Superstructure definition: Superstructure 1

Ahead span

Span no.:

2

Superstructure definition: Superstructure 1

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, VO: 12.00 mph

Transverse superstructure length: 120.000 ft

Friction length, ZO: 8.20 ft

Superstructure design elevation: 35.594 ft

Base design wind velocity, VB: 100.00 mph

Design height, Z: 30.094 ft

V30: 100.00 mph

Override design height, Z

Loads for wind from left to right

Display

Computed Override

Use override values

Override...

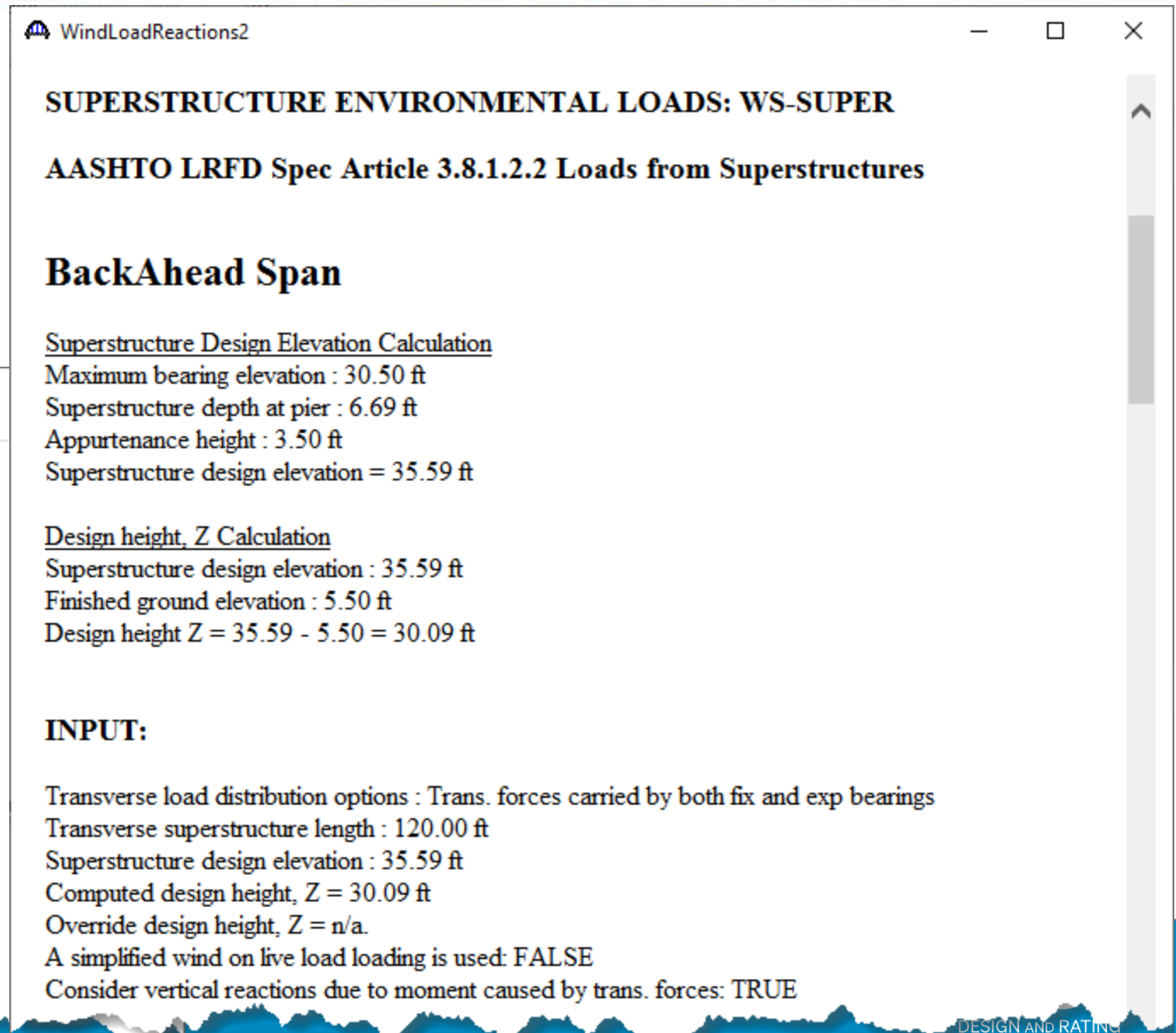
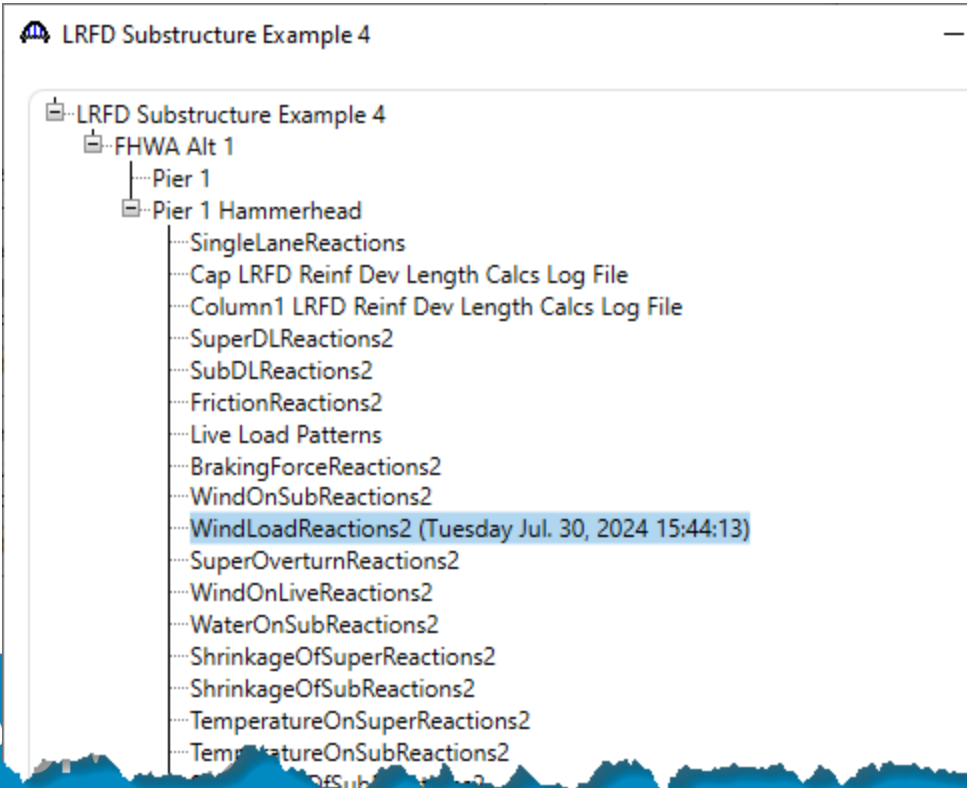
Calcs...

Superstructure longitudinal force (kip)

Wind skew angle (Degrees)	G1	G2	G3	G4	G5
> 0	12.188	12.188	12.188	12.188	12.188
15	10.725	10.725	10.725	10.725	10.725

Pier Loads

- Reports are available for all computed loads



User Control of Loads

- Load palette controls usage of load types

The screenshot shows a 'Load Palette' dialog box with two columns of load types. Each load type has three columns: 'Use', 'Input defined', and 'Override'. The 'Use' column contains a blue checkmark icon. The 'Input defined' column contains a checkmark, 'X', or 'NA'. The 'Override' column contains a blue checkmark icon or an empty checkbox.

Use	Input defined	Override	Use	Input defined	Override
DC	✓	✓	EH Active	NA	
DW	✓	✓	EH At-Rest	NA	
LL	✓				
PL	X				
BR	✓		TU	X	
CT	NA		TG	NA	
WA	✓		SH	X	
WS	✓		CR	NA	
WL	✓		SE	NA	
			FR	X	
			CV	NA	

Buttons at the bottom: 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: Preliminary Design Setting (US) LRFD factors: 2010 AASHTO LRFD Specifications

Chosen limit states

- STRENGTH-I
- STRENGTH-II
- STRENGTH-III
- STRENGTH-IV
- STRENGTH-V
- SERVICE-I
- SERVICE-II
- SERVICE-III
- SERVICE-IV

Settings

Water levels

- Low
- Mean
- Design flood
- Check flood

Temperature change

- Rise
- Fall

Wind direction

- Left to right
- Right to left

Wind angles

- 0 degrees
- 15 degrees
- 30 degrees
- 45 degrees
- 60 degrees

Additional combinations

- Check overall stability
- Check for deformations

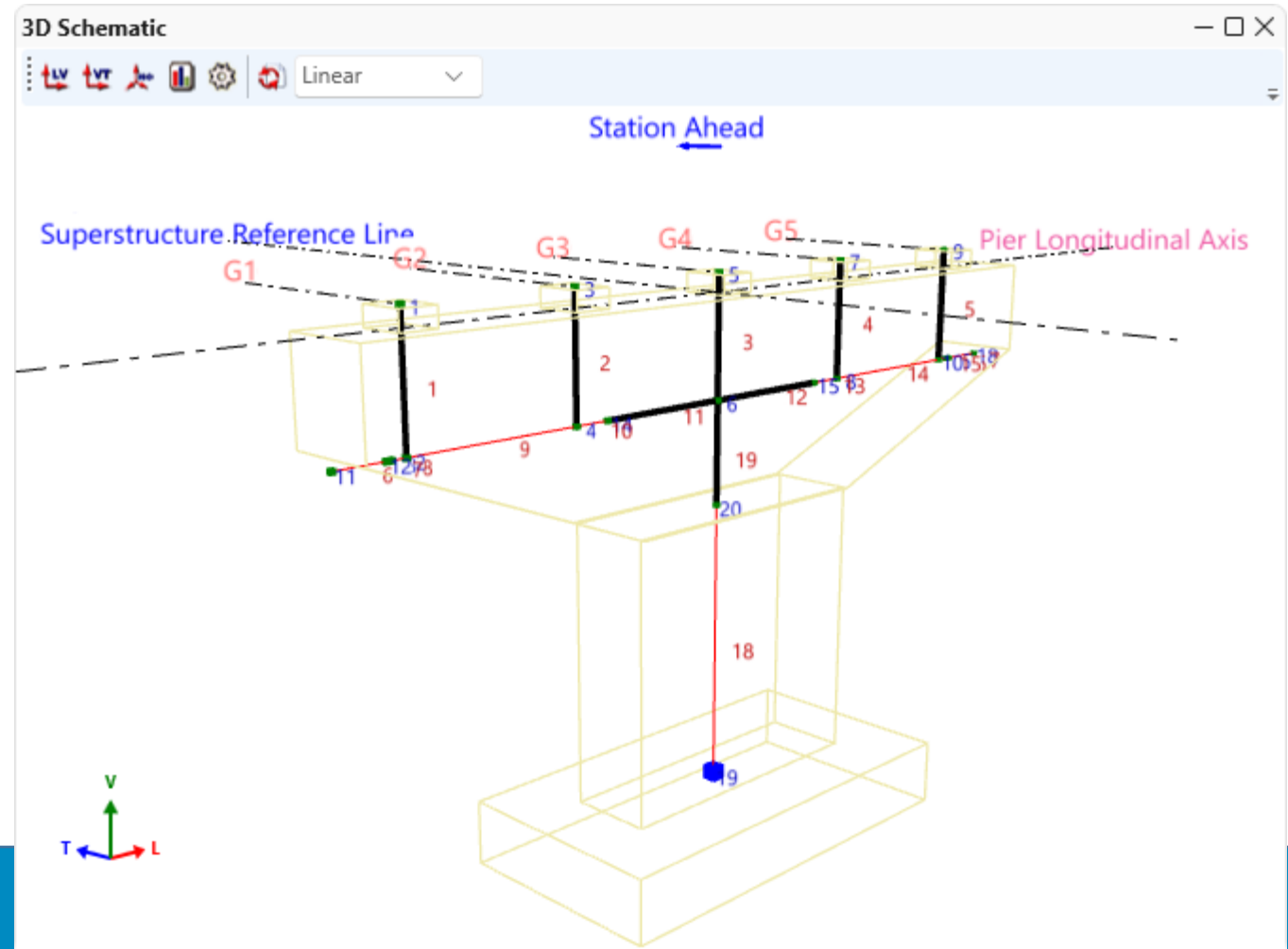
Consider simplified wind loading

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

Tabular Results - New Tabular Report

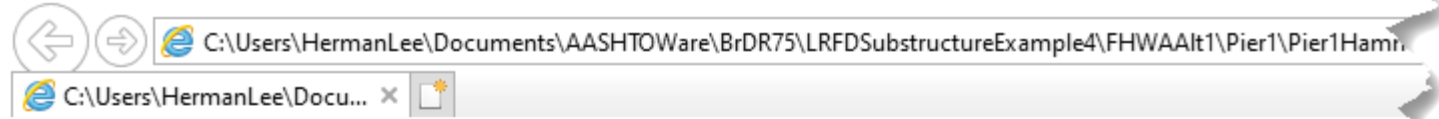
Report

New Open Save Save as

Model Loads Reactions Displacements Forces Envelope Spec check results

- Nodes
- Beams
- Section properties
- Materials
- Supports
- Member releases
- Load cases

Select all Clear all



Specification Check Summary

Article	Status
Cap Flexure (5.7.3.2, 5.7.3.3.2)	Fail
Cap Shear (5.8.2.5, 5.8.2.7, 5.8.3.3, 5.8.3.5)	Fail
Cap Serviceability (5.7.3.4 crack, 5.7.3.4 long skin, 5.10.8 shrink & temp)	Pass
Cap Fatigue (5.5.3.2)	Pass
Column1 Biaxial Moment Interaction (5.7.4.5)	Pass
Column1 Shear (5.8.2.5, 5.8.2.7, 5.8.3.3, 5.8.3.5)	Pass
Column1 Serviceability (5.10.8 shrink & temp)	Pass
Column1:Pile footing Pile Forces (5.13.3.2)	Pass
Column1:Pile footing Flexure (5.7.3.2, 5.7.3.3.2)	Pass
Column1:Pile footing Shear (5.8.3.3, 5.13.3.6.3, 5.8.3.5)	Pass
Column1:Pile footing Serviceability (5.7.3.4 Crack, 5.10.8 shrink & temp)	Pass
Column1:Pile footing Fatigue (5.5.3.2)	Pass

NR = Spec check not required at this location

Cap LRFD Analysis Spec Check Results

Graphical Results

View Results

Display

- Limited state envelope
- Load case
- Load combination

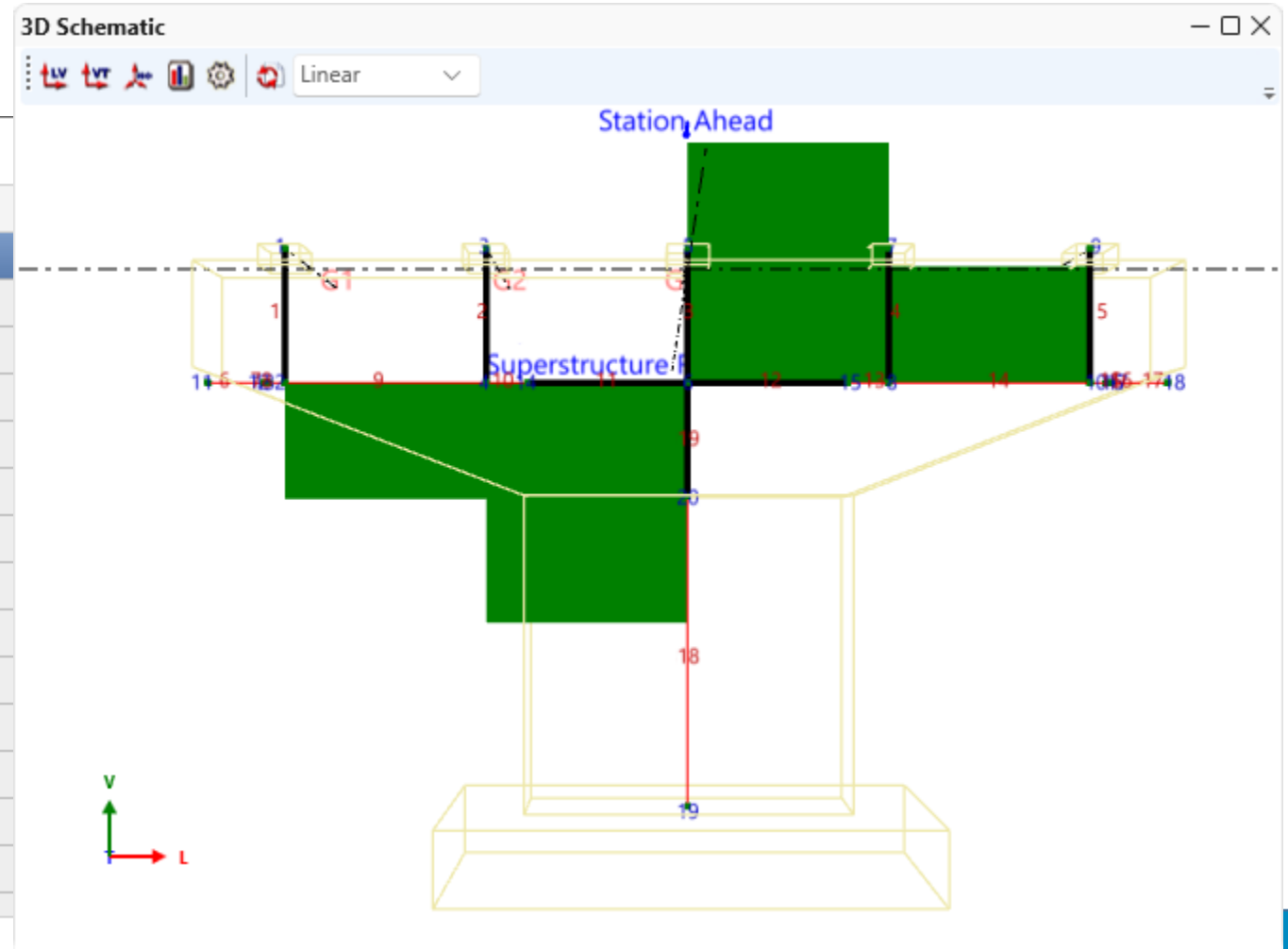
Action

- Axial
- Compression ■
- Tension ■
- Shear yy ■
- Shear zz ■
- Bending yy ■
- Bending zz ■
- Torsion ■
- Deflection

Name
> Superstructure DC
Superstructure DW
Substructure Self Weight - DC
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
LL14 T DV:14

Auto apply

OK Apply Cancel



Specification Checks

Specification Checks for Pier 1 Hammerhead - 11 of 273

Properties
Generate
Articles: All articles
Format: Bullet list

Specification filter

- Pier Component
 - Cap
 - Column1
 - 0.00 ft.
 - 15.00 ft.
 - Column1:Pile footing
 - Pile Footing
 - Footing Longitudinal Moment Section
 - Footing Transverse Moment Section
 - Footing Longitudinal Shear Section
 - Footing Transverse Shear Section
 - Column Punching Shear Section
 - Pile Punching Shear Section

Specification reference

- ✓ 5.10.8 Shrinkage and Temperature Reinforcement
- 5.4.2.5 Poisson's Ratio
- 5.4.2.6 Modulus of Rupture
- 5.7.2.2 Rectangular Stress Distribution
- ✓ 5.7.4.2 Limits for Reinforcement
- ✓ 5.7.4.5 Biaxial Flexure
- ✓ 5.8.2.1 Torsion
- ✓ 5.8.2.5 Minimum Transverse Reinforcement
- ✓ 5.8.2.7 Maximum Spacing of Transverse Reinforcement
- ✓ 5.8.3.3 Nominal Shear Resistance
- 5.8.3.4 Procedures for Determining Shear Resistance

Spec Check Detail for 5.7.4.5 Biaxial Flexure

Analysis of the full cross section (Does not meet minimum reinforcement requirement)

Limit State	Load Combination	Pu kip	Mux kip-ft	Muy kip-ft	Mur kip-f
STR-I	69	3569.38	-2168.78	5091.28	5533.9
STR-I	69	3569.38	-2168.78	5091.28	5533.9
STR-I	69	3569.38	-2168.78	5091.28	5533.9
STR-I	69	3569.38	-2168.78	5091.28	5533.9
STR-I	149	2226.48	-1020.60	-8166.03	8229.5
STR-I	61	3019.18	-1020.60	-8166.03	8229.5
STR-I	133	2226.48	-1020.60	8166.03	8229.5
STR-I	45	3019.18	-1020.60	8166.03	8229.5
STR-I	89	2150.18	-1020.60	6889.93	6965.1
STR-I	113	2614.28	-2168.78	4295.73	4812.1
STR-I	25	3406.98	-2168.78	4295.73	4812.1
STR-I	157	2776.68	-2168.78	5091.28	5533.9
STR-I	69	3569.38	-2168.78	5091.28	5533.9
STR-I	157	2776.68	-2168.78	5091.28	5533.9
STR-I	153	2552.50	-1701.00	8842.75	9004.8
STR-I	65	3345.20	-1701.00	8842.75	9004.8
STR-I	153	2552.50	-1701.00	8842.75	9004.8
STR-I	65	3345.20	-1701.00	8842.75	9004.8
STR-I	153	2552.50	-1701.00	8842.75	9004.8
STR-I	173	2552.50	-1701.00	-8842.75	9004.8
STR-I	85	3345.20	-1701.00	-8842.75	9004.8
STR-I	173	2552.50	-1701.00	-8842.75	9004.8
STR-I	85	3345.20	-1701.00	-8842.75	9004.8
STR-I	173	2552.50	-1701.00	-8842.75	9004.8
STR-I	65	3345.20	-1701.00	8842.75	9004.8
STR-I	65	3345.20	-1701.00	8842.75	9004.8
STR-I	1	2942.88	-1020.60	6889.93	6965.1
STR-I	25	3406.98	-2168.78	4295.73	4812.1

Analysis of a voided cross section to satisfy Article 5.7.4.2 Limits for Reinforcement

Limit State	Load Combination	Pu kip	Mux kip-ft	Muy kip-ft	Mur kip-f
-------------	------------------	-----------	---------------	---------------	--------------

OK

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
- 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

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

Structure type

- Frame structure simplified definition
- Integral with substructure
 - Consider substructure skew in FE section properties
- Not integral with pier

Help

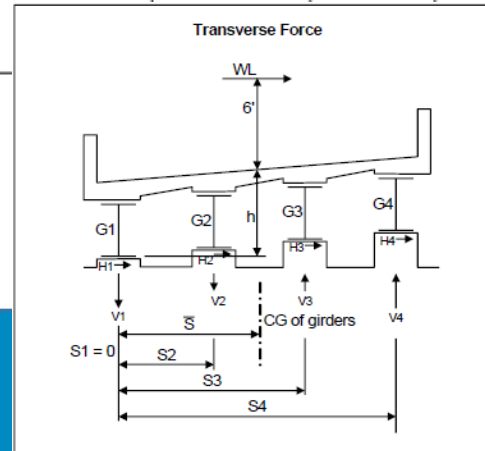
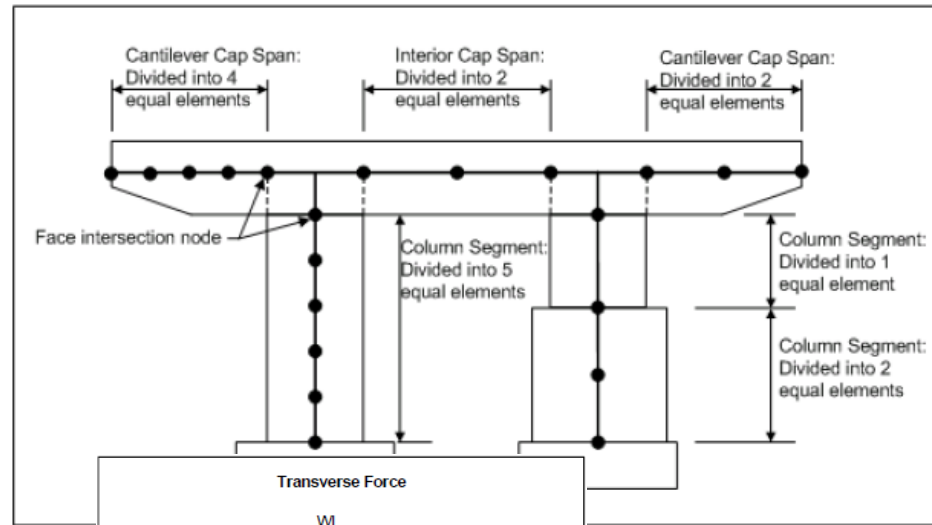
- AASHTO LRFD Substructure Method of Solution Manual

AASHTO LRFD Substructure - Adobe Acrobat Reader (64-bit)

File Edit View Sign Window Help

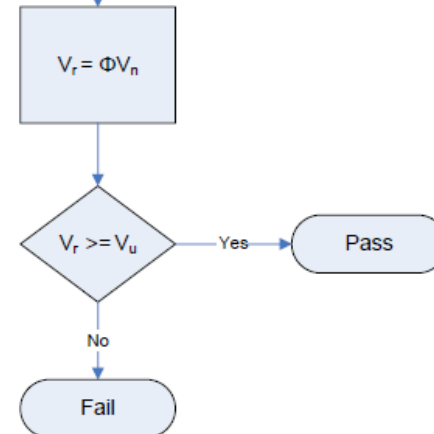
Home Tools Document 2 / 128 Share Sign In

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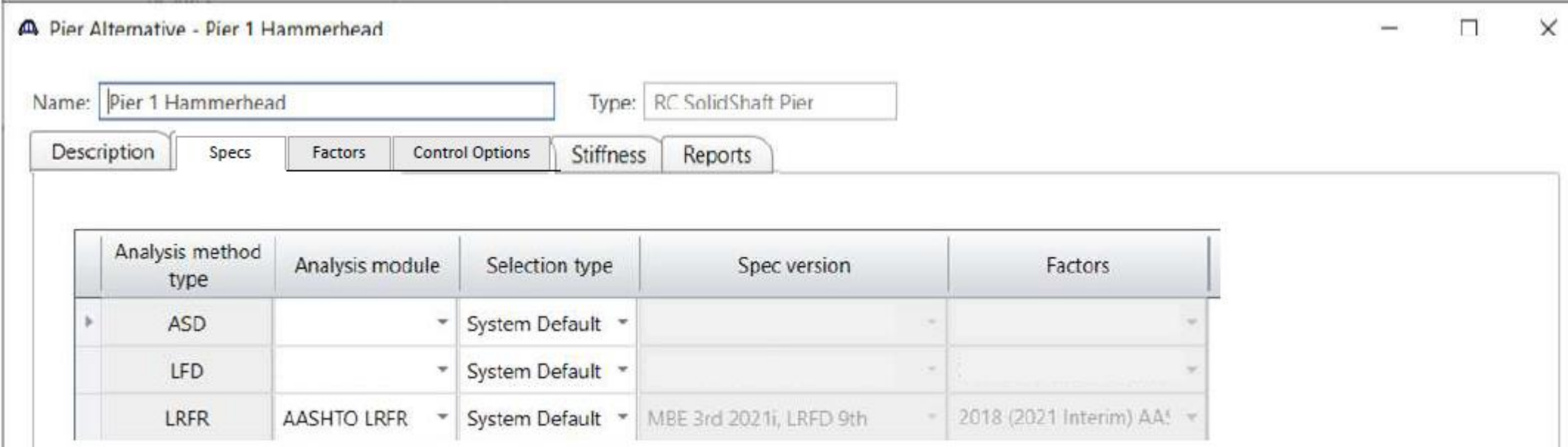
Two Way Shear Spec Check
Article 5.13.3.6.3

$$V_n = \left(0.063 + \frac{0.126}{\beta_c} \right) \sqrt{f'_c} b_o d_v \leq 0.126 \sqrt{f'_c} b_o d_v \quad (5.13.3.6.3-1)$$



What's Coming in BrDR 7.7

- Reinforced concrete pier cap LRFR analysis
 - LRFR factors
 - Additional inputs for load rating purpose including deterioration profiles
 - Adjacent vehicle analysis and NSG vehicle analysis



The screenshot shows a software window titled "Pier Alternative - Pier 1 Hammerhead". It features a form with "Name: Pier 1 Hammerhead" and "Type: RC SolidShaft Pier". Below the form are tabs for "Description", "Specs", "Factors", "Control Options", "Stiffness", and "Reports". The "Factors" tab is active, displaying a table with the following data:

Analysis method type	Analysis module	Selection type	Spec version	Factors
ASD		System Default	-	
LFD		System Default	-	
LRFR	AASHTO LRFR	System Default	MBE 3rd 2021i, LRFD 9th	2018 (2021 Interim) AA ¹

What's Coming in BrDR 7.7

- Substructure Bridge Workspace architecture revisions
 - Associating pier alternatives to link certain pier geometry and data between alternatives
 - User fully enters a pier alternative for a pier. This pier alternative is considered as the control pier alternative.
 - For another pier within the same bridge alternative, user creates a new pier alternative of the same type and associates this new pier alternative with the control pier. This pier alternative is considered as the dependent pier alternative.

What's Coming in BrDR 7.7

- Substructure reinforcement data entry revisions
 - Control point data entry method

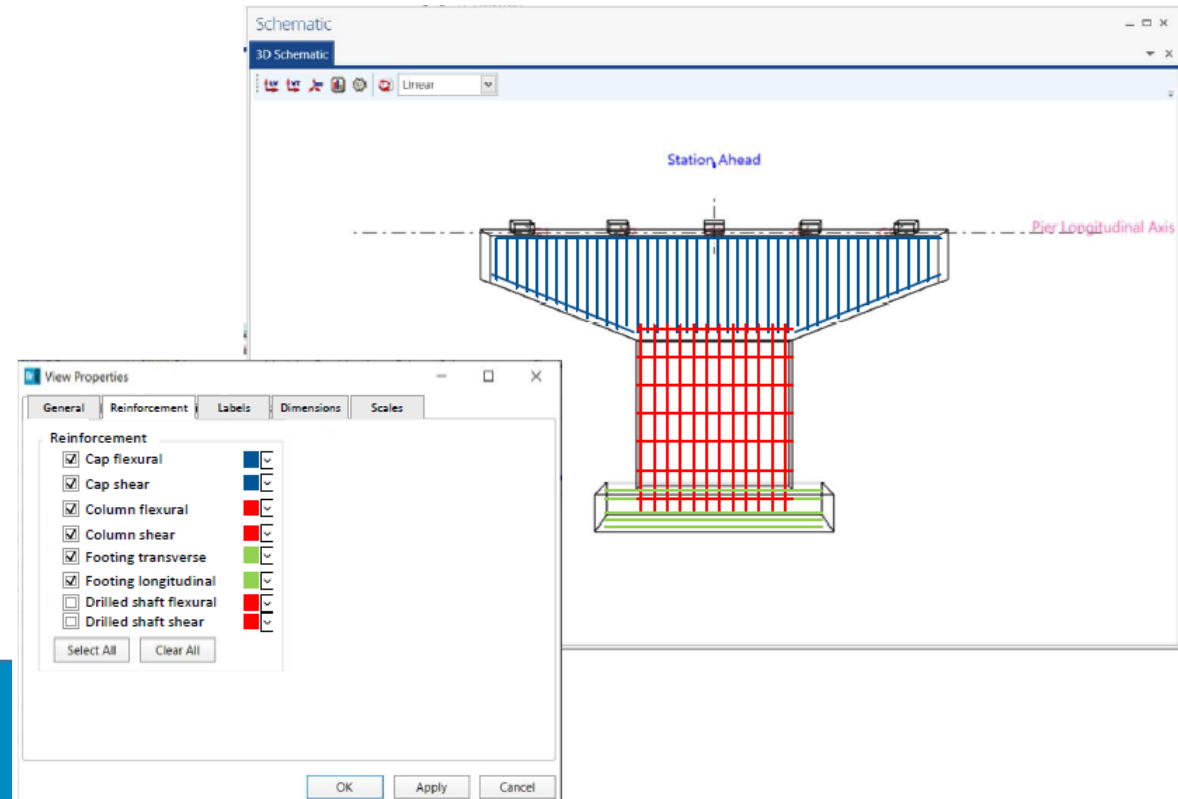
Data entry method

Distance
 Control point

Set	Pattern	① Start control point	Start distance (ft)	① End control point	End distance (ft)	Length (ft)	Hook at start	Hook at end	Developed at start	Developed at end	Follows profile
1	Def #1	Bottom of column	-3.00	Bottom of column	7.00	10.00	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2	Def #1	Bottom of column	0.00	Bottom of column	15.00	15.00	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3	Def #1	Top of column	-10	Top of column	3.00	13.00	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

What's Coming in BrDR 7.7

- 10 Additional Substructure TAG enhancement requests
 - 3D Schematic - predefined plan view, show reinforcement
 - Copy/paste enhancement
 - Hexagon column shape



Thank you for your time!

