AASHTOWare BrDR 7.5.0

Substructure Tutorial

BrDR Substructure Overview

Topics Covered

- BrDR Substructure Capabilities
- Bridge Workspace
- Pier Components – Geometry and Reinforcement
- Loads
- Analysis and Spec Check
- Output
- “Engineer in the loop” spec checking

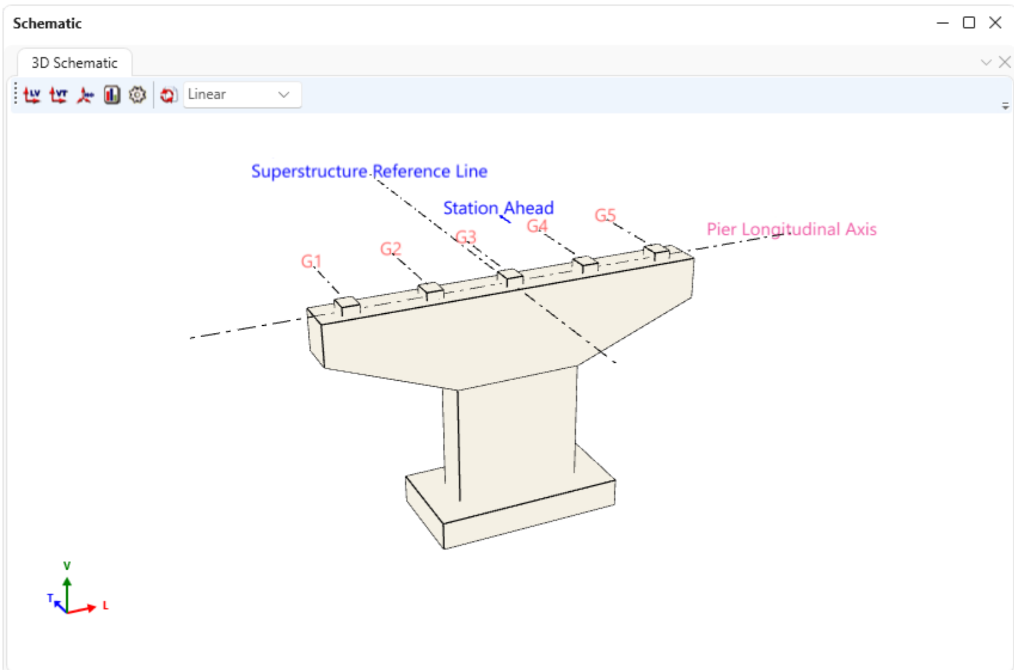
BrDR Substructure Capabilities

- Solid shaft (hammerhead), frame, wall and pile bent piers
- Spread and pile footings, drilled shaft structural analysis available (no soil interaction yet)
- BrDR superstructure loads automatically transferred down to pier
- Define pier geometry and reinforcement
- Computed loads or user overridden loads
- Elastic first-order finite element analysis, with moment magnification
- Reinforcement development lengths automatically computed and taken into account in the spec checks
- Spec checking for:
    - AASHTO LRFD Bridge Design Specifications, 4th Edition, with 2008 interims
    - AASHTO LRFD Bridge Design Specifications, 4th Edition, with 2009 interims
    - AASHTO LRFD Bridge Design Specifications, 5th Edition
    - AASHTO LRFD Bridge Design Specifications, 5th Edition, with 2010 interims
    - AASHTO LRFD Bridge Design Specifications, 6th Edition
    - AASHTO LRFD Bridge Design Specifications, 6th Edition, with 2013 interims
    - AASHTO LRFD Bridge Design Specifications, 7th Edition
    - AASHTO LRFD Bridge Design Specifications, 7th Edition, with 2015 interims
    - AASHTO LRFD Bridge Design Specifications, 7th Edition, with 2016 interims
    - AASHTO LRFD Bridge Design Specifications, 8th Edition
    - AASHTO LRFD Bridge Design Specifications, 9th Edition
- “Engineer in the loop” spec checking – examine effects of changing reinforcement or geometry without re-analyzing the entire pier.

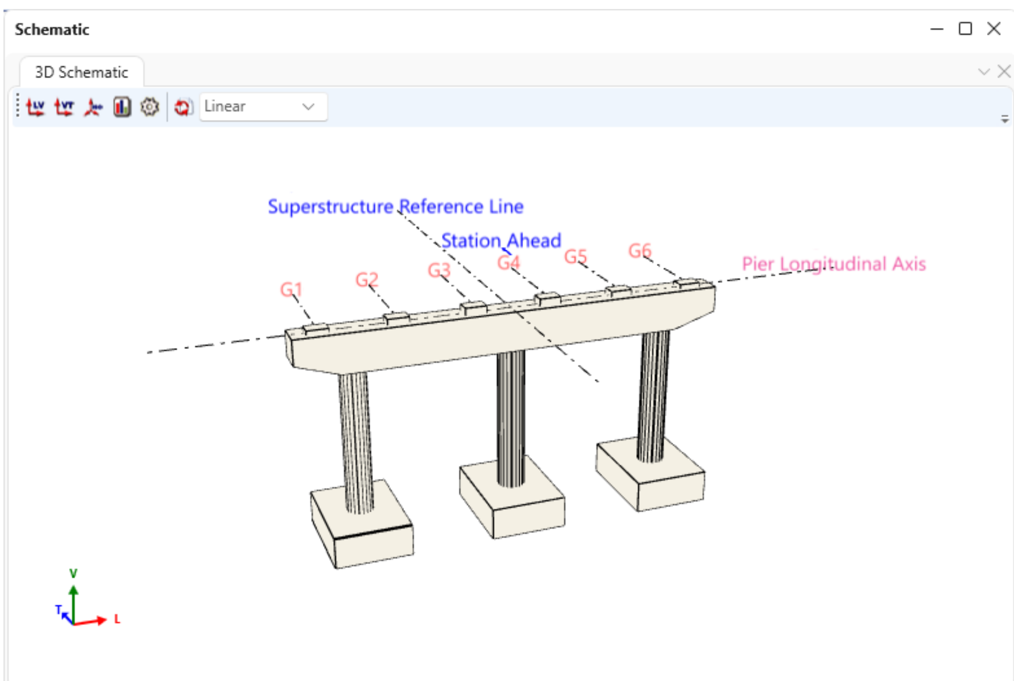
BrDR Substructure Overview

The following schematics from BrDR Substructure illustrate the pier types that can be modeled:

Hammerhead

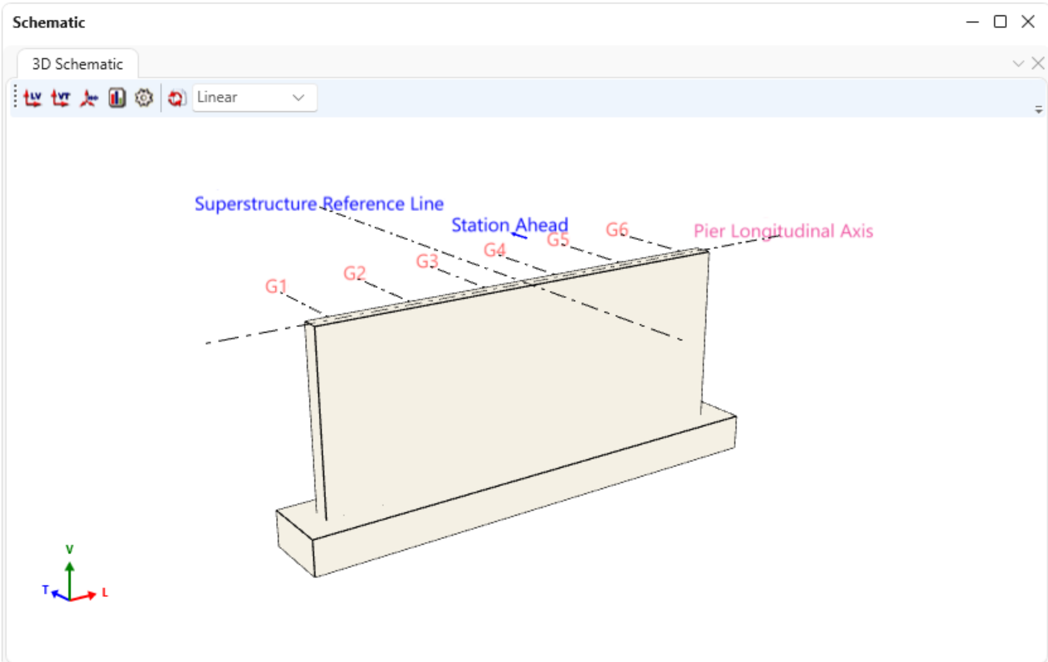


3-column pier

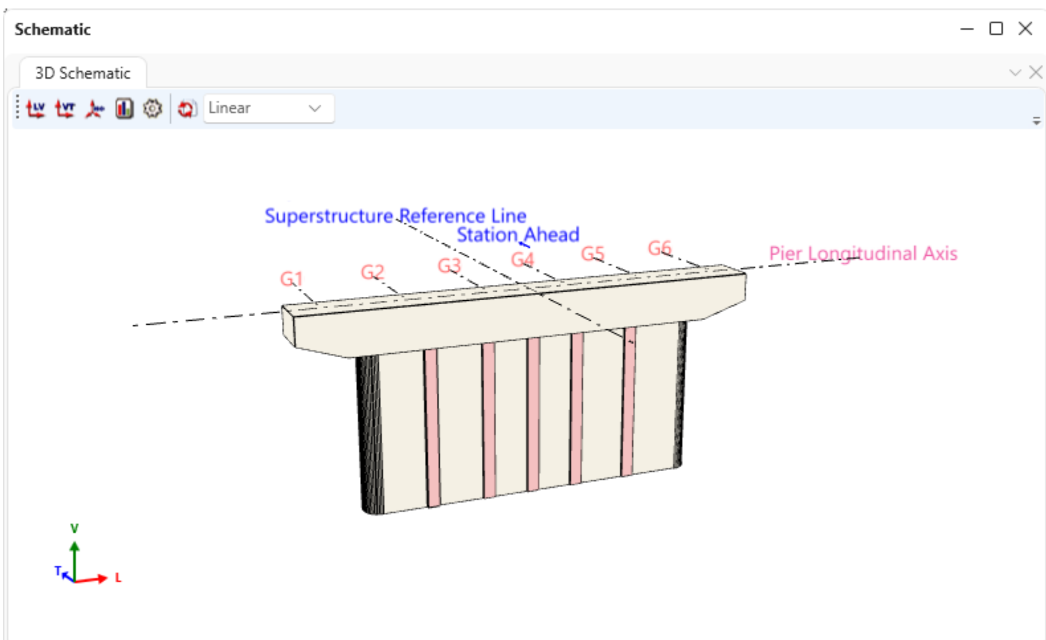


BrDR Substructure Overview

Wall pier

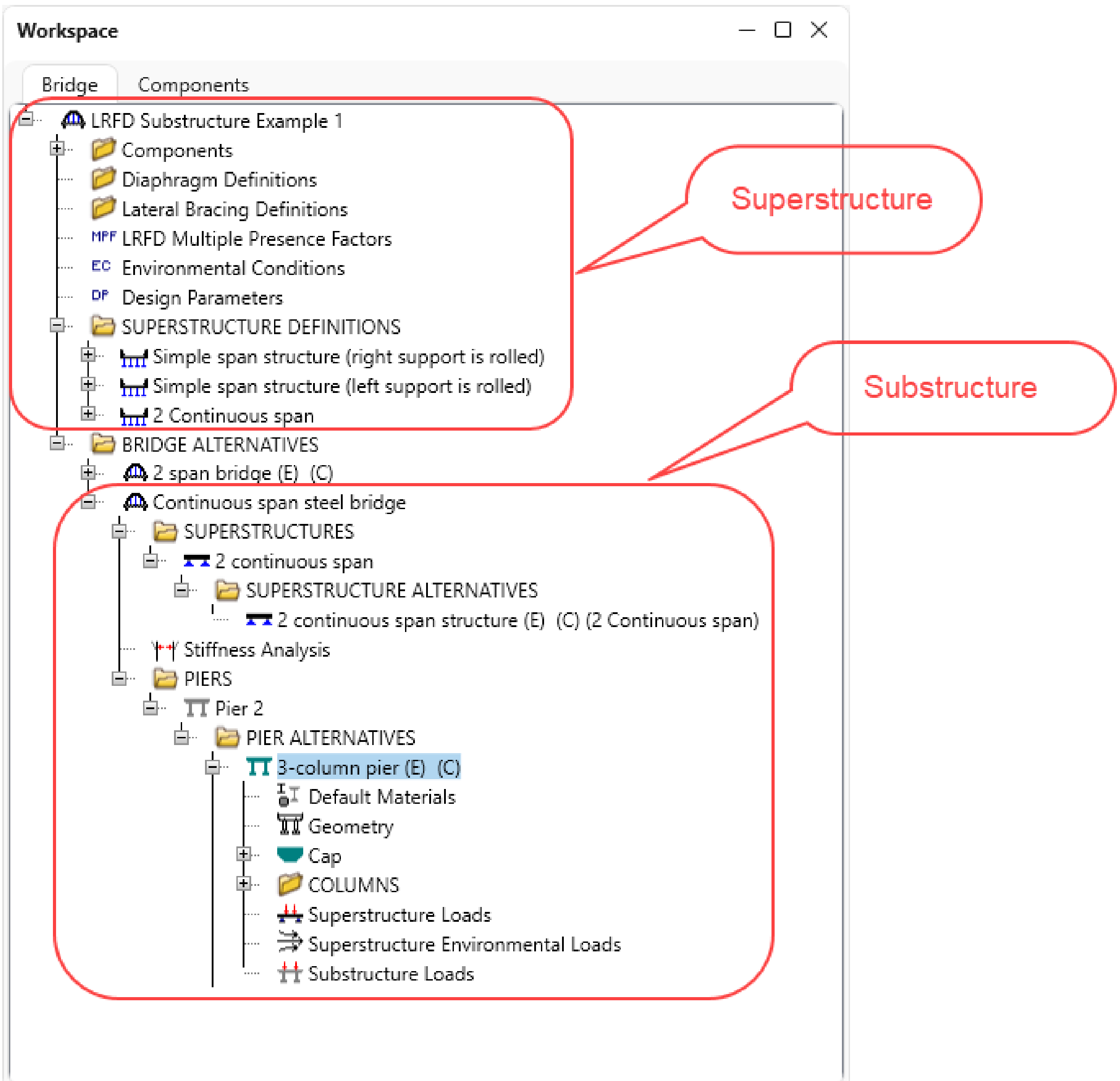


Pile bent pier



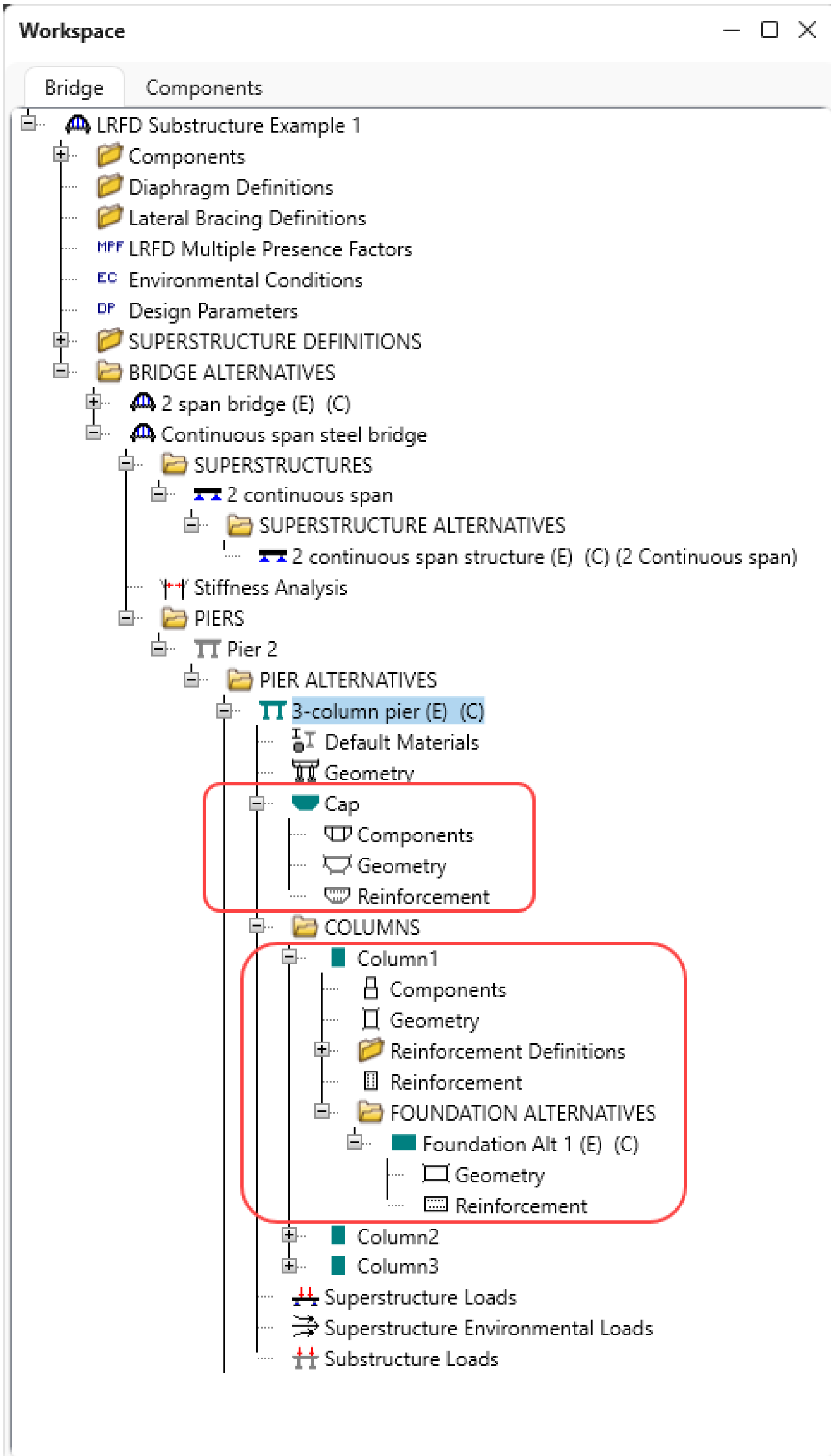
Bridge Workspace

Superstructure definitions are defined in the upper portion of the **Bridge Workspace** tree. The superstructure definition is assigned to a bridge alternative and then piers are defined to support this superstructure. Pier alternatives can be used to compare designs (e.g., hammerhead vs. frame pier).



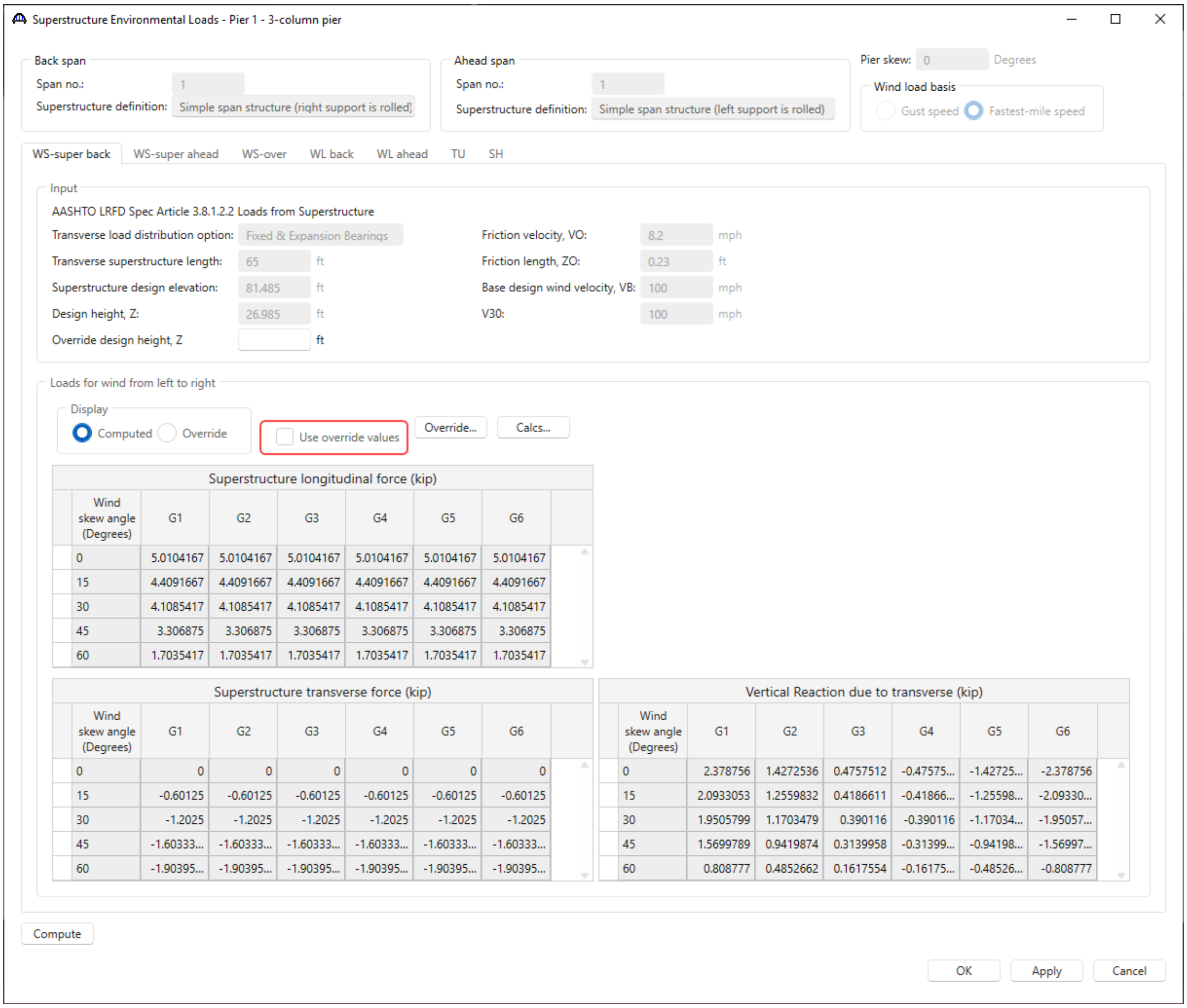
Pier Components – Geometry and Reinforcement

The geometry and reinforcement for each pier component (cap, column, foundation) can be described.



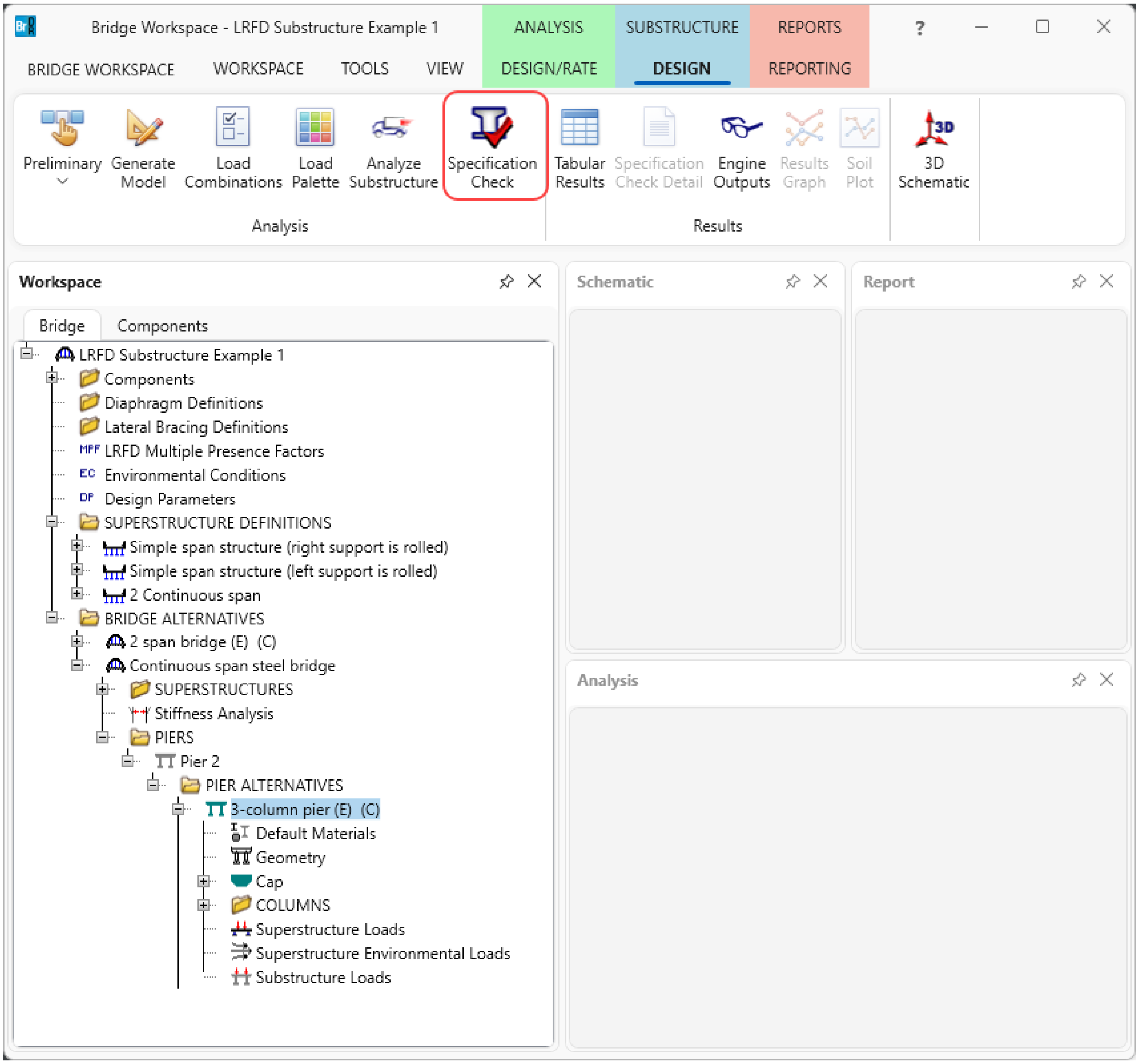
Loads

BrDR computes the superstructure dead and live loads and transfers them down to the pier. BrDR also computes all the additional superstructure and substructure loads such as wind, water, temperature and shrinkage and applies them to the pier finite element model. The user has the ability to use these loads or override them with their own loads.



Analysis and Spec Check

The **Specification Check** button on the **Analysis** group of the **DESIGN** ribbon for pier alternatives can be used to analyze the pier.

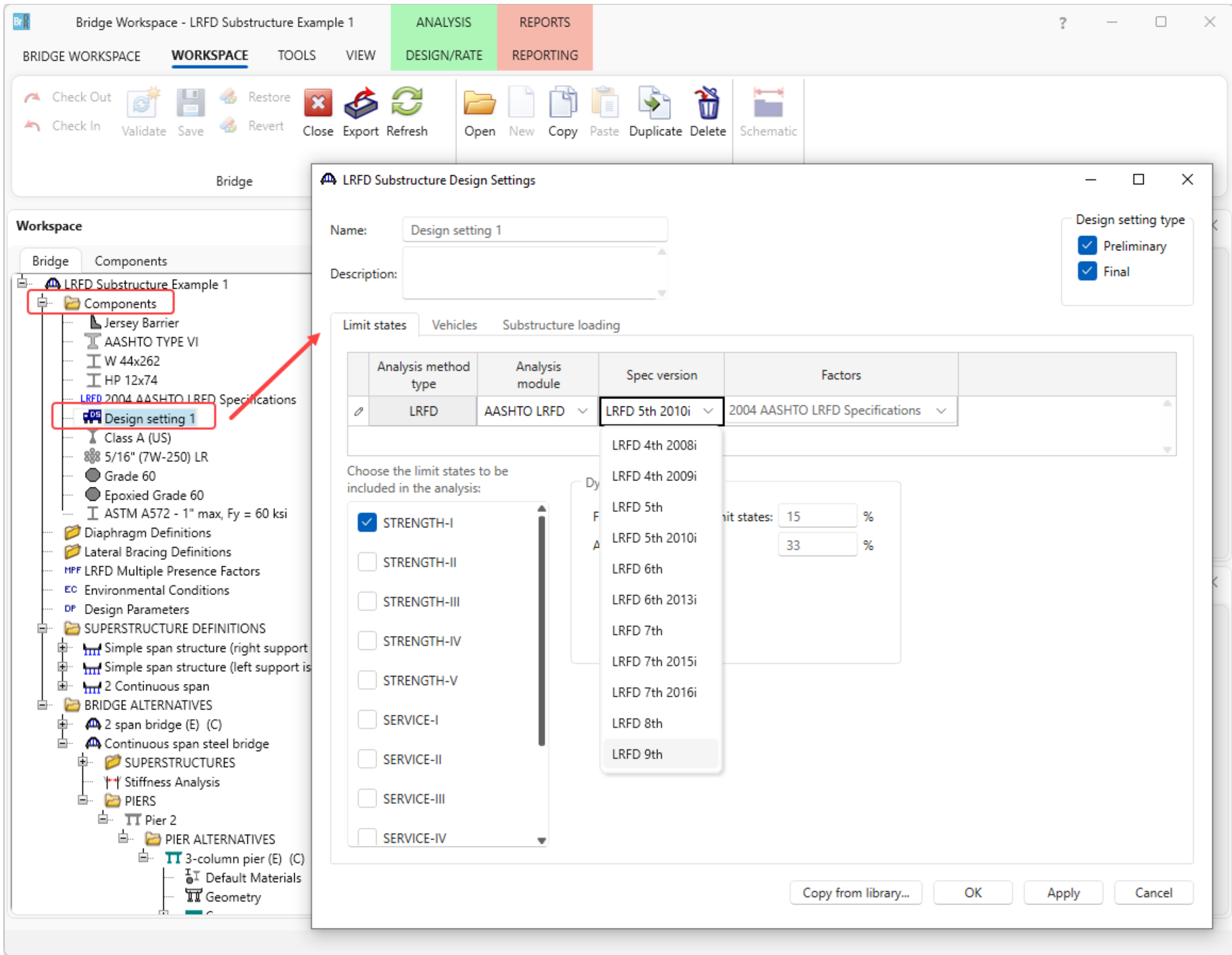


The superstructure will first be analyzed to determine the superstructure dead load reactions. The remaining loads acting on the pier (such as live load, wind, etc.) are computed and applied to the pier finite element analysis. Load combinations are generated and then the specification checks are processed.

BrDR performs spec checks at each node in the finite element model along with locations where the reinforcement is developed and at a distance dv from the face of each column.

If the FE analysis results do not exist when **Specification Check** is selected, BrDR will perform the FE analysis automatically. The next time a **Specification Check** is performed on the same system, BrDR will use the existing FE analysis results. This allows to fine-tune the reinforcement quickly and geometry without re-doing the FE analysis every time. Once the reinforcement and geometry that satisfies the spec checks is found, a final FE analysis and spec check can be performed.

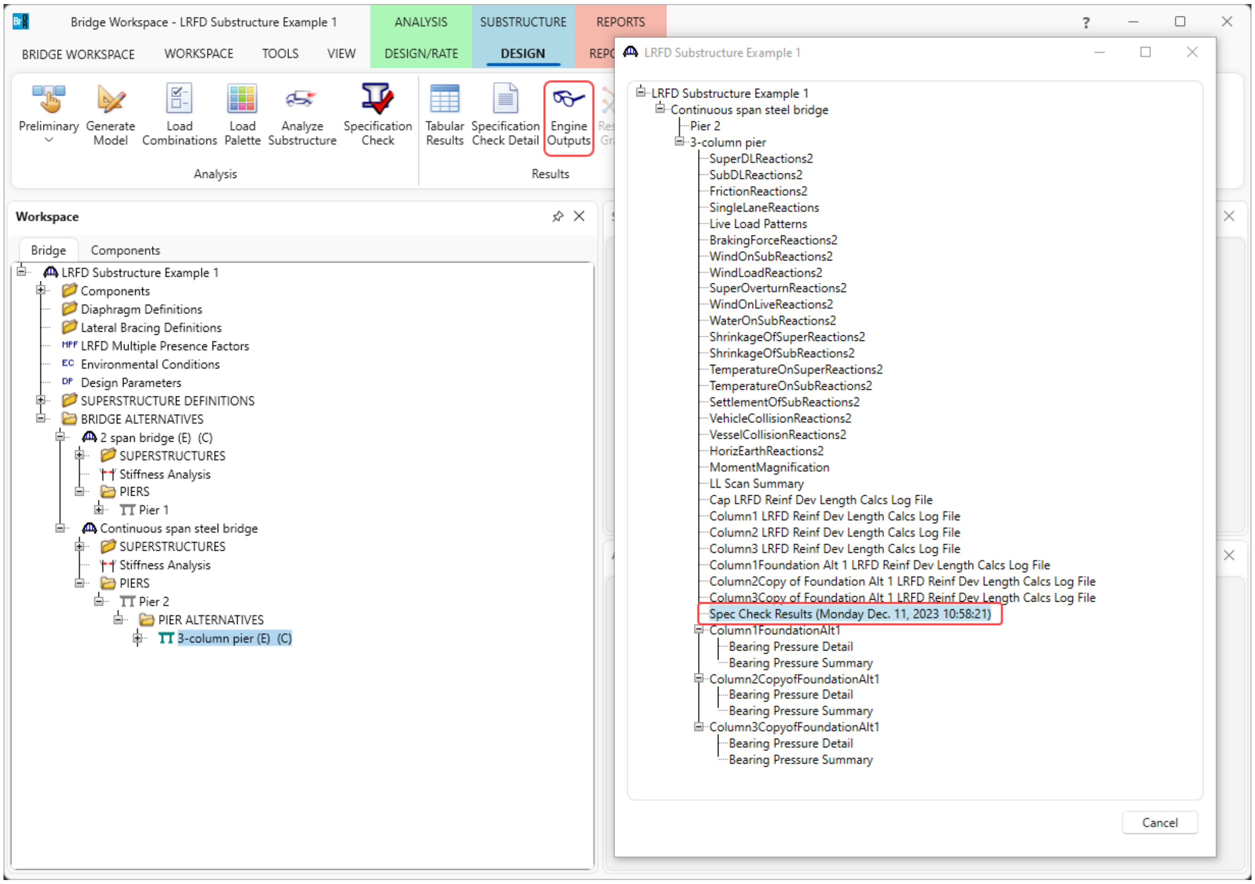
Navigate to the **LRFD Substructure Design Settings** window by clicking on the **Design setting 1** node in the **Components** folder in the **Bridge Workspace** tree as shown below.
With Version 7.5.0, the user can pick from the following specifications to use for spec checking.

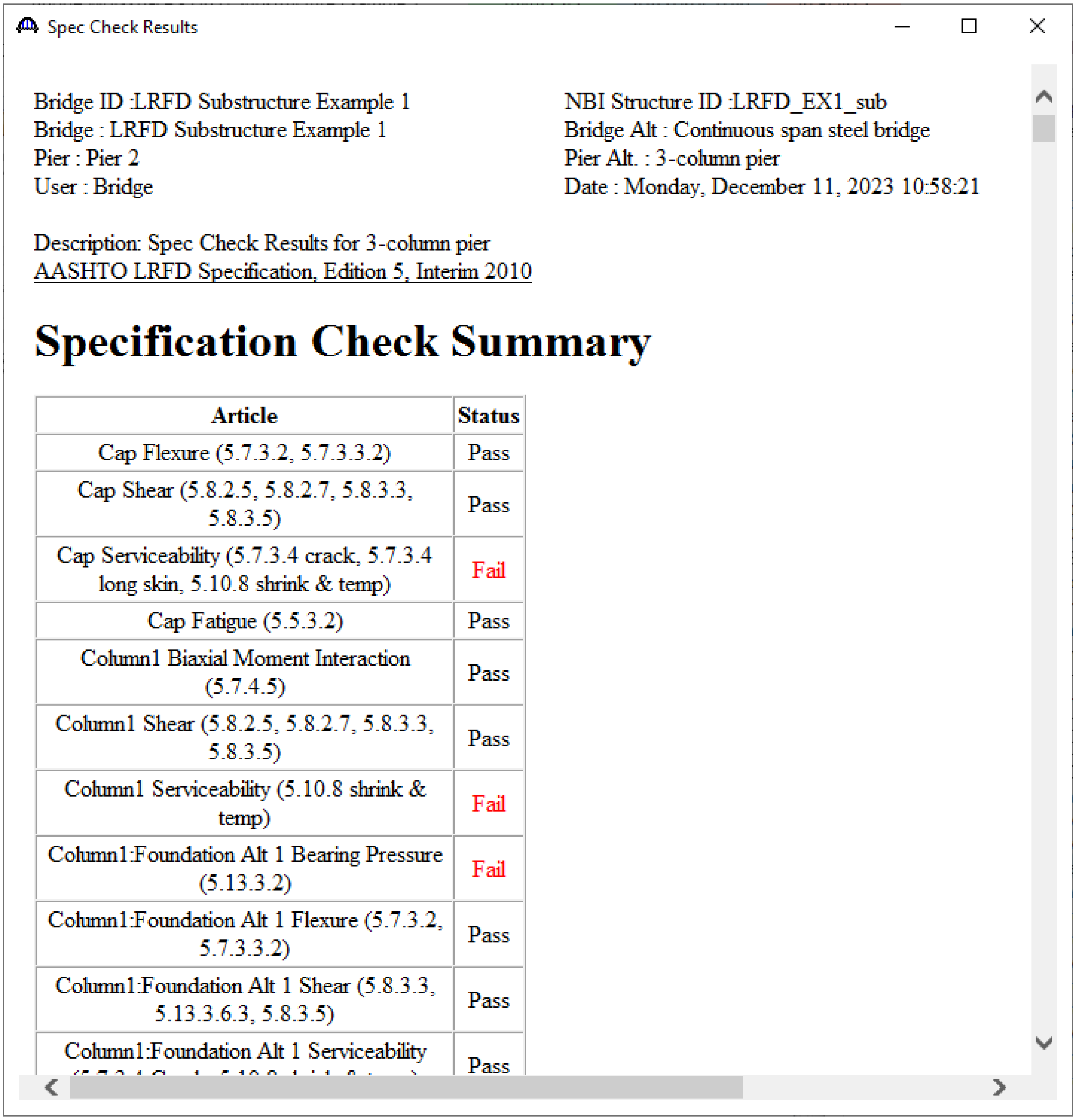


Output

Engine outputs

Reports are automatically created that contain a summary of the specification checks, the loads computed by BrDR, the reinforcement development length calculations, footing bearing pressure details, etc.




Spec Check Results

Bridge ID :LRFD Substructure Example 1
Bridge : LRFD Substructure Example 1
Pier : Pier 2
User : Bridge

NBI Structure ID :LRFD_EX1_sub
Bridge Alt : Continuous span steel bridge
Pier Alt. : 3-column pier
Date : Monday, December 11, 2023 10:58:21

Description: Spec Check Results for 3-column pier
AASHTO LRFD Specification, Edition 5, Interim 2010

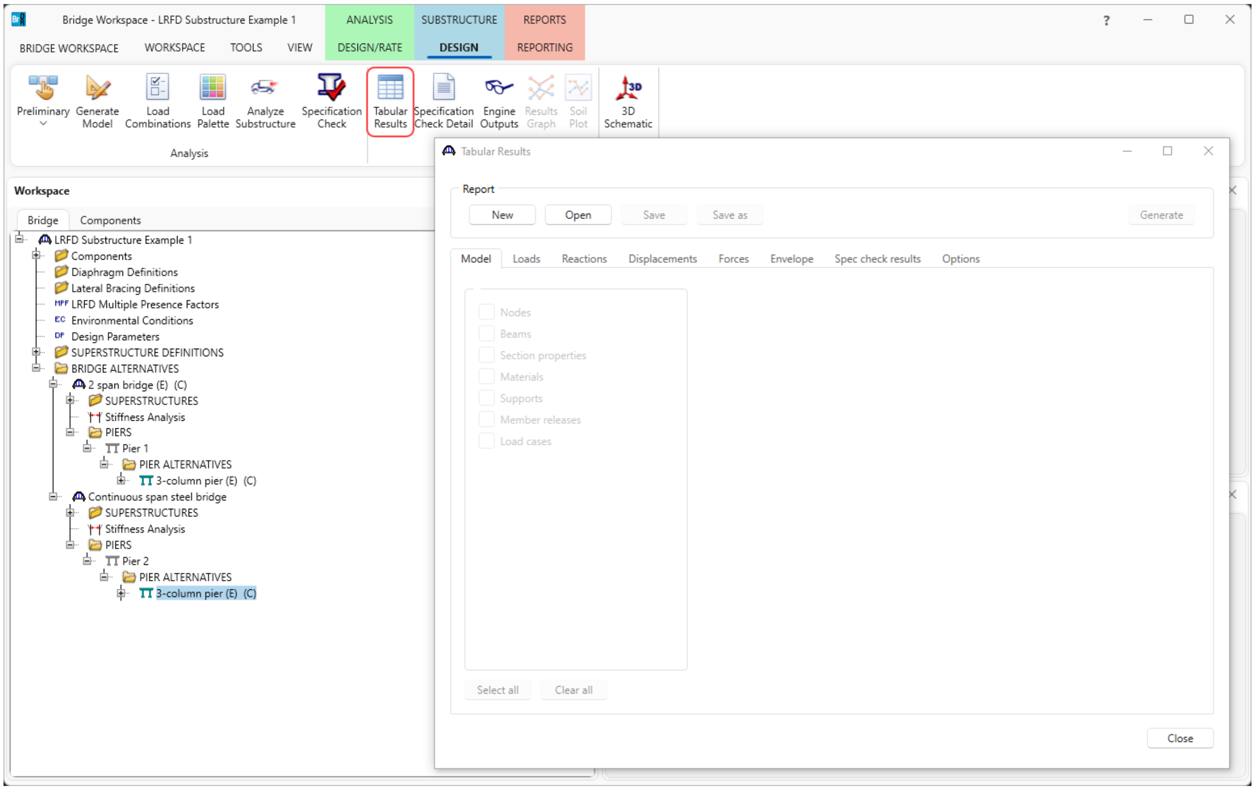
Specification Check Summary

Article	Status
Cap Flexure (5.7.3.2, 5.7.3.3.2)	Pass
Cap Shear (5.8.2.5, 5.8.2.7, 5.8.3.3, 5.8.3.5)	Pass
Cap Serviceability (5.7.3.4 crack, 5.7.3.4 long skin, 5.10.8 shrink & temp)	Fail
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)	Fail
Column1:Foundation Alt 1 Bearing Pressure (5.13.3.2)	Fail
Column1:Foundation Alt 1 Flexure (5.7.3.2, 5.7.3.3.2)	Pass
Column1:Foundation Alt 1 Shear (5.8.3.3, 5.13.3.6.3, 5.8.3.5)	Pass
Column1:Foundation Alt 1 Serviceability	Pass

This file contains a summary of the results of each spec check along with the design ratios for each spec article at each spec check location point. The design ratio is the ratio of the capacity to demand. A design ratio less than one indicates the demand is greater than the capacity and the spec article fails. A design ratio equal to 99.0 indicates the section is subject to zero demand.

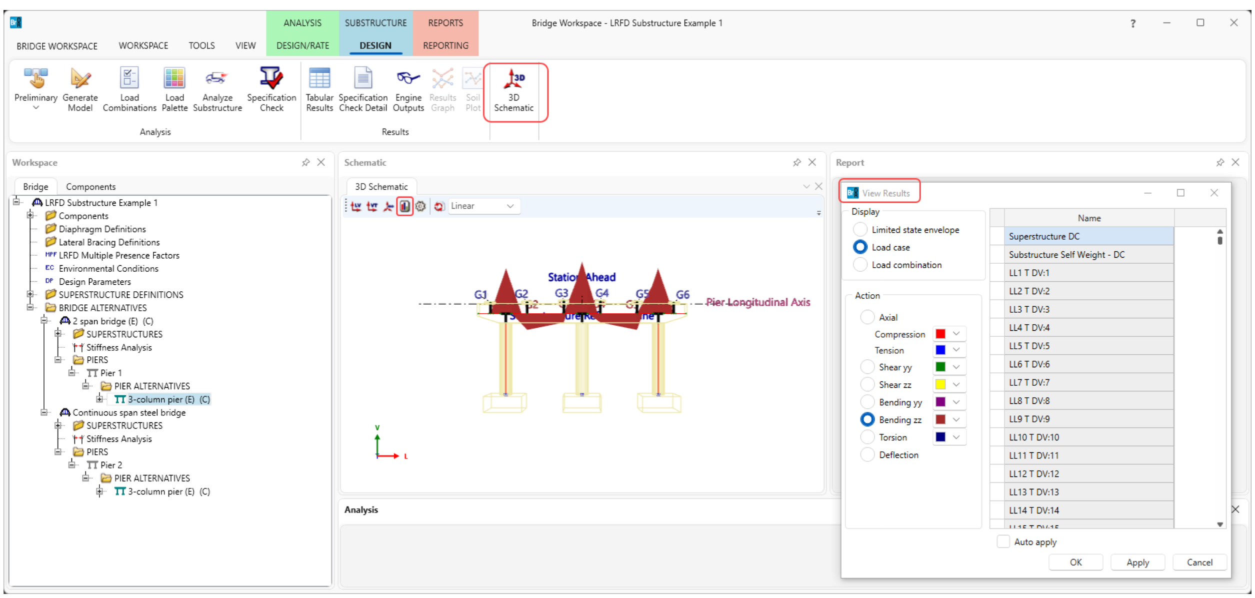
Tabular Results

Additional reports can be tailored to the user's needs and generated in the **Tabular Results** window.



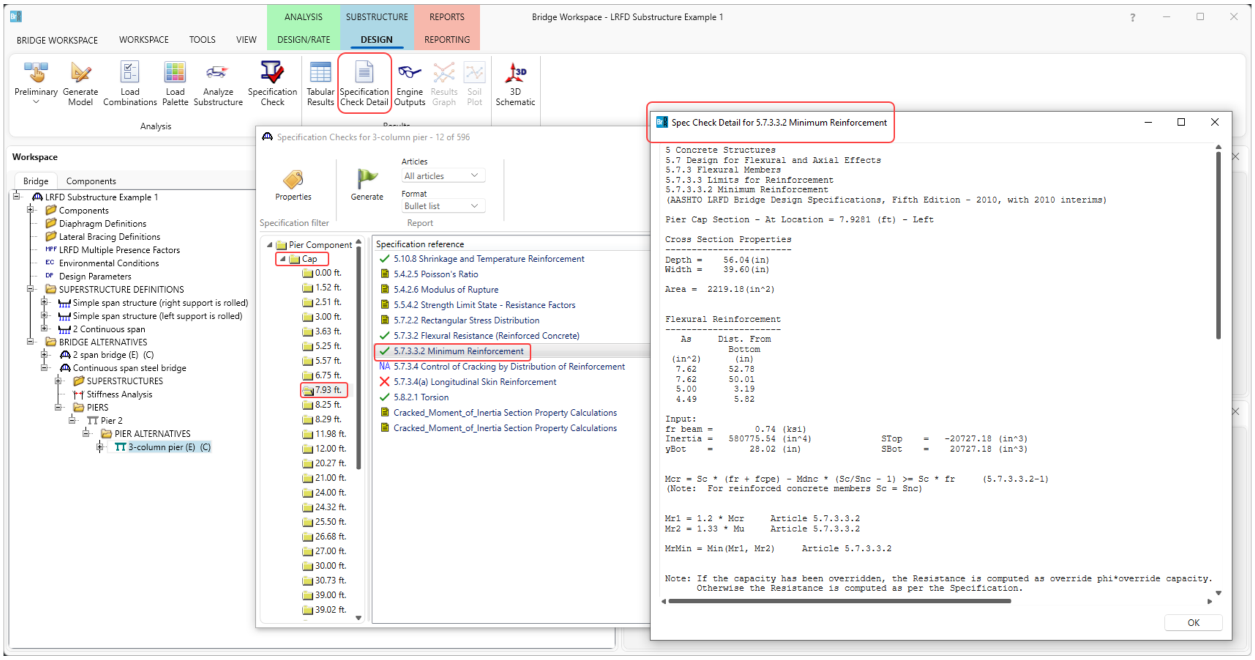
FE model and results

The FE model and results can be shown graphically in the Pier 3D Schematic as shown below.



Specification Check Detail

Details for each spec article evaluated can be viewed in the **Spec Check** viewer. Reports containing these article details can be generated and saved.



"Engineer in the Loop" Spec Checking

"Engineer in the Loop" refers to the ability of the engineer to refine the reinforcement or section dimensions and evaluate the spec articles without having to do another full-blown finite element analysis.

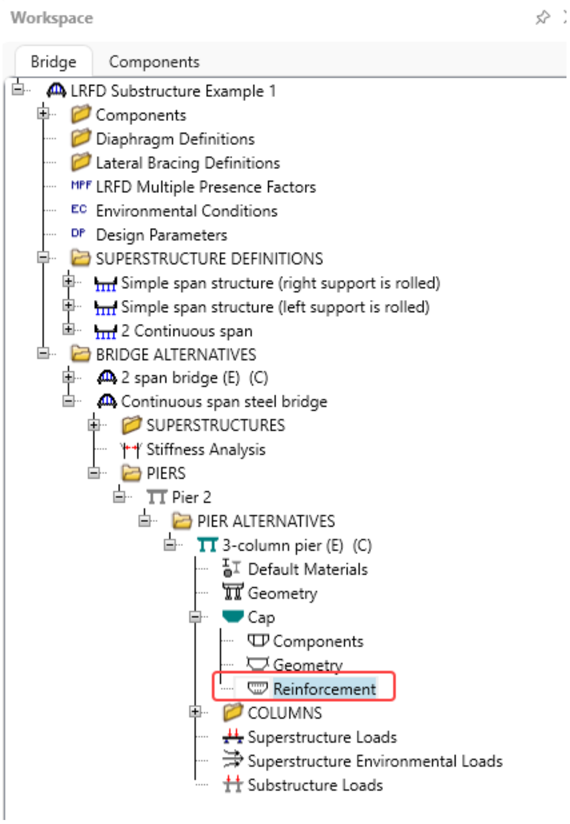
In this example, the cap longitudinal reinforcement was shown as failing in the **Spec Check Summary** report.

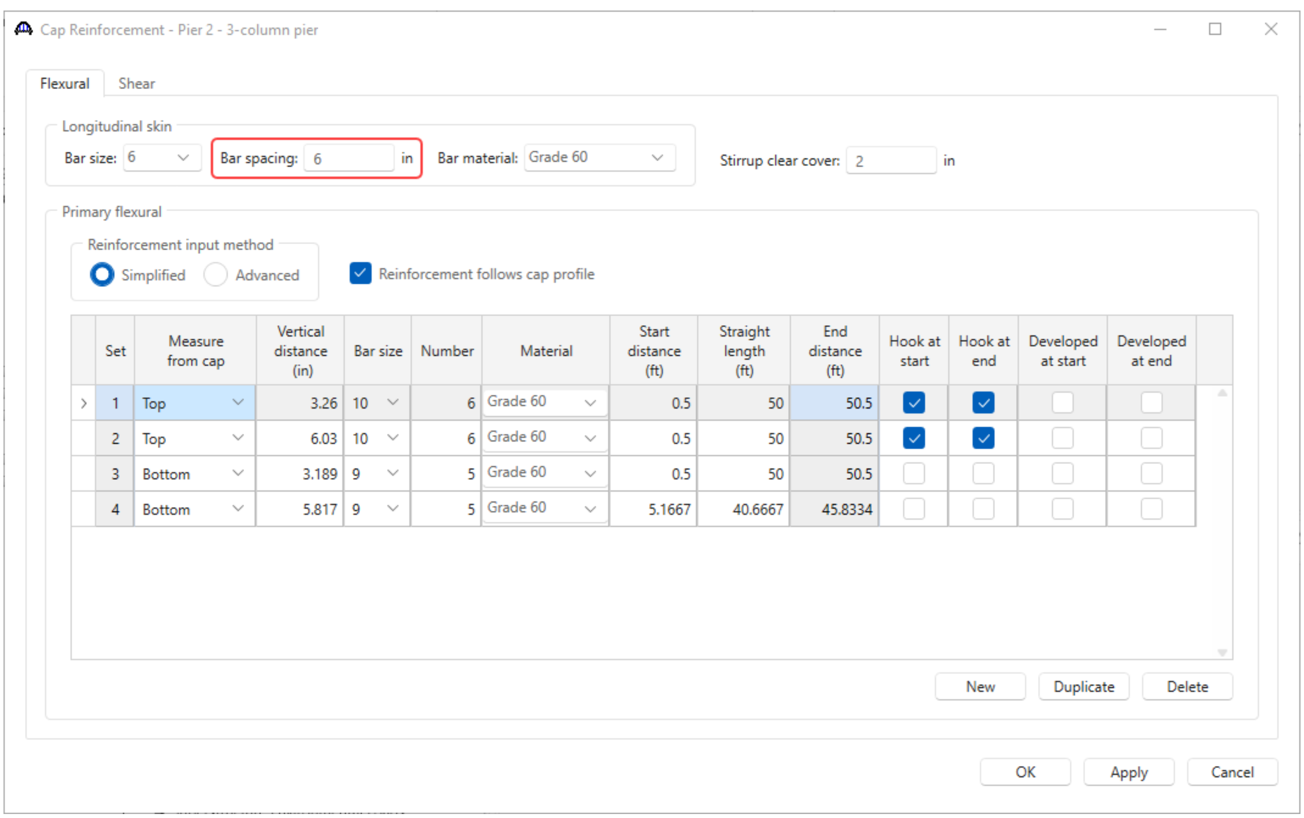
Spec Check Results

Cap Longitudinal Skin Analysis

Location (ft)	As (in^2)	Effective Depth (in)	Actual Spac. (in)	Max. Spac. (in)	Actual Ask (in^2/ft)	Required Ask (in^2/ft)	Code
0.000	0.000		15.000		0.352		Pass
1.522							
2.511	18.508	42.516	15.000	7.086	0.352	0.150	Fail
3.000	19.300	44.406	15.000	7.401	0.352	0.173	Fail
3.625	20.240	46.822	15.000	7.804	0.352	0.202	Fail
5.250	20.479	51.537	15.000	8.590	0.352	0.258	Fail
5.572	20.988	51.537	15.000	8.590	0.352	0.258	Fail
6.750	22.856	51.537	15.000	8.590	0.352	0.258	Fail
7.928	24.728	51.537	15.000	8.590	0.352	0.258	Fail
8.250	25.240	51.537	15.000	8.590	0.352	0.258	Fail
8.292	25.240	51.537	15.000	8.590	0.352	0.258	Fail
11.977							
12.000	25.240	51.537	15.000	8.590	0.352	0.258	Fail
20.273							
21.000	25.240	51.537	15.000	8.590	0.352	0.258	Fail
24.000	25.240	51.537	15.000	8.590	0.352	0.258	Fail
24.322	25.240	51.537	15.000	8.590	0.352	0.258	Fail
25.500	25.240	51.537	15.000	8.590	0.352	0.258	Fail
26.678	25.240	51.537	15.000	8.590	0.352	0.258	Fail
27.000	25.240	51.537	15.000	8.590	0.352	0.258	Fail
30.000	25.240	51.537	15.000	8.590	0.352	0.258	Fail
30.727							

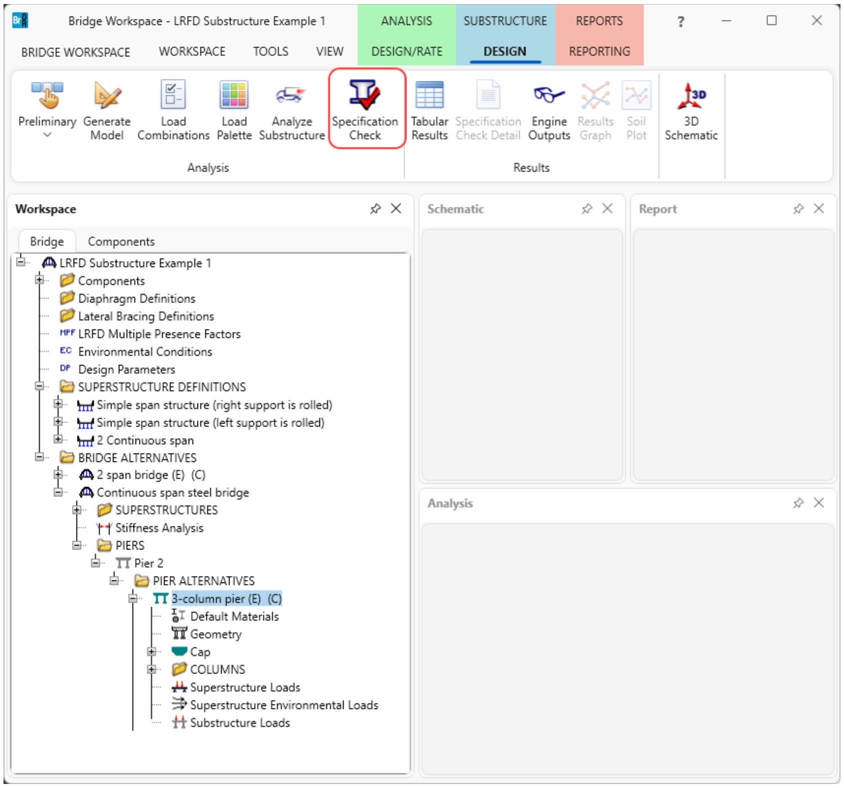
The user can change the longitudinal reinforcement spacing from 15” to 6” and process the Spec Checks again.



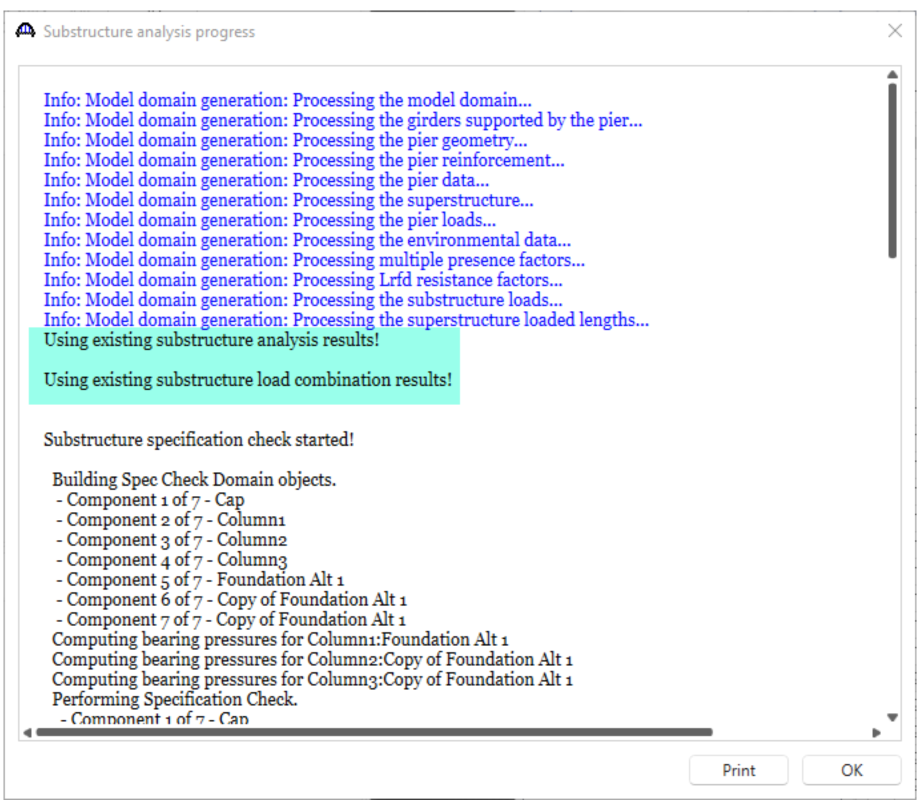


Set	Measure from cap	Vertical distance (in)	Bar size	Number	Material	Start distance (ft)	Straight length (ft)	End distance (ft)	Hook at start	Hook at end	Developed at start	Developed at end
1	Top	3.26	10	6	Grade 60	0.5	50	50.5	☑	☑	☐	☐
2	Top	6.03	10	6	Grade 60	0.5	50	50.5	☑	☑	☐	☐
3	Bottom	3.189	9	5	Grade 60	0.5	50	50.5	☐	☐	☐	☐
4	Bottom	5.817	9	5	Grade 60	5.1667	40.6667	45.8334	☐	☐	☐	☐

Run the spec check again by clicking on the Specification Check button from the ribbon as shown below.



The spec checks will be performed again using the results of the previous finite element analysis.



Changing the cap reinforcement results in the cap longitudinal reinforcement passing in the **Spec Check Summary** as shown below. The engineer can use this process to fine-tune the design. After finding reinforcement and dimensions that satisfy the specification articles, a final finite element analysis and spec check can be performed.

Spec Check Results

Cap Longitudinal Skin Analysis

Location (ft)	As (in^2)	Effective Depth (in)	Actual Spac. (in)	Max. Spac. (in)	Actual Ask (in^2/ft)	Required Ask (in^2/ft)	Code
0.000	0.000		6.000		0.880		Pass
1.522							
2.511	18.508	42.516	6.000	7.086	0.880	0.150	Pass
3.000	19.300	44.406	6.000	7.401	0.880	0.173	Pass
3.625	20.240	46.822	6.000	7.804	0.880	0.202	Pass
5.250	20.479	51.537	6.000	8.590	0.880	0.258	Pass
5.572	20.988	51.537	6.000	8.590	0.880	0.258	Pass
6.750	22.856	51.537	6.000	8.590	0.880	0.258	Pass
7.928	24.728	51.537	6.000	8.590	0.880	0.258	Pass
8.250	25.240	51.537	6.000	8.590	0.880	0.258	Pass
8.292	25.240	51.537	6.000	8.590	0.880	0.258	Pass
11.977							
12.000	25.240	51.537	6.000	8.590	0.880	0.258	Pass
20.273							
21.000	25.240	51.537	6.000	8.590	0.880	0.258	Pass
24.000	25.240	51.537	6.000	8.590	0.880	0.258	Pass
24.322	25.240	51.537	6.000	8.590	0.880	0.258	Pass
25.500	25.240	51.537	6.000	8.590	0.880	0.258	Pass
26.678	25.240	51.537	6.000	8.590	0.880	0.258	Pass
27.000	25.240	51.537	6.000	8.590	0.880	0.258	Pass
30.000	25.240	51.537	6.000	8.590	0.880	0.258	Pass
30.727							
39.000	25.240	51.537	6.000	8.590	0.880	0.258	Pass