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:
  - o AASHTO LRFD Bridge Design Specifications, 4th Edition, with 2008 interims
  - o AASHTO LRFD Bridge Design Specifications, 4th Edition, with 2009 interims
  - AASHTO LRFD Bridge Design Specifications, 5th Edition
  - o AASHTO LRFD Bridge Design Specifications, 5th Edition, with 2010 interims
  - AASHTO LRFD Bridge Design Specifications, 6th Edition
  - o AASHTO LRFD Bridge Design Specifications, 6th Edition, with 2013 interims
  - o AASHTO LRFD Bridge Design Specifications, 7th Edition
  - o AASHTO LRFD Bridge Design Specifications, 7th Edition, with 2015 interims
  - o AASHTO LRFD Bridge Design Specifications, 7th Edition, with 2016 interims
  - o 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 reanalyzing the entire pier.

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

#### Hammerhead



### 3-column pier



### 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.

ack span						Ahea	d span					Pier sk	ew: 0	Degree	25		
pan no.:		1				Span	no.:	1				Wir	d load basis				
Superstru	cture definitio	on: Simple	e span structu	ure (right supp	port is rolled)	Supe	rstructure definitio	n: Simple	span struc	ture (left sup:	port is rolled)		Gust speed	O Fastest-	mile speed		
/S-super	back WS-	super ahea	d WS-ov	er WL bad	k WL ahe	ad TU	SH										
Input																	
AASHT	O LRFD Spec	Article 3.8.	1.2.2 Loads fr	om Superstru	icture												
Transve	erse load dist	ribution op	tion: Fixed	& Expansion I	Bearings		Friction velocity, V	0:	8.2	mph							
Transve	erse superstru	ucture lengt	th: 65	ft			Friction length, ZO		0.23	ft							
Supers	tructure desid	on elevation	n: 81.485	i ft			Base design wind v	velocity, VB:	100	mph							
Desian	n height. Z:	-	26.985	i ft			V30:	2	100	mph							
Overrie	de design bei	aht Z	20.503	ft					100								
si ( 0 15 30 45	Wind kew angle Degrees) 5 4 5 4 5 4 5 1 5 1 5 1 5 1 5 1 5 1 5 1 5 1 5 1 5 1	G1 5.0104167 4.4091667 4.1085417 3.306875 1.7035417	G2 5.0104167 4.4091667 4.1085417 3.306875 1.7035417	G3 5.0104167 4.4091667 4.1085417 3.306875 1.7035417	dinal force ( G4 5.0104167 4.4091667 4.1085417 3.306875 1.7035417	kip) G5 5.0104167 4.4091667 4.1085417 3.306875 1.7035417	G6 5.0104167 4.4091667 4.1085417 3.306875 1.7035417										
			-														
	Wind		Superstruc	ture transve	erse force (k	ap)			Wind	Ve	ertical React	ion due to	transverse	(кір)			
si (	kew angle (Degrees)	G1	G2	G3	G4	G5	G6	sk (E	ew angle Degrees)	G1	G2	G3	G4	G5	G6		
0		0	0	0	0	0	0	<b>0</b>		2.378756	1.4272536	0.4757512	-0.47575	-1.42725	-2.378756	-	
15	5	-0.60125	-0.60125	-0.60125	-0.60125	-0.60125	-0.60125	15		2.0933053	1.2559832	0.4186611	-0.41866	-1.25598	-2.09330		
20	D	-1.2025	-1.2025	-1.2025	-1.2025	-1.2025	-1.2025	30		1.9505799	1.1703479	0.390116	-0.390116	-1.17034	-1.95057		
30	5 -	1.60333	-1.60333	-1.60333	-1.60333	-1.60333	-1.60333	45		1.5699789	0.9419874	0.3139958	-0.31399	-0.94198	-1.56997		
45	0 -	1.90395	-1.90395	-1.90395	-1.90395	-1.90395	-1.90395	60		0.808777	0.4852662	0.1617554	-0.16175	-0.48526	-0.808777		
45 60 si ( 0 15	Wind kew angle [Degrees]	3.3068/5 1.7035417 G1 0 -0.60125 1.60333 1.90395	3.306875 1.7035417 Superstruct G2 0 -0.60125 -1.2025 -1.60333 -1.90395	3.306875 1.7035417 ture transve G3 0 -0.60125 -1.2025 -1.60333 -1.90395	3.306875 1.7035417 erse force (k G4 0 -0.60125 -1.2025 -1.60333 -1.90395	3.306875 1.7035417 iip) G5 0 -0.60125 -1.2025 -1.60333 -1.90395	3.3068/5 1.7035417 G66 0 -0.60125 -1.2025 -1.60333 -1.90395	sk (( 0 15 30 45 60	Wind ew angle begrees)	G1 2.378756 2.0933053 1.9505799 1.5699789 0.808777	G2 1.4272536 1.2559832 1.1703479 0.9419874 0.4852662	ion due to G3 0.4757512 0.4186611 0.390116 0.3139958 0.1617554	G4 -0.47575 -0.41866 -0.390116 -0.31399 -0.16175	(kip) G5 -1.42725 -1.25598 -1.17034 -0.94198 -0.48526	G6 -2.378756 -2.09330 -1.95057 -1.56997 -0.808777		

# 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.

Bridge Workspace - LRFD Substructure Examp	ple 1 ANALYSIS	REPORTS			? – 🗆 X
BRIDGE WORKSPACE TOOLS	VIEW DESIGN/RAT	E REPORTING			
<ul> <li>Check Out</li> <li>Check In</li> <li>Check In</li> <li>Validate Save </li> <li>Revert</li> <li>Close</li> </ul>	e Export Refresh	pen New Copy F	aste Duplicate Delete	Schematic	
Bridge 4	LRFD Substructure Designation	gn Settings			x
Workspace	Name: Design sett	ing 1			Design setting type
Bridge Components	Description:		v		Final
AASHTO TYPE VI	Limit states Vehicles	Substructure loa	ding		
HP 12x74	Analysis method type	Analysis module	Spec version	Factors	
Design setting 1	ℓ LRFD	AASHTO LRFD $$	LRFD 5th 2010i 🗸	2004 AASHTO LRFD Specifications 🗸	<u>^</u>
	Choose the limit states included in the analysis STRENGTH-I STRENGTH-II STRENGTH-IV STRENGTH-IV STRENGTH-V SERVICE-I SERVICE-II SERVICE-III SERVICE-IV	to be s:	LRFD 4th 2008i           y         LRFD 4th 2009i           LRFD 5th         2000           p         LRFD 5th 2010i           LRFD 6th         2000           LRFD 7th         2000           LRFD 7th         2016i           LRFD 7th 2016i         2016i           LRFD 8th         2000           LRFD 9th         2016i	iit states: 15 % 33 %	
·····································				Copy from library OK	Apply Cancel

# 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.



long skin, 5.10.8 shrink & temp) Cap Fatigue (5.5.3.2)

Column1 Biaxial Moment Interaction

(5.7.4.5) Column1 Shear (5.8.2.5, 5.8.2.7, 5.8.3.3,

5.8.3.5) Column1 Serviceability (5.10.8 shrink &

temp) Column1:Foundation Alt 1 Bearing Pressure

(5.13.3.2) Column1:Foundation Alt 1 Flexure (5.7.3.2,

5.7.3.3.2) Column1:Foundation Alt 1 Shear (5.8.3.3,

5.13.3.6.3, 5.8.3.5) Column1:Foundation Alt 1 Serviceability

< 10 0

å	Spec Check Results		- 0	×
	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 AASHTO LRFD Specification, Edition 5, Inte	n pier erim 2010		
	Specification Check	Sum	mary	
	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	T7 11		

Fail

Pass

Pass

Pass

Fail

Fail

Pass

Pass

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.

		Effective	Actual	Max	Actual	Required	
Location (ft)	As (in^2)	Depth (in)	Spac. (in)	Spac. (in)	Actual Ask (in^2/ft)	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							
20.000	25 240	E1 E27	15 000	0 200	0.252	0.250	77-3

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



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.

Substructure analysis progress  $\times$ Info: Model domain generation: Processing the model domain... Info: Model domain generation: Processing the girders supported by the pier... Info: Model domain generation: Processing the pier geometry... Info: Model domain generation: Processing the pier reinforcement... Info: Model domain generation: Processing the pier data... Info: Model domain generation: Processing the superstructure. Info: Model domain generation: Processing the pier loads... Info: Model domain generation: Processing the environmental data... Info: Model domain generation: Processing multiple presence factors... Info: Model domain generation: Processing Lrfd resistance factors... Info: Model domain generation: Processing the substructure loads... Info: Model domain generation: Processing the superstructure loaded lengths... Using existing substructure analysis results! Using existing substructure load combination results! Substructure specification check started! Building Spec Check Domain objects. Building Spec Check Domain objects. - Component 1 of 7 - Cap - Component 2 of 7 - Column1 - Component 3 of 7 - Column2 - Component 4 of 7 - Column3 - Component 5 of 7 - Foundation Alt 1 - Component 6 of 7 - Copy of Foundation Alt 1 - Component 7 of 7 - Copy of Foundation Alt 1 - Computing bearing pressures for Column1:Foundation Alt 1 Computing bearing pressures for Column2:Copy of Foundation Alt 1 Computing bearing pressures for Column3:Copy of Foundation Alt 1 Performing Specification Check. Component 1 of 7 - Cap v b. Print OK

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.

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#### A Spec Check Results

# Cap Longitudinal Skin Analysis

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		6.000		0.880		Pass
						_
18.508	42.516	6.000	7.086	0.880	0.150	Pass
19.300	44.406	6.000	7.401	0.880	0.173	Pass
20.240	46.822	6.000	7.804	0.880	0.202	Pass
20.479	51.537	6.000	8.590	0.880	0.258	Pass
20.988	51.537	6.000	8.590	0.880	0.258	Pass
22.856	51.537	6.000	8.590	0.880	0.258	Pass
24.728	51.537	6.000	8.590	0.880	0.258	Pass
25.240	51.537	6.000	8.590	0.880	0.258	Pass
25.240	51.537	6.000	8.590	0.880	0.258	Pass
25.240	51.537	6.000	8.590	0.880	0.258	Pass
25.240	51.537	6.000	8.590	0.880	0.258	Pass
25.240	51.537	6.000	8.590	0.880	0.258	Pass
25.240	51.537	6.000	8.590	0.880	0.258	Pass
25.240	51.537	6.000	8.590	0.880	0.258	Pass
25.240	51.537	6.000	8.590	0.880	0.258	Pass
25.240	51.537	6.000	8.590	0.880	0.258	Pass
25.240	51.537	6.000	8.590	0.880	0.258	Pass
25.240	51.537	6.000	8.590	0.880	0.258	Pass
	As (in^2) 0.000 18.508 19.300 20.240 20.240 20.479 20.988 22.856 24.728 25.240 25.240 25.240 25.240 25.240 25.240 25.240 25.240 25.240	As (in^2)         Effective Depth (in)           0.000         18.508         42.516           19.300         44.406         20.240         46.822           20.479         51.537         20.988         51.537           20.988         51.537         22.856         51.537           22.856         51.537         25.240         51.537           25.240         51.537         25.240         51.537           25.240         51.537         25.240         51.537           25.240         51.537         25.240         51.537           25.240         51.537         25.240         51.537           25.240         51.537         25.240         51.537           25.240         51.537         25.240         51.537           25.240         51.537         25.240         51.537           25.240         51.537         25.240         51.537           25.240         51.537         25.240         51.537           25.240         51.537         25.240         51.537           25.240         51.537         25.240         51.537	As (in^2)         Effective Depth (in)         Actual Spac. (in)           0.000         6.000           18.508         42.516         6.000           19.300         44.406         6.000           20.240         46.822         6.000           20.240         46.822         6.000           20.479         51.537         6.000           20.479         51.537         6.000           20.479         51.537         6.000           22.856         51.537         6.000           24.728         51.537         6.000           25.240         51.537         6.000           25.240         51.537         6.000           25.240         51.537         6.000           25.240         51.537         6.000           25.240         51.537         6.000           25.240         51.537         6.000           25.240         51.537         6.000           25.240         51.537         6.000           25.240         51.537         6.000           25.240         51.537         6.000           25.240         51.537         6.000           25.240         51.537	As (in^2)         Effective Depth (in)         Actual Spac. (in)         Max. Spac. (in)           0.000         6.000           18.508         42.516         6.000         7.086           19.300         44.406         6.000         7.086           19.300         44.406         6.000         7.401           20.240         46.822         6.000         7.804           20.479         51.537         6.000         8.590           22.856         51.537         6.000         8.590           24.728         51.537         6.000         8.590           25.240         51.537         6.000         8.590           25.240         51.537         6.000         8.590           25.240         51.537         6.000         8.590           25.240         51.537         6.000         8.590           25.240         51.537         6.000         8.590           25.240         51.537         6.000         8.590           25.240         51.537         6.000         8.590           25.240         51.537         6.000         8.590           25.240         51.537         6.000         8.590 <t< td=""><td>As (in^2)         Effective Depth (in)         Actual Spac. (in)         Max. Spac. (in)         Actual Ask (in^2/ft)           0.000         6.000         0.880           18.508         42.516         6.000         7.086         0.880           19.300         44.406         6.000         7.401         0.880           20.240         46.822         6.000         7.804         0.880           20.240         46.822         6.000         8.590         0.880           20.479         51.537         6.000         8.590         0.880           22.856         51.537         6.000         8.590         0.880           24.728         51.537         6.000         8.590         0.880           25.240         51.537         6.000         8.590         0.880           25.240         51.537         6.000         8.590         0.880           25.240         51.537         6.000         8.590         0.880           25.240         51.537         6.000         8.590         0.880           25.240         51.537         6.000         8.590         0.880           25.240         51.537         6.000         8.590         0.880     <td>As (in^2)         Effective Depth (in)         Actual Spac. (in)         Max. Spac. (in)         Actual Ask (in^2/ft)         Required Ask (in^2/ft)           0.000         6.000         0.880         0.150           18.508         42.516         6.000         7.086         0.880         0.150           19.300         44.406         6.000         7.401         0.880         0.202           20.240         46.822         6.000         7.804         0.880         0.202           20.479         51.537         6.000         8.590         0.880         0.258           20.988         51.537         6.000         8.590         0.880         0.258           24.728         51.537         6.000         8.590         0.880         0.258           25.240         51.537         6.000         8.590         0.880         0.258           25.240         51.537         6.000         8.590         0.880         0.258           25.240         51.537         6.000         8.590         0.880         0.258           25.240         51.537         6.000         8.590         0.880         0.258           25.240         51.537         6.000         8.590         <t< td=""></t<></td></td></t<>	As (in^2)         Effective Depth (in)         Actual Spac. (in)         Max. Spac. (in)         Actual Ask (in^2/ft)           0.000         6.000         0.880           18.508         42.516         6.000         7.086         0.880           19.300         44.406         6.000         7.401         0.880           20.240         46.822         6.000         7.804         0.880           20.240         46.822         6.000         8.590         0.880           20.479         51.537         6.000         8.590         0.880           22.856         51.537         6.000         8.590         0.880           24.728         51.537         6.000         8.590         0.880           25.240         51.537         6.000         8.590         0.880           25.240         51.537         6.000         8.590         0.880           25.240         51.537         6.000         8.590         0.880           25.240         51.537         6.000         8.590         0.880           25.240         51.537         6.000         8.590         0.880           25.240         51.537         6.000         8.590         0.880 <td>As (in^2)         Effective Depth (in)         Actual Spac. (in)         Max. Spac. (in)         Actual Ask (in^2/ft)         Required Ask (in^2/ft)           0.000         6.000         0.880         0.150           18.508         42.516         6.000         7.086         0.880         0.150           19.300         44.406         6.000         7.401         0.880         0.202           20.240         46.822         6.000         7.804         0.880         0.202           20.479         51.537         6.000         8.590         0.880         0.258           20.988         51.537         6.000         8.590         0.880         0.258           24.728         51.537         6.000         8.590         0.880         0.258           25.240         51.537         6.000         8.590         0.880         0.258           25.240         51.537         6.000         8.590         0.880         0.258           25.240         51.537         6.000         8.590         0.880         0.258           25.240         51.537         6.000         8.590         0.880         0.258           25.240         51.537         6.000         8.590         <t< td=""></t<></td>	As (in^2)         Effective Depth (in)         Actual Spac. (in)         Max. Spac. (in)         Actual Ask (in^2/ft)         Required Ask (in^2/ft)           0.000         6.000         0.880         0.150           18.508         42.516         6.000         7.086         0.880         0.150           19.300         44.406         6.000         7.401         0.880         0.202           20.240         46.822         6.000         7.804         0.880         0.202           20.479         51.537         6.000         8.590         0.880         0.258           20.988         51.537         6.000         8.590         0.880         0.258           24.728         51.537         6.000         8.590         0.880         0.258           25.240         51.537         6.000         8.590         0.880         0.258           25.240         51.537         6.000         8.590         0.880         0.258           25.240         51.537         6.000         8.590         0.880         0.258           25.240         51.537         6.000         8.590         0.880         0.258           25.240         51.537         6.000         8.590 <t< td=""></t<>