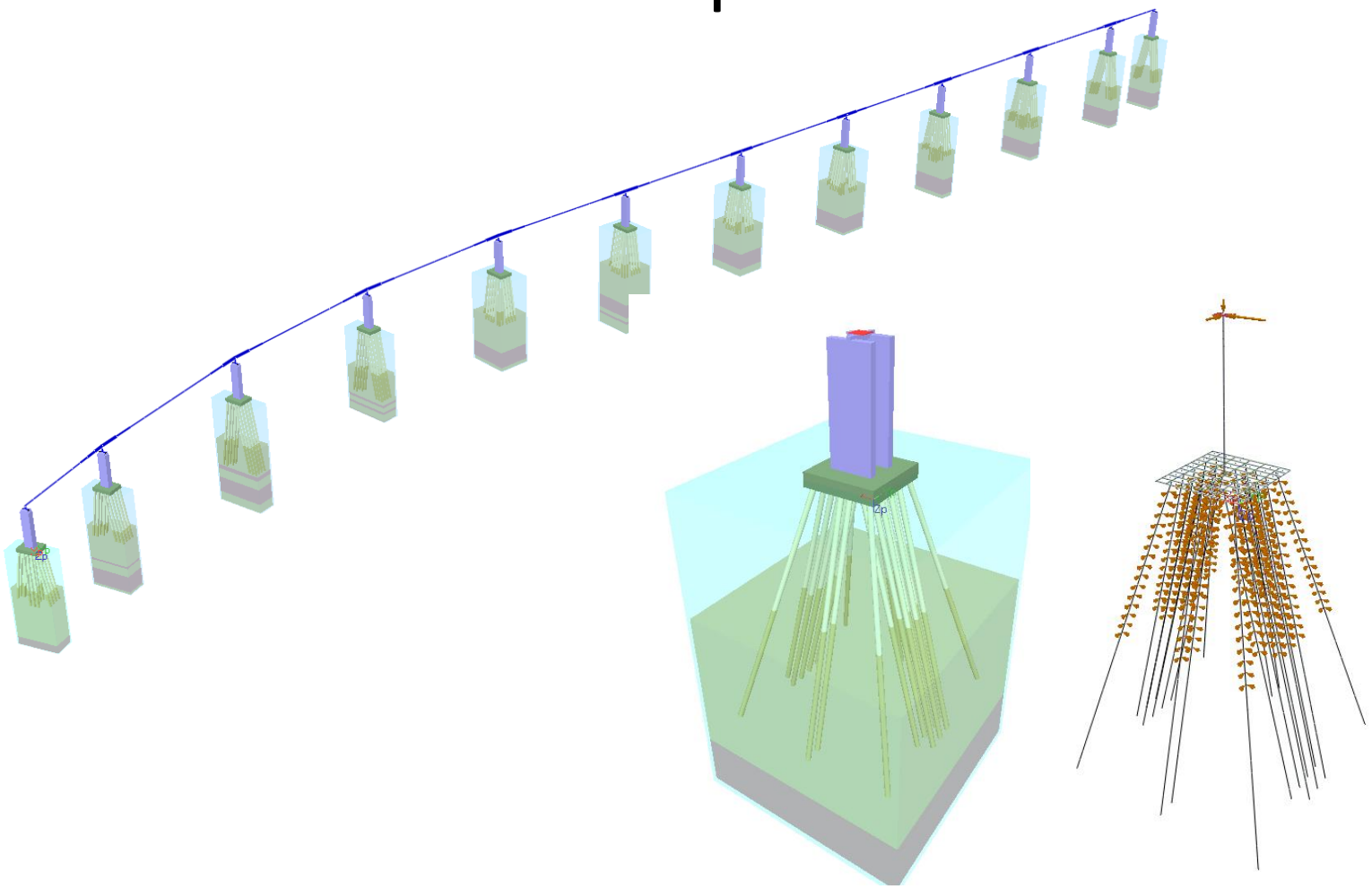
FB-MultiPier Update

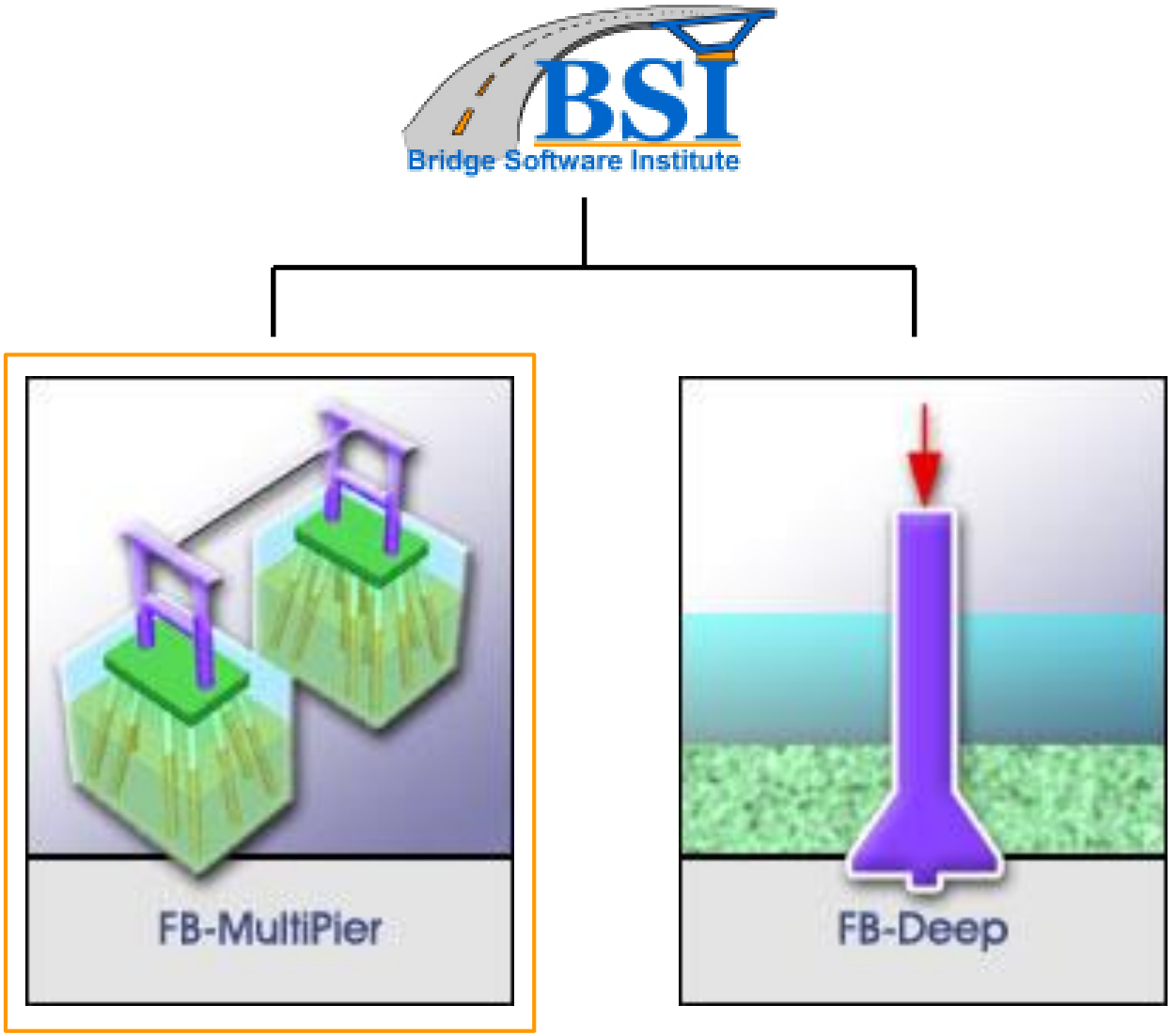


Jae H. Chung, Ph.D. and Henry T. Bollmann, P.E.
Bridge Software Institute
University of Florida
Gainesville, Florida
June 11, 2014

Agenda

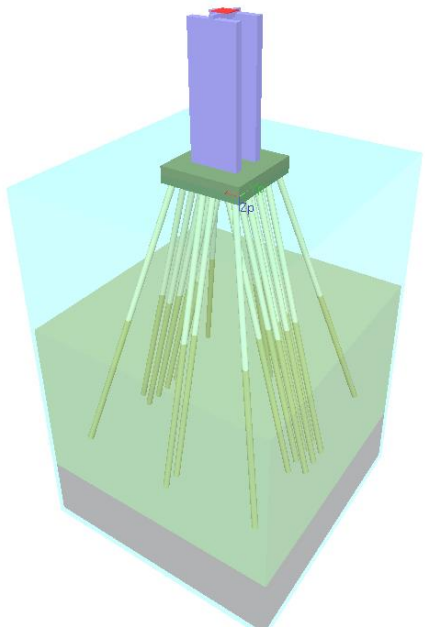
- Part I: FB-MultiPier New Features of Upcoming Releases and Medium-Term Development (presented by Jae Chung)
- Part II: Use of Design Tables and Model Showcase (presented by Henry Bollmann)

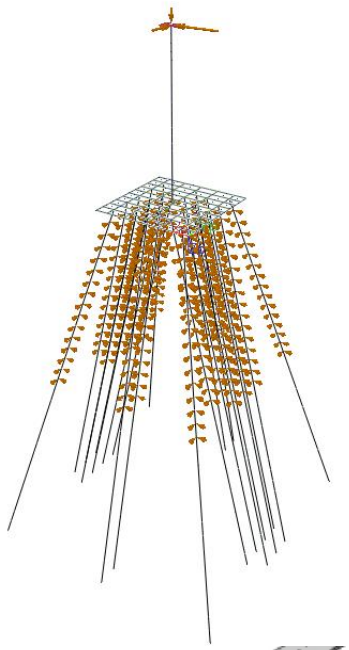
Bridge Software Institute (BSI) Products



FB-MultiPier Software Program

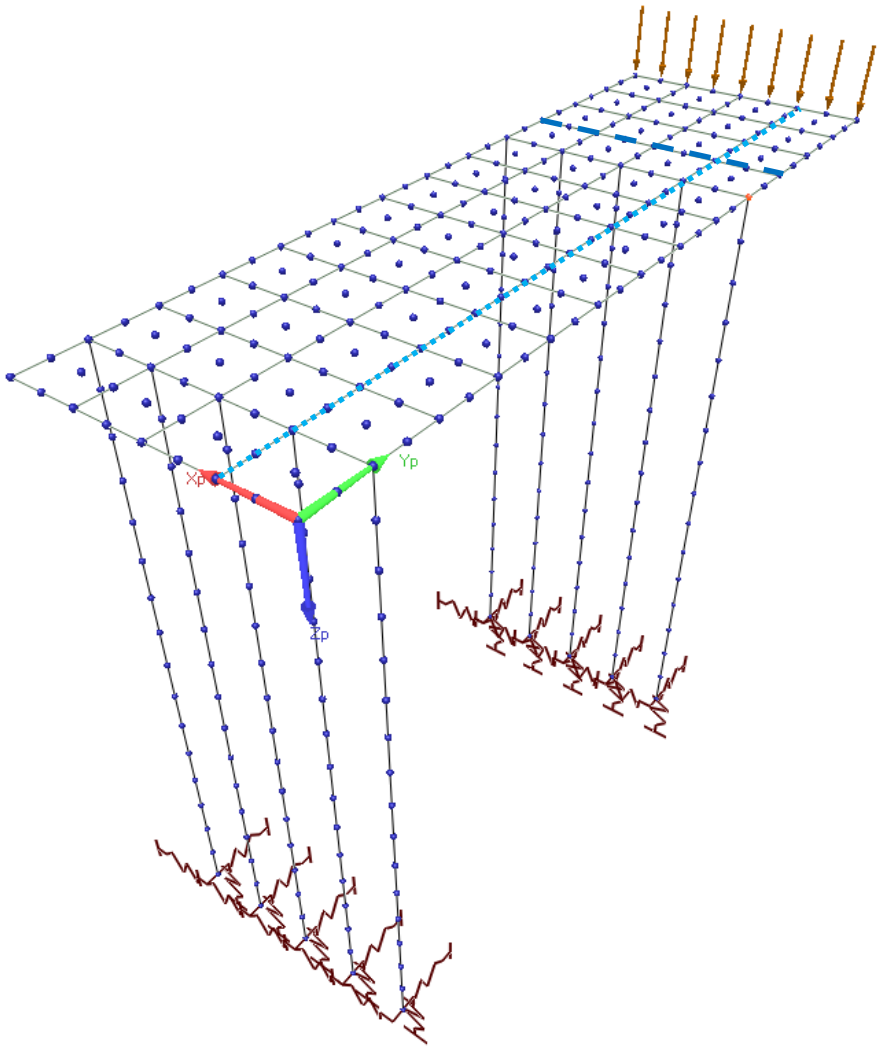
- Nonlinear Finite Element Analysis Tool for Use in Bridge Design Application
  - Material nonlinearity and large-deformation (p-delta effect) can be analyzed using a 3-D frame finite element formulation coupled with soil resistance (4 nonlinear soil springs per each node of FE structure frame).
  - Quasi-static and dynamic analyses can be performed either separately or simultaneously.
  - Simplified input process in geometric definition of pier components and automated FE mesh (structural skeleton) generation saves time and makes it easy for model calibration.
  - Biaxial Moment-Interaction Diagram and easy-to-use materials modeling options are a few to mention.
  - Analysis capabilities of coupled soil-structure interaction is the main strength of the program.





Features for Upcoming Releases: Pile Cap Summary Forces (V4.19.1)

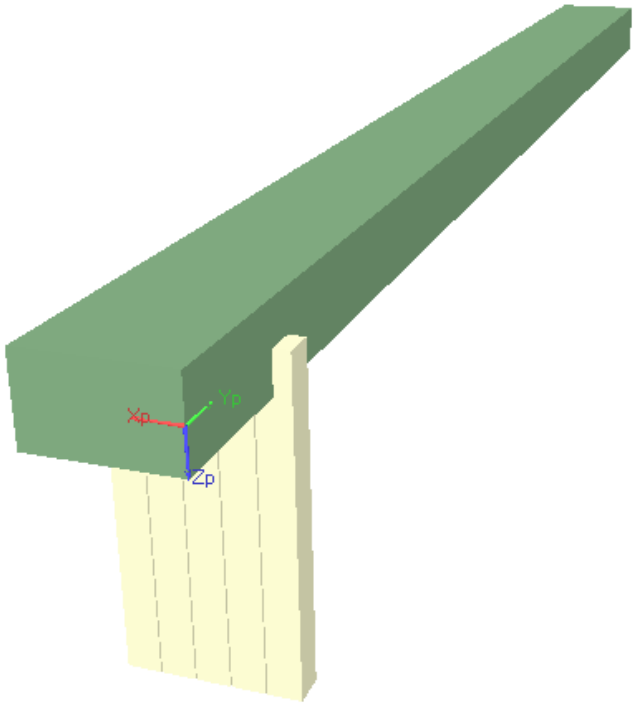
- Flexure
  - Max positive moment
  - Max negative moment
- Shear
  - Max magnitude shear force
- Force Envelopes
  - Across all load cases
  - Per load case



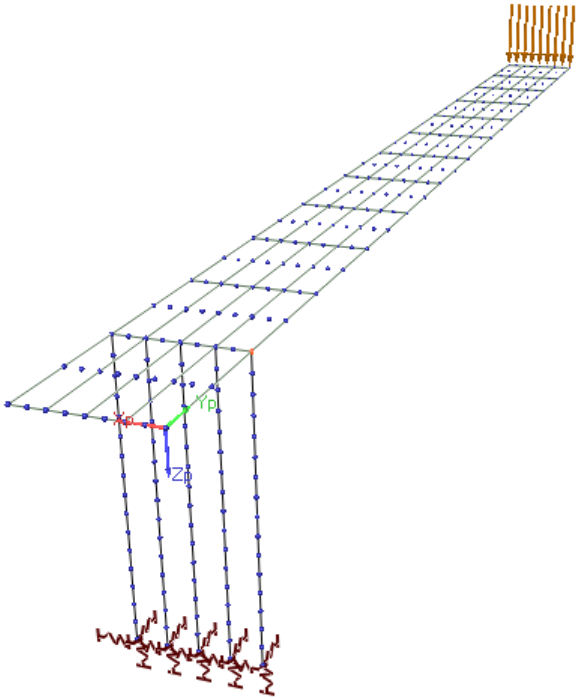
BSI Bridge Software Institute

Illustration of Pile Cap Summary Forces (V4.19.1)

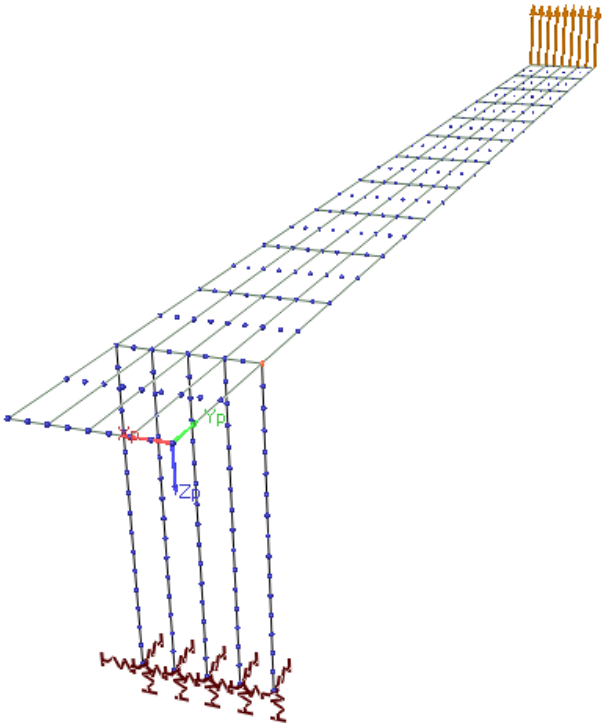
- Pile Cap Summary Force Calculations



Pile and cap model



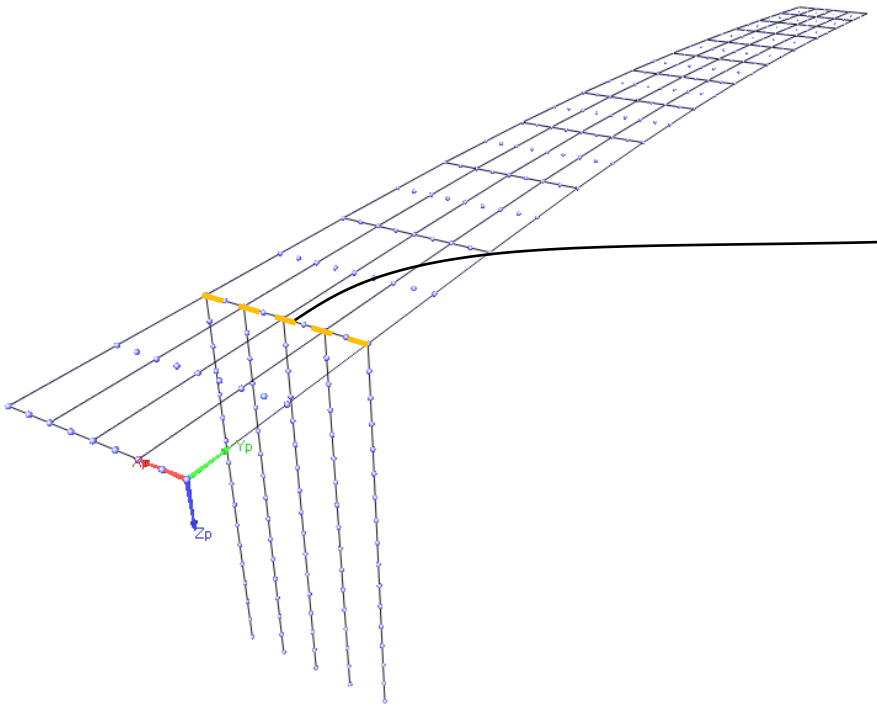
Load Case 1

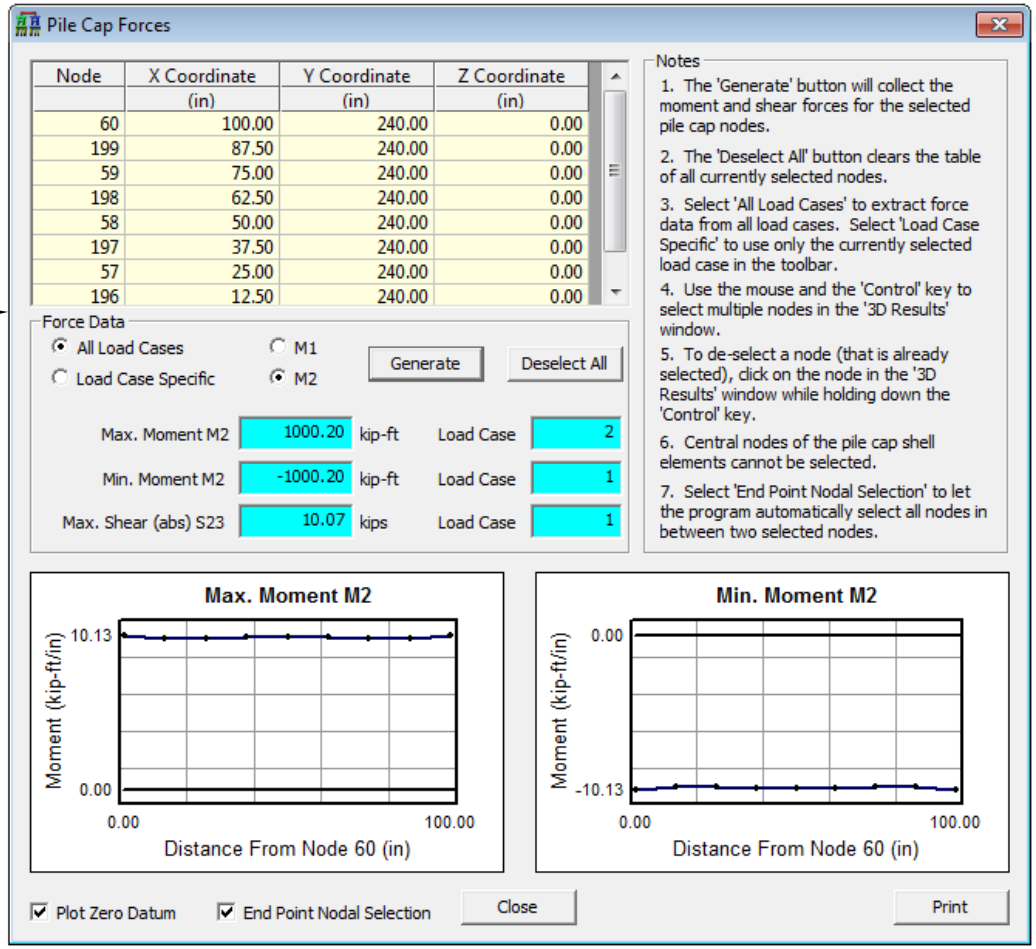


Load Case 2

Pile Cap Summary Forces (V4.19.1)

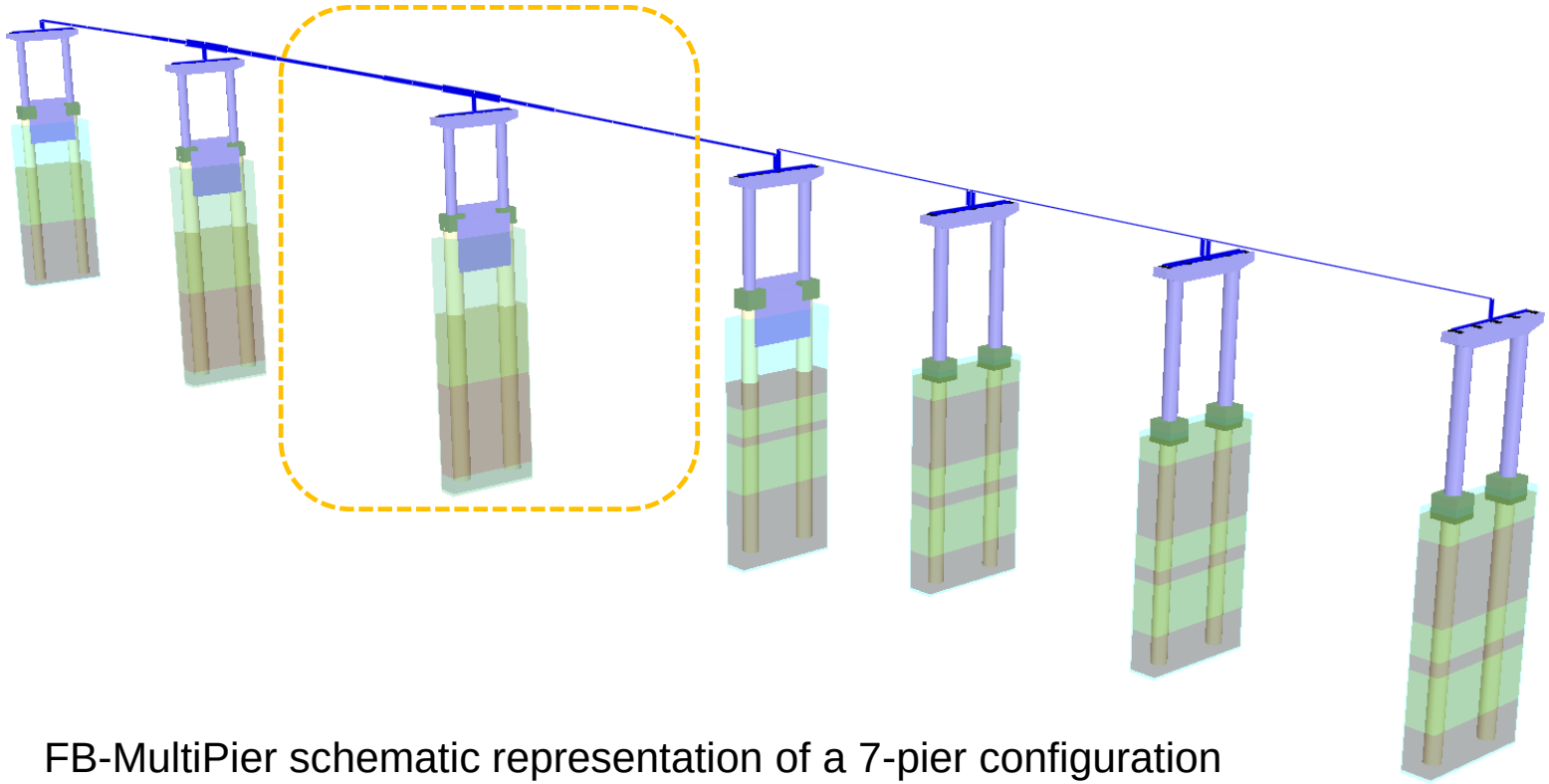
- 3D results
- Graphical selection of section





Features for Upcoming Releases: One-Pier Two-Span Model (V4.20)

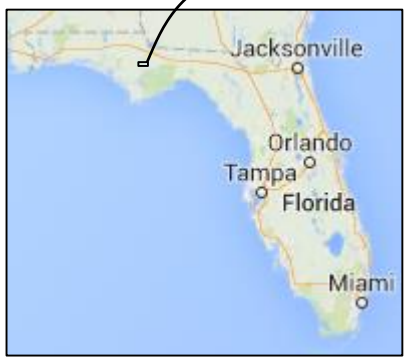
- Simplified Bridge Model for Dynamic Analysis
  - A single pier of interest
  - Two Adjacent Spans
  - 6 DOF's discrete springs are at both ends of the two adjacent spans



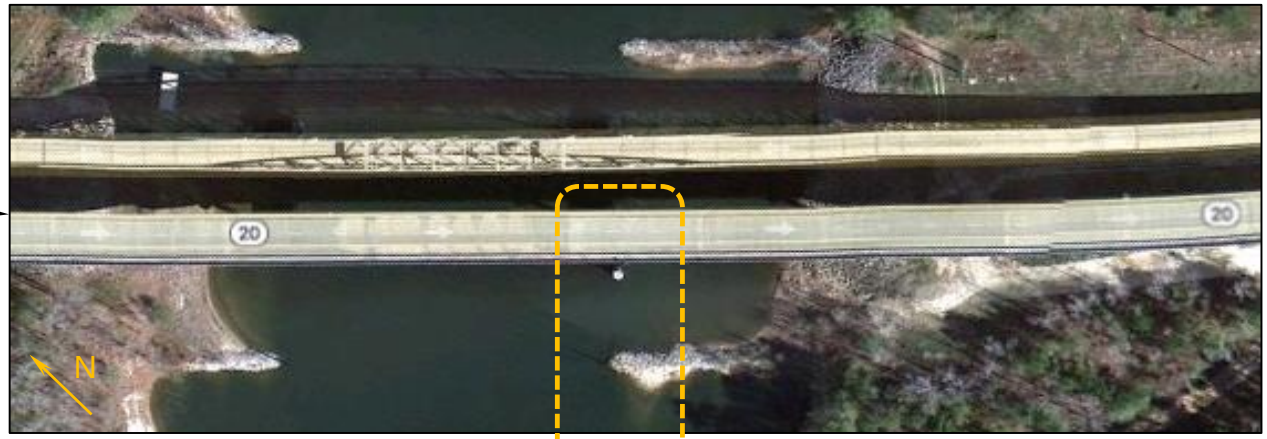
FB-MultiPier schematic representation of a 7-pier configuration

Illustration of OPTS Model

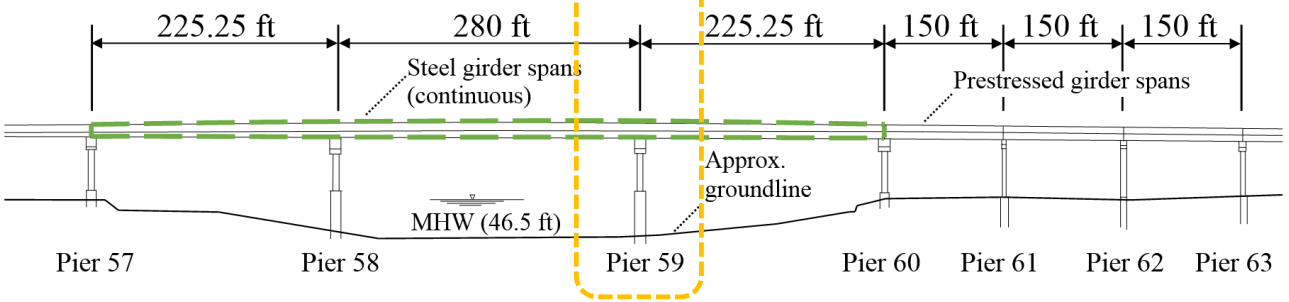
- Multiple-pier model of SR-20 Apalachicola River Bridge
  - Eastern channel pier (Pier 59) subjected to lateral dynamic loading



Source: Google maps

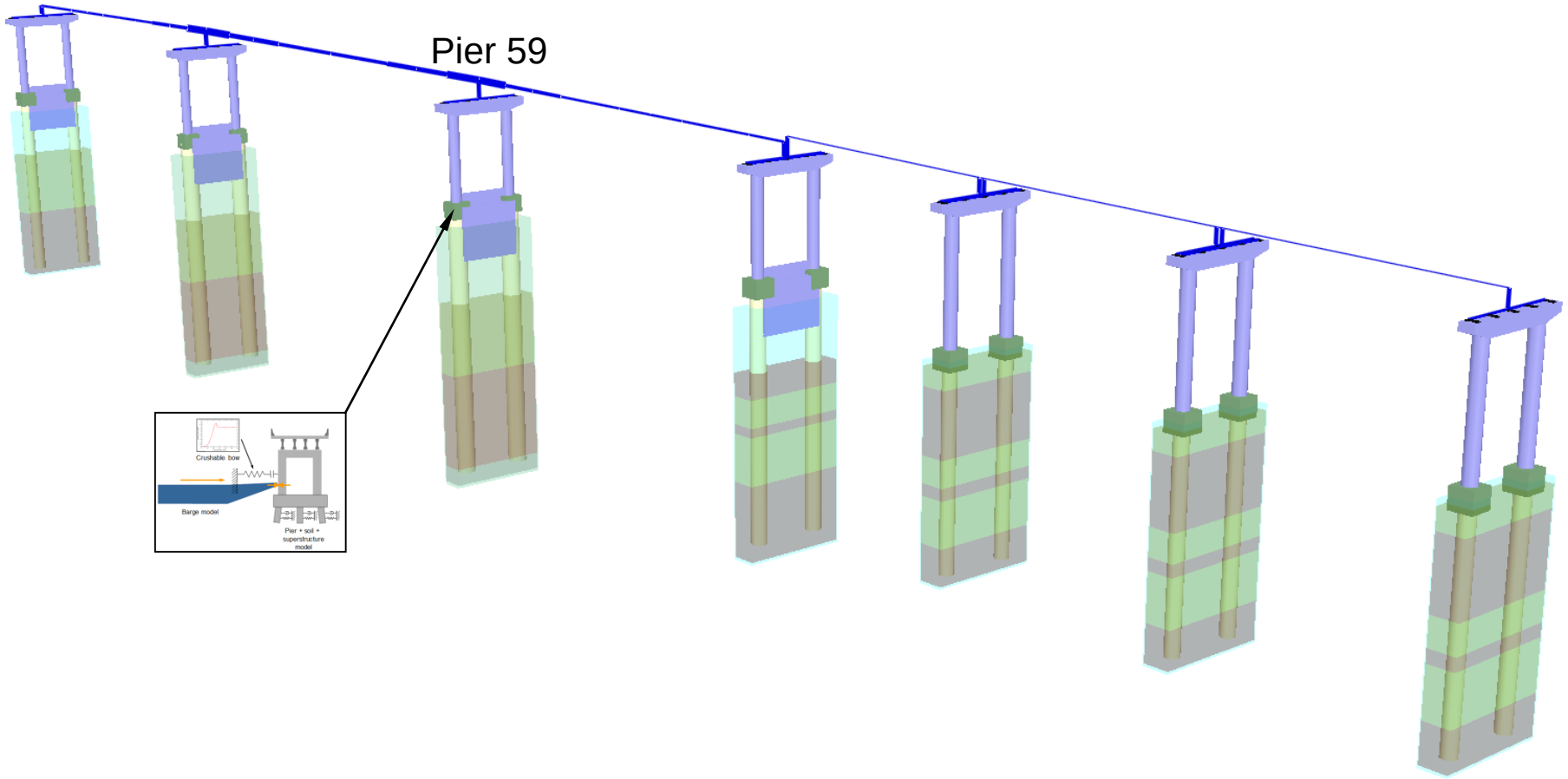


Source: Google maps



FB-MultiPier Analysis

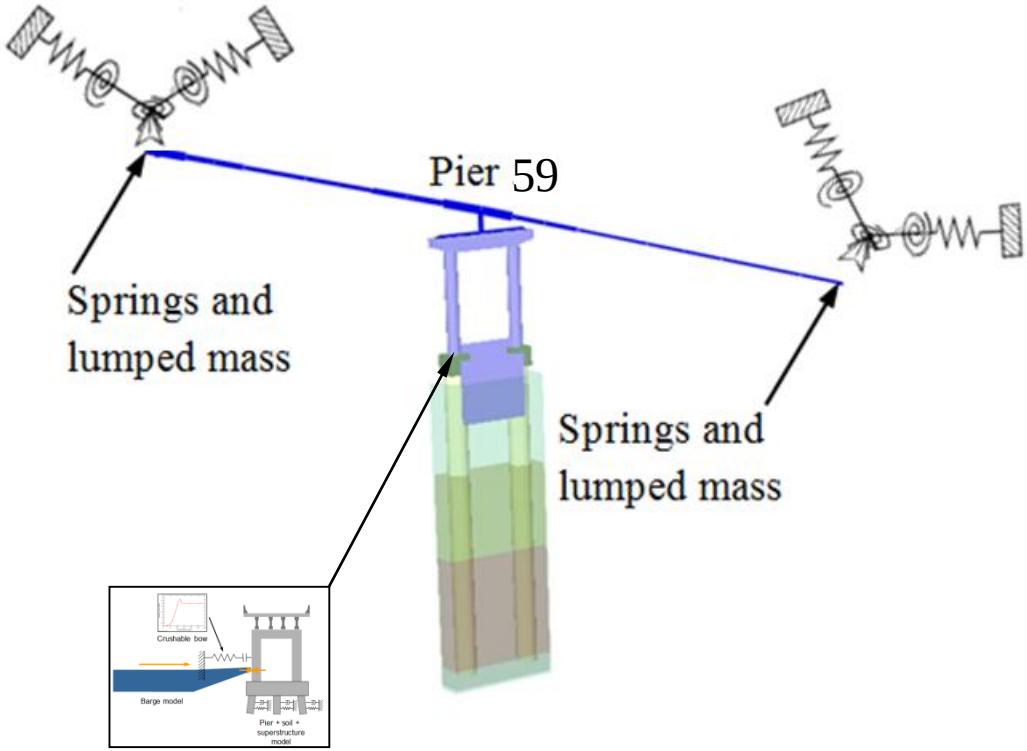
- Seven-Pier model of SR-20 Apalachicola River Bridge
  - Lateral dynamic load on Pier 59



4 sec simulation in 112 min.

FB-MultiPier Analysis Model

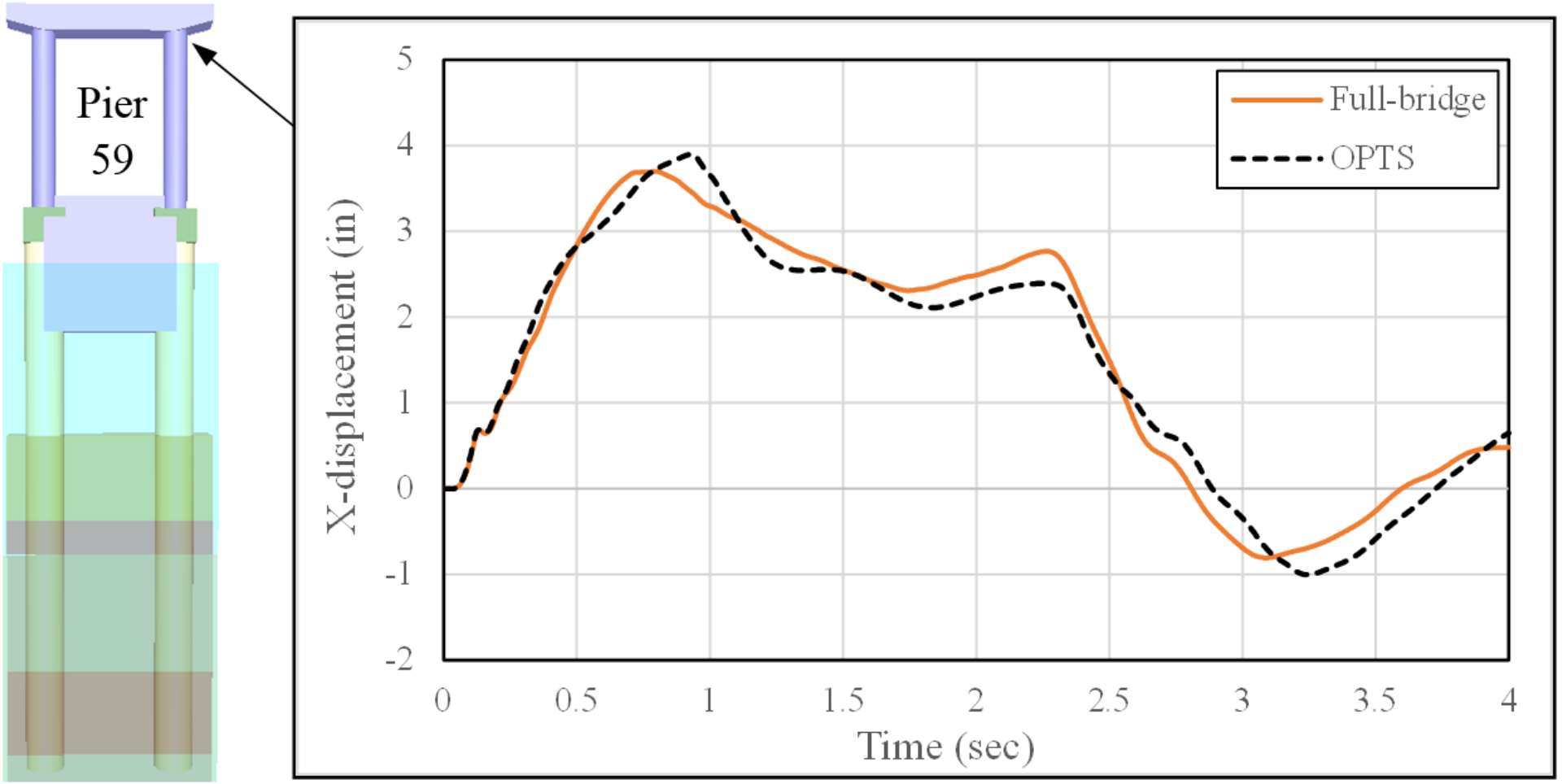
- OPTS modeling approach
  - Lateral dynamic load on Pier 59



4 sec simulation in 5 min.

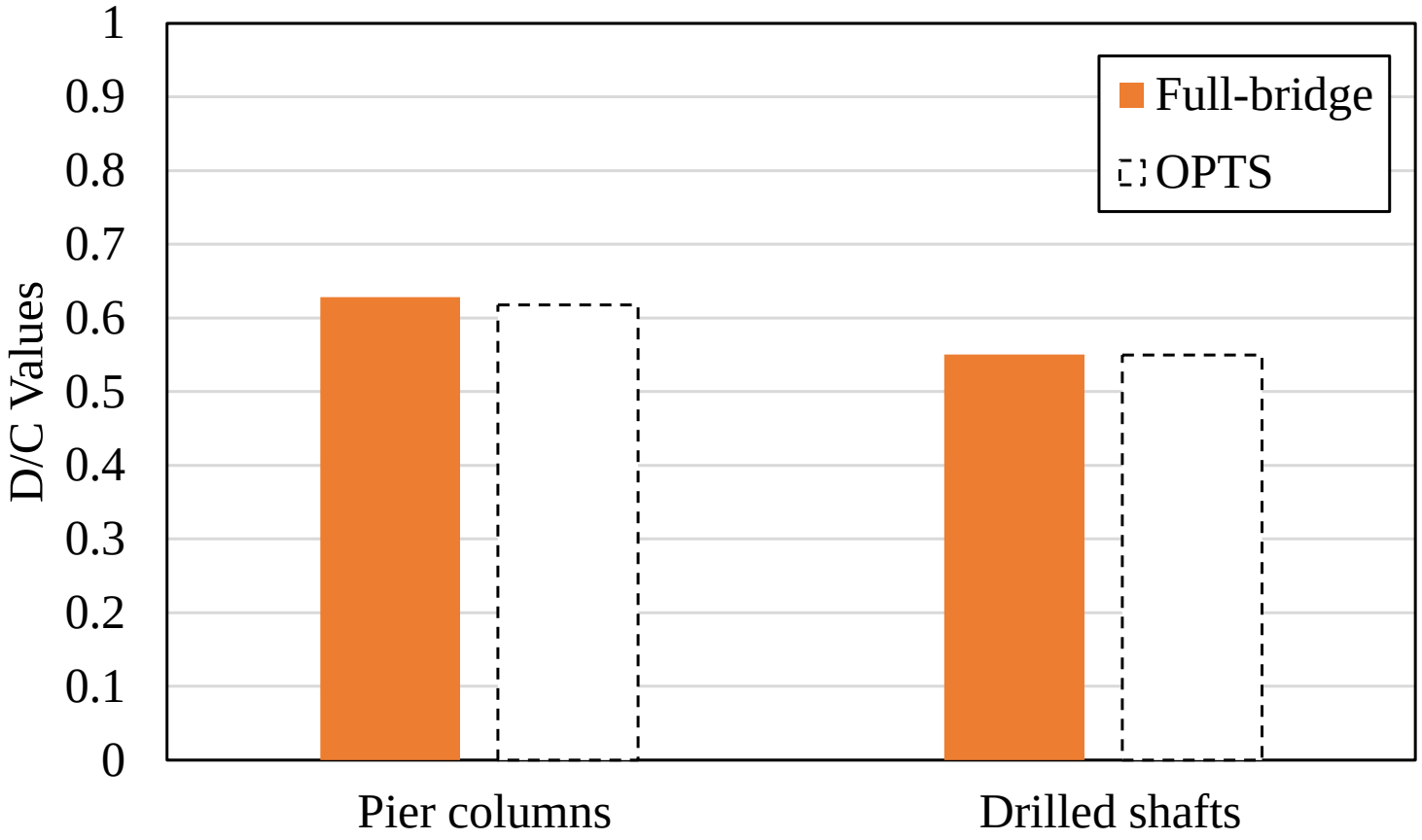
Comparison of Analysis Results

- Lateral displacement prediction



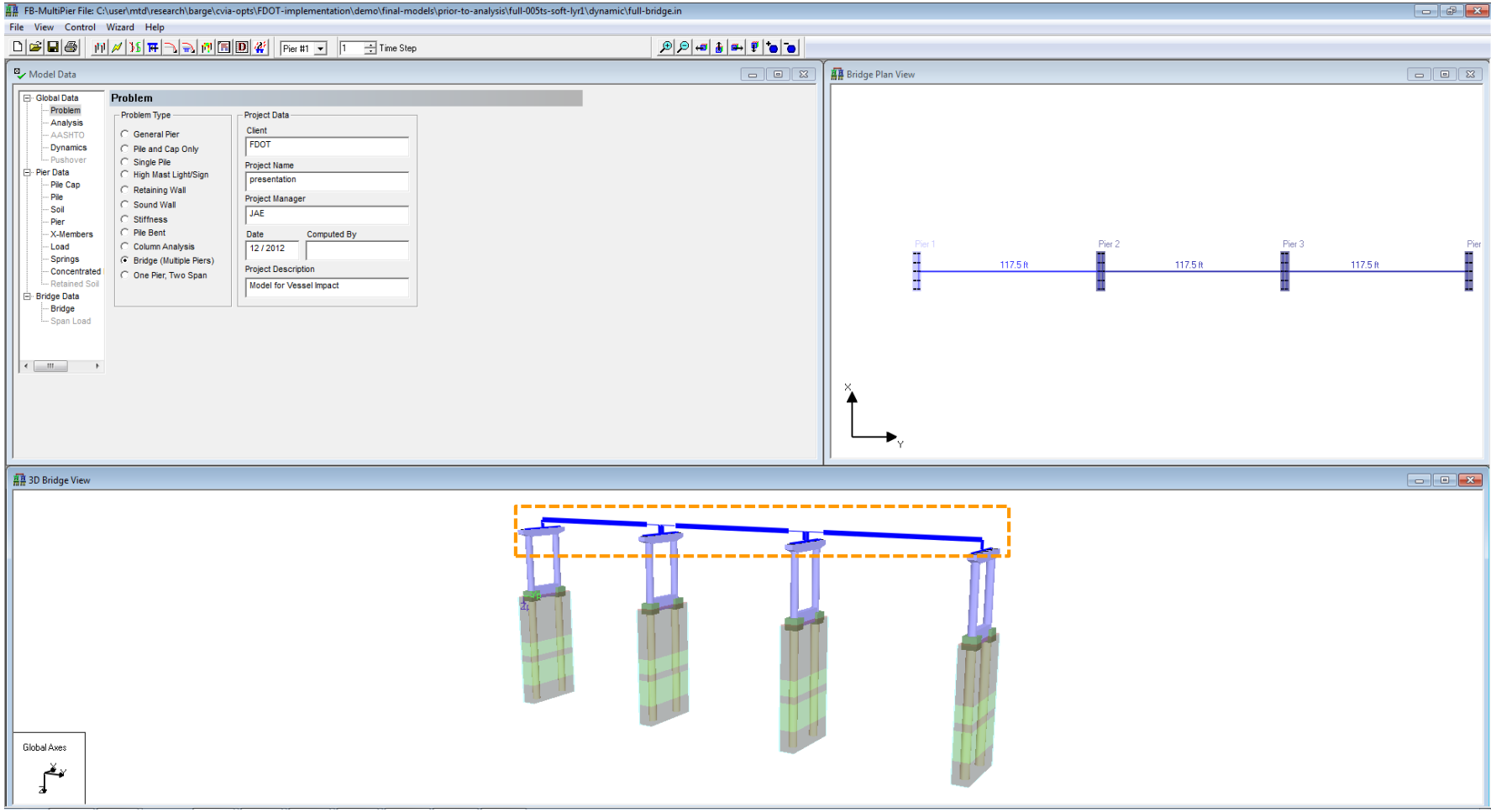
Analysis Results

- Comparison of 7-pier model vs OPTS
  - 2% difference in maximum D/C values



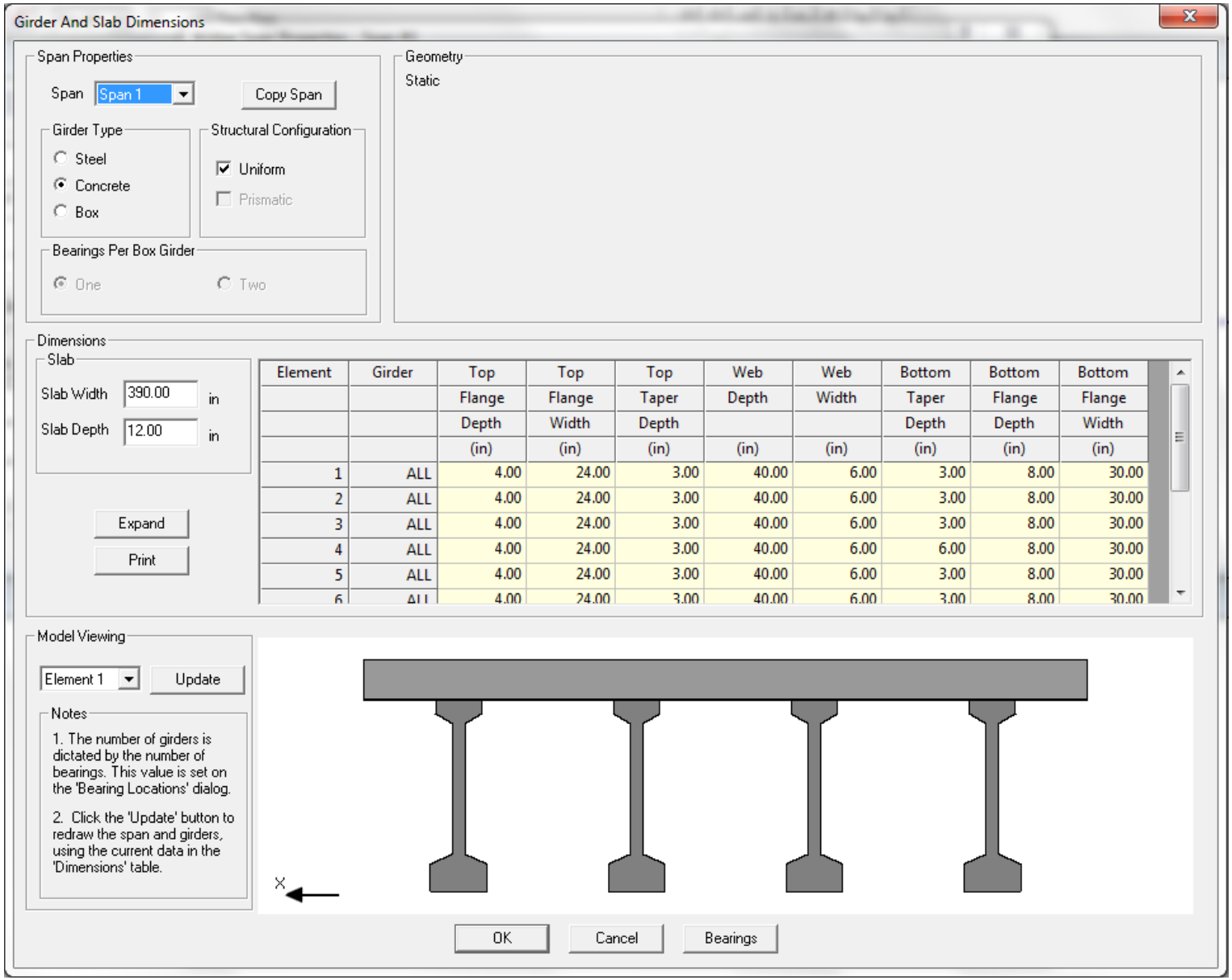
Thermal Load Effects in Piers (V4.21)

- Implemented in Beta Version of FB-MultiPier
  - Can generate AASHTO TU, TG reactions at bearings

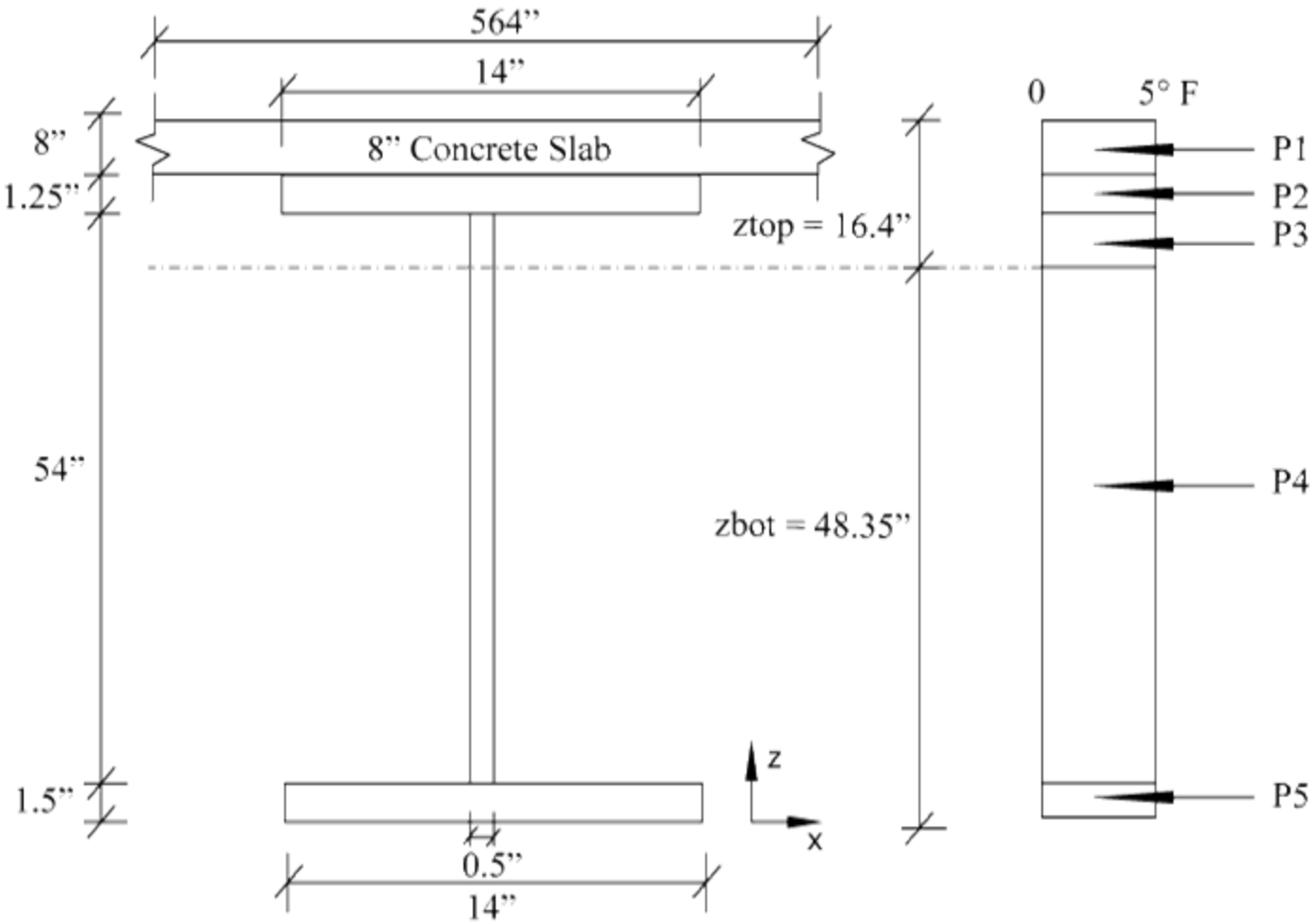


FB-MultiPier GUI

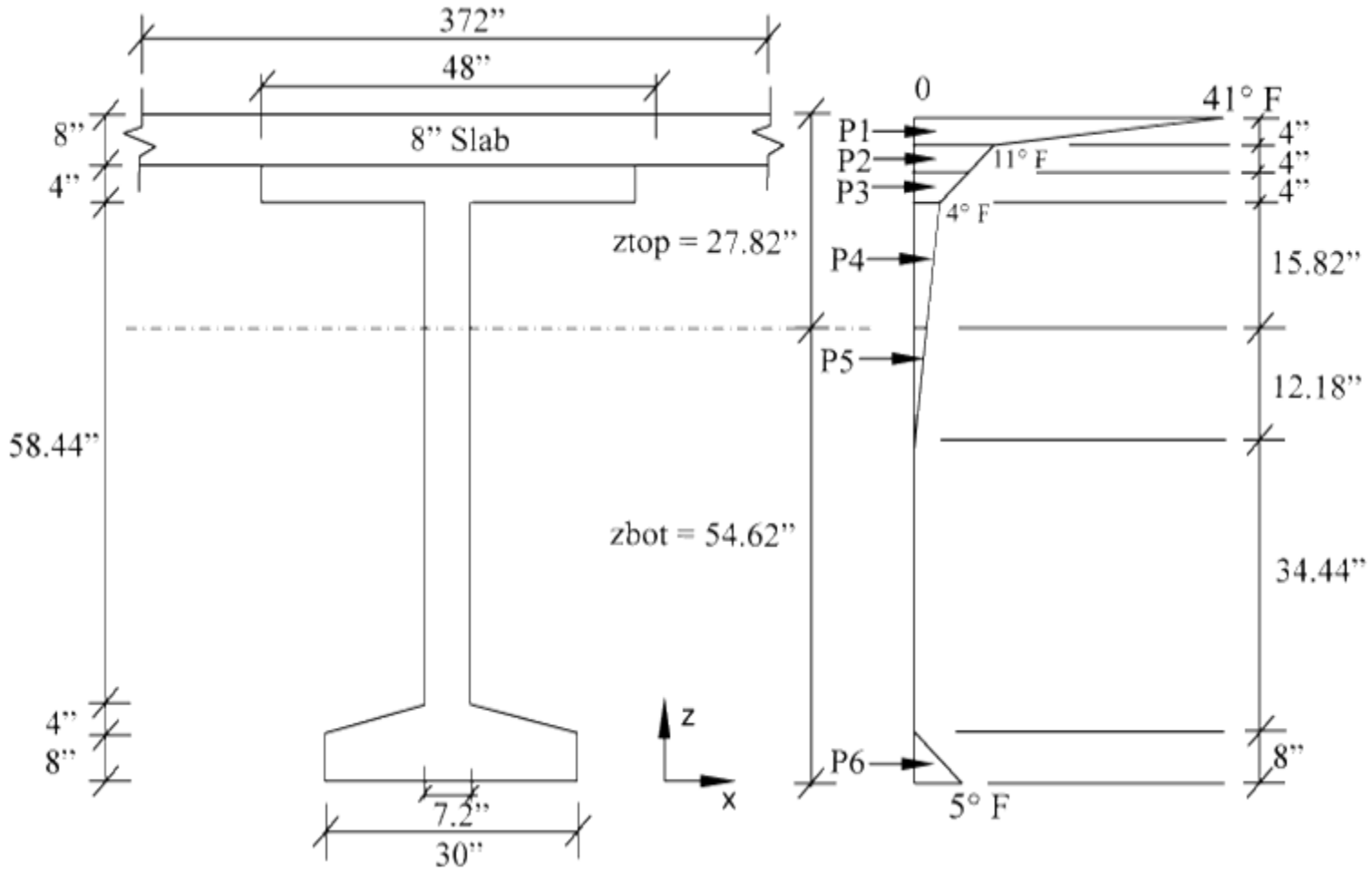
Superstructure Configuration (V4.21)



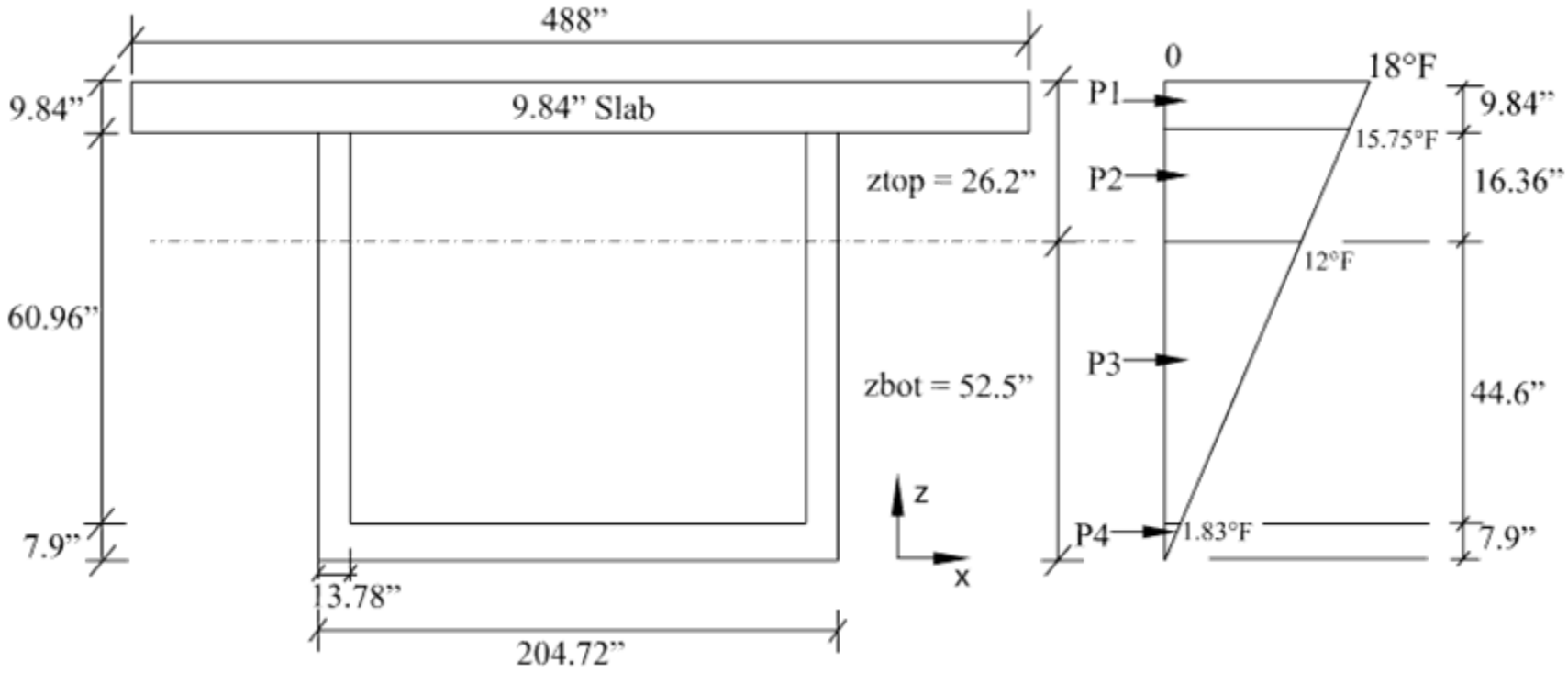
Uniform Temperature Loading: TU (V4.21)



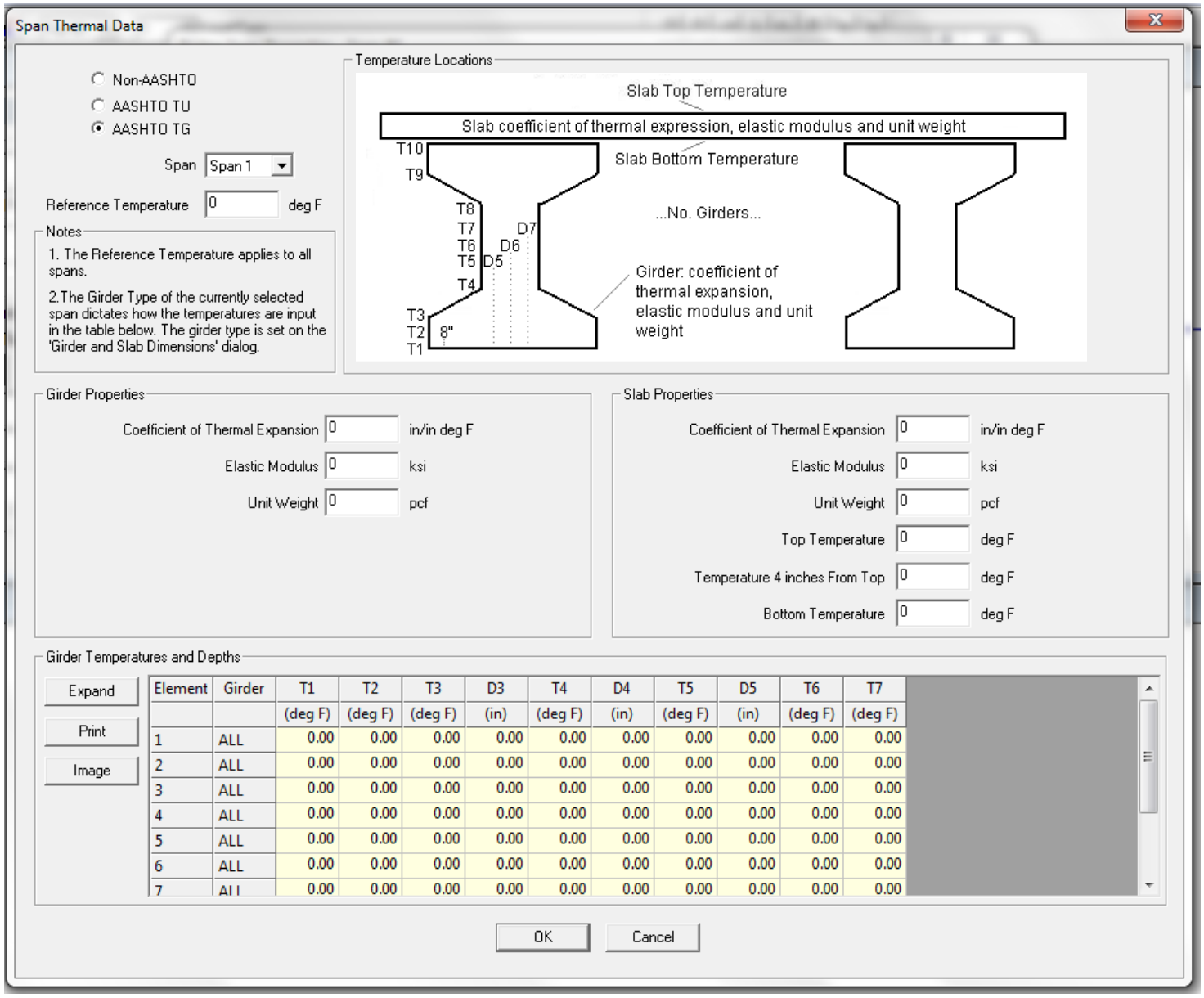
Thermal Gradient Loading: TG (V4.21)



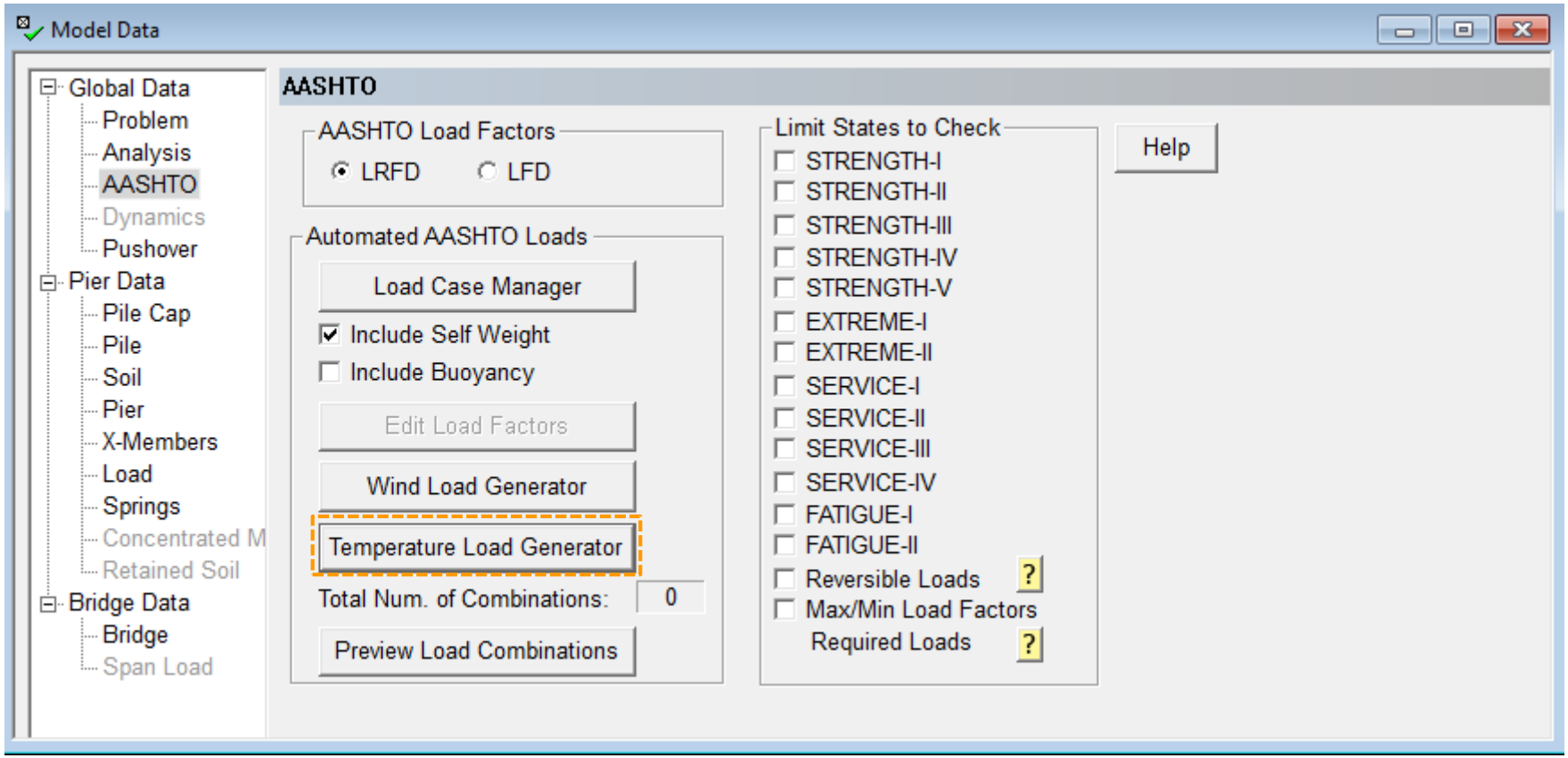
Span-Thermal Loading : User's Option (V4.21)



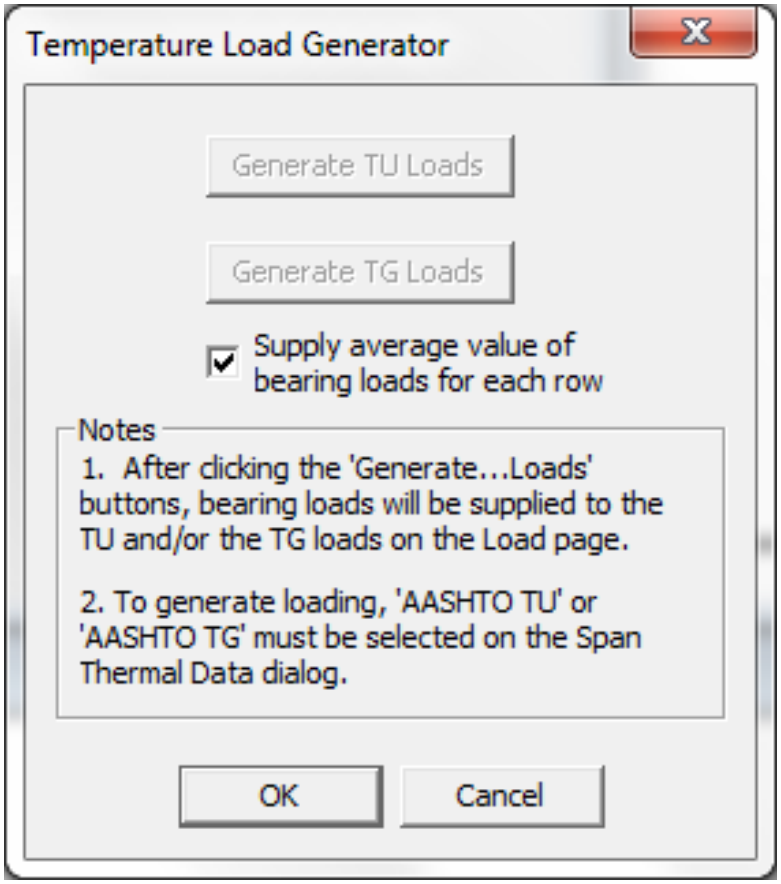
AASHTO Span-Thermal Loading : User's Option (V4.21)



Application of Span-Thermal Loading (V4.21)

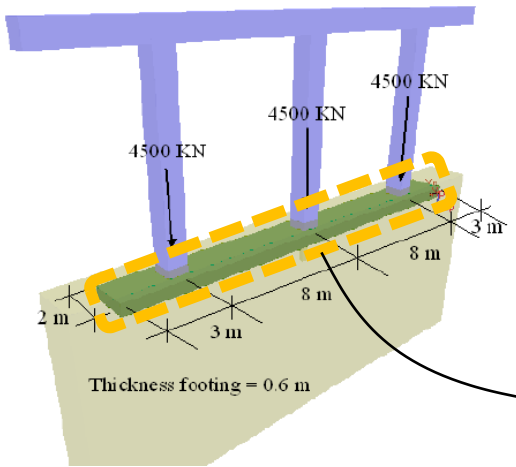


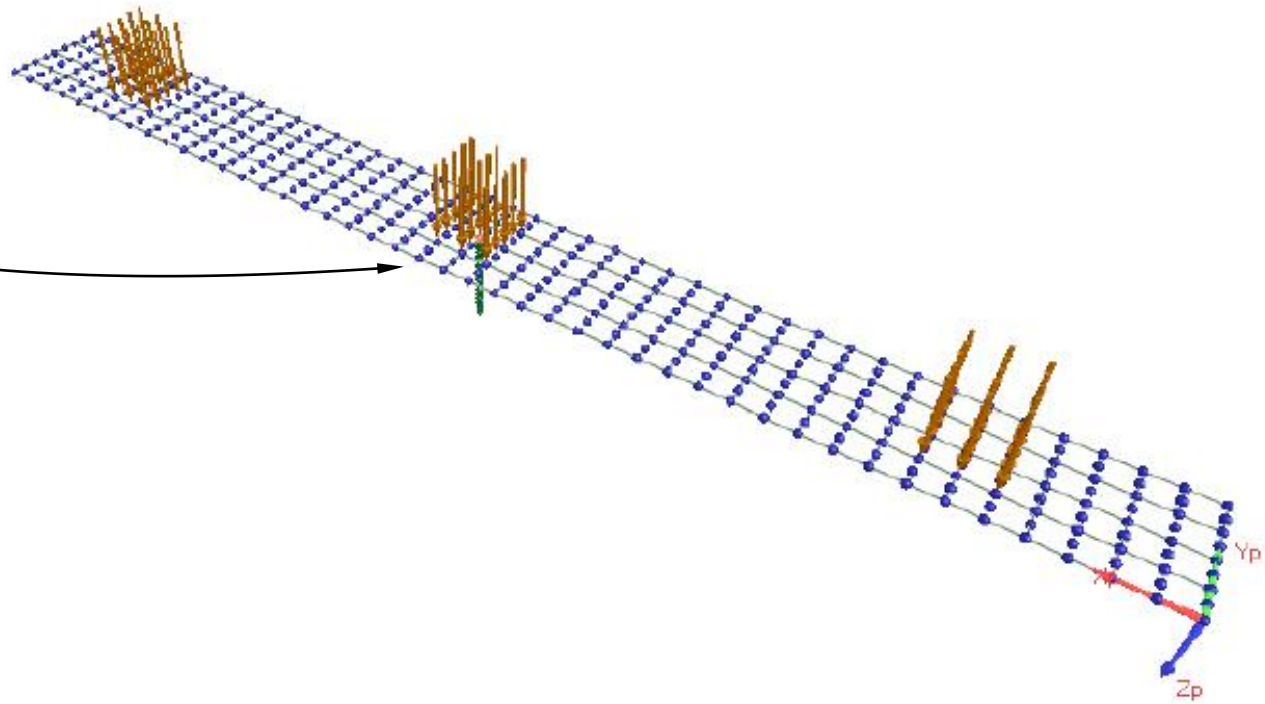
Span-Thermal Loading (V4.21)



Shallow Foundation Modeling (~2016)

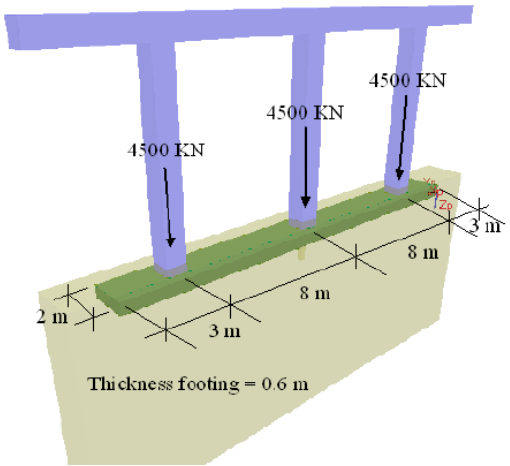
- Spread (or Strip) footings
- Options to model overlying structure and/or pile foundation as usual

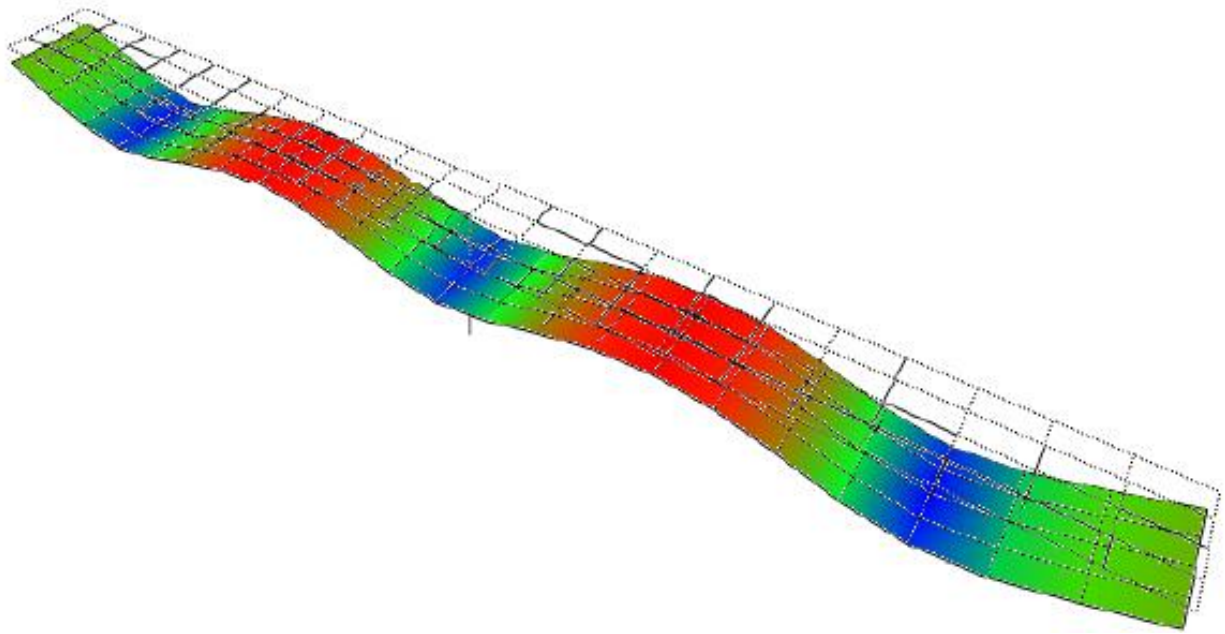




Shallow Foundation Modeling (~2016)

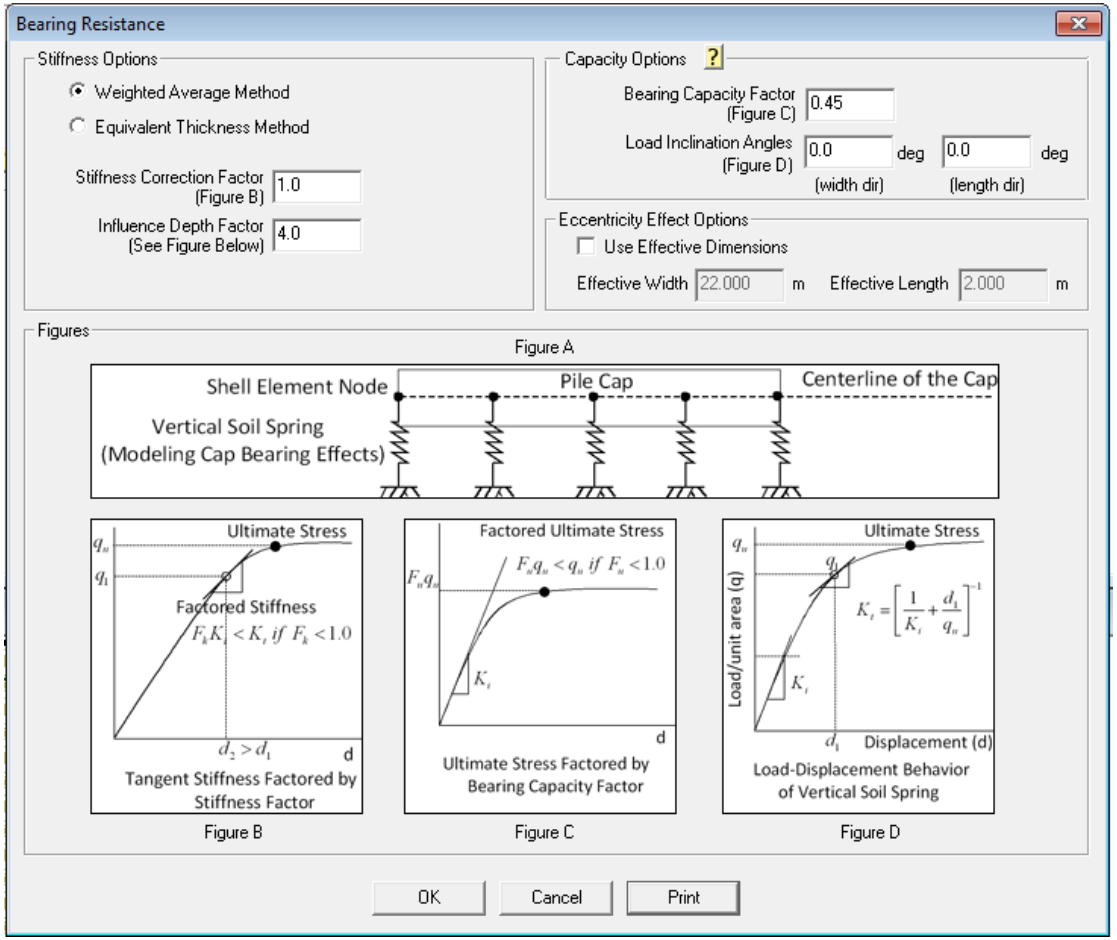
- Nonlinear Soil-Structure Interaction Analysis
  - Numerical integration of vertical stress through a depth
  - Resultant internal forces in finite shell elements coupled with soil resistance
  - Computation of ultimate bearing resistance and settlement distribution

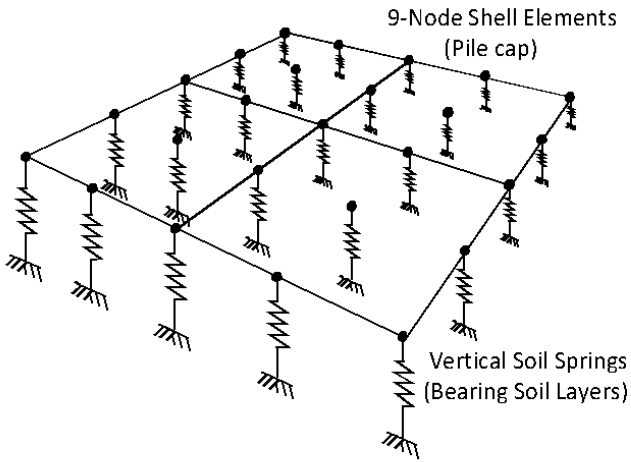




Shallow Foundation Modeling (~2016)

- Partially implemented in a Beta Version of FB-MultiPier for academic education purposes
- Hyperbolic constitutive model (Duncan and Chang)
- Nathan Newmark's stress superposition method, i.e., Stress-Influence Method

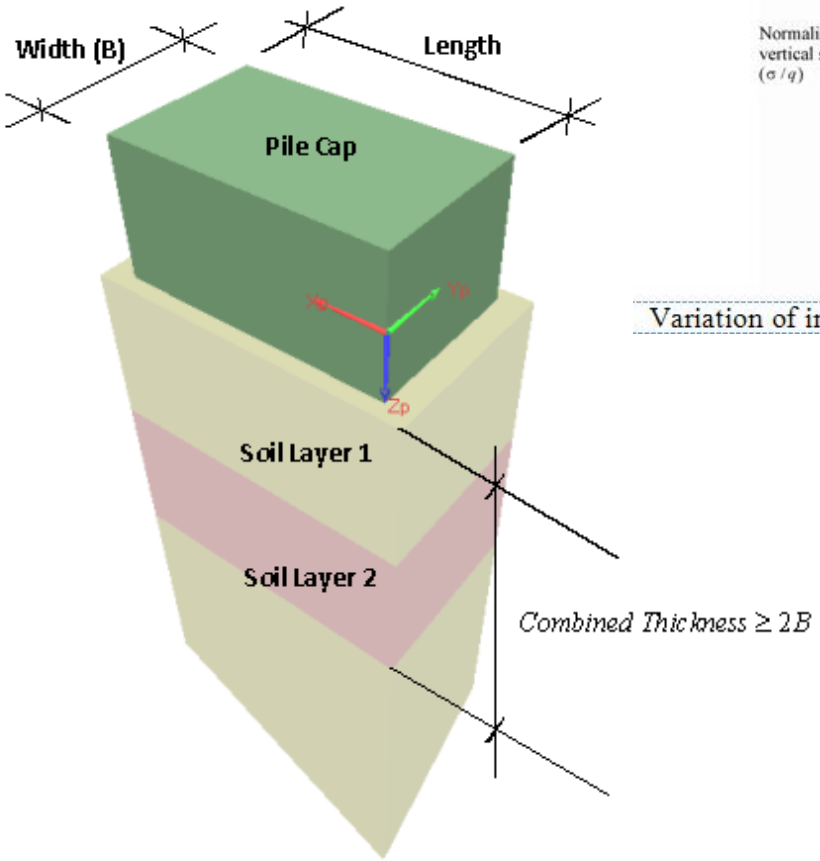


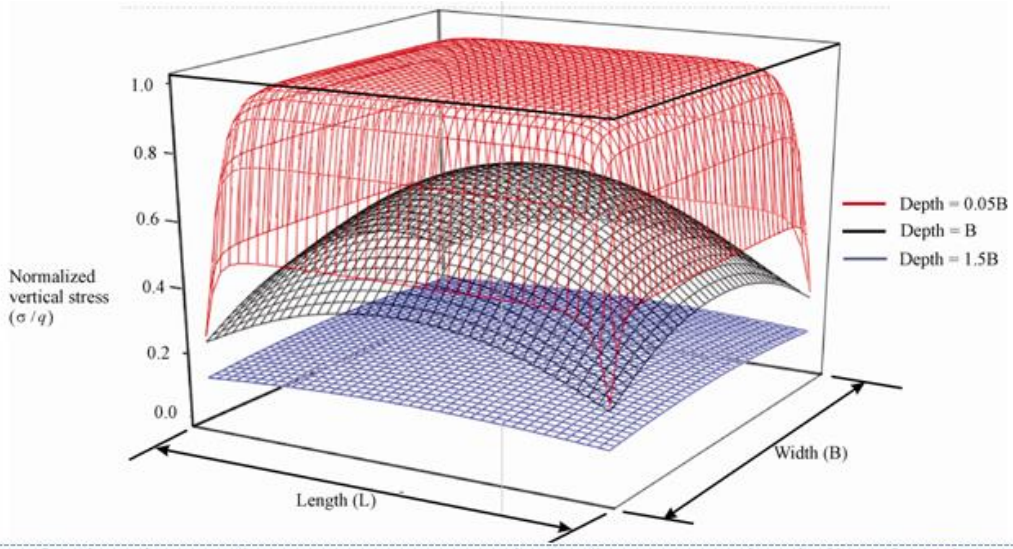


Shallow Foundation Modeling Dialog

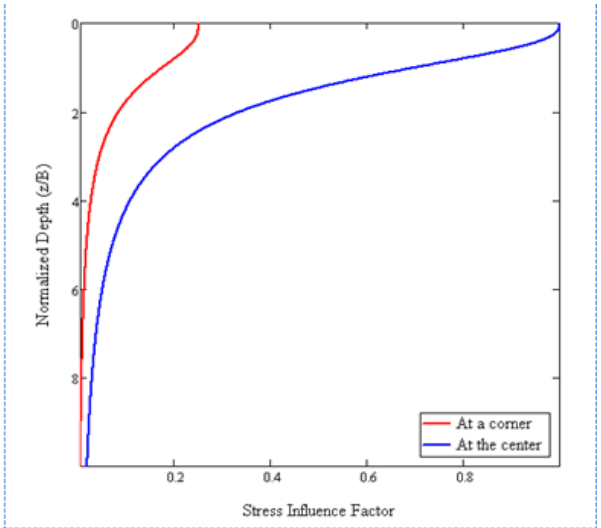
Shallow Foundation Modeling (~2016)

- Limitation of existing theories
- Need for strain-based method



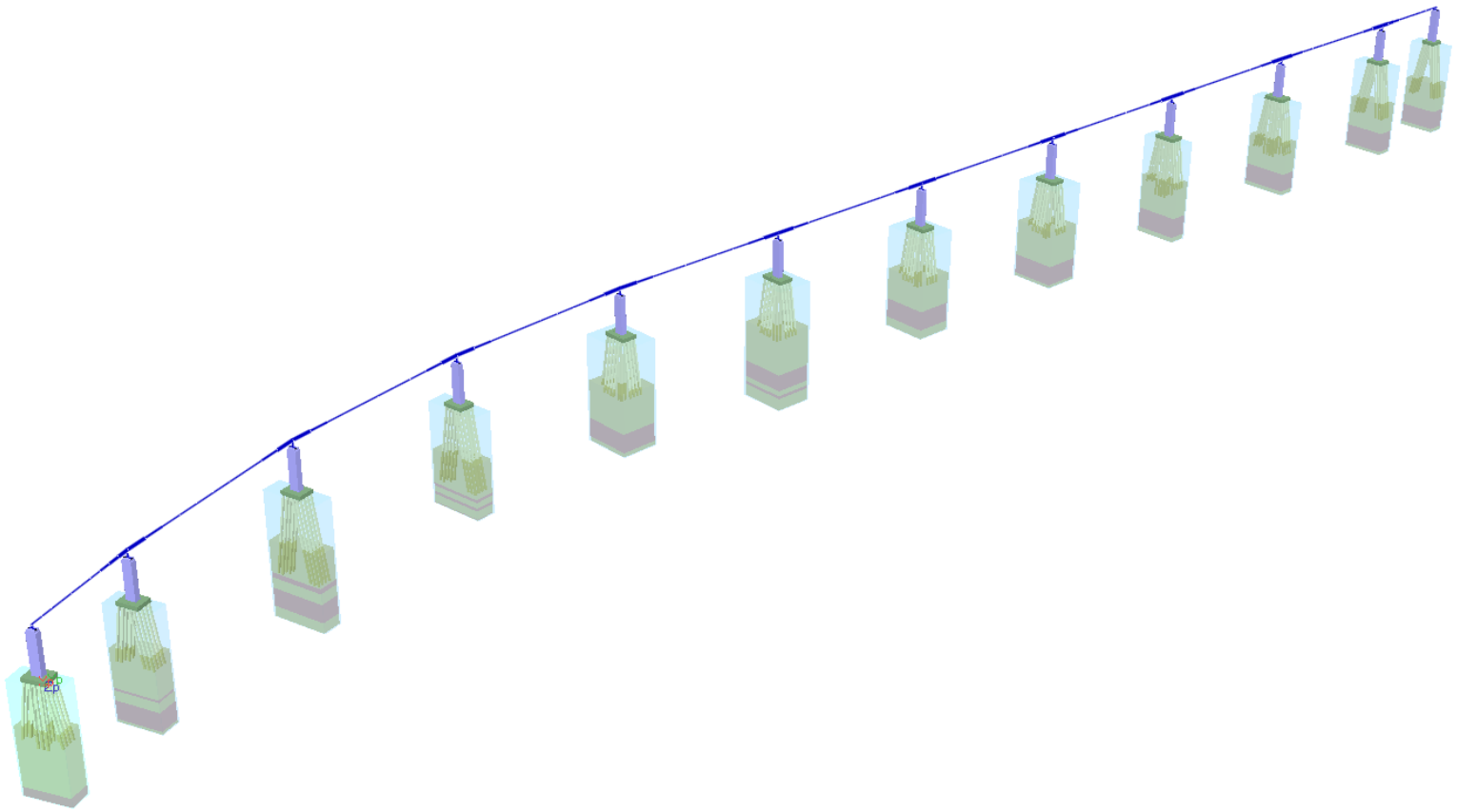


Variation of induced vertical compressive stresses beneath a rectangular shallow foundation

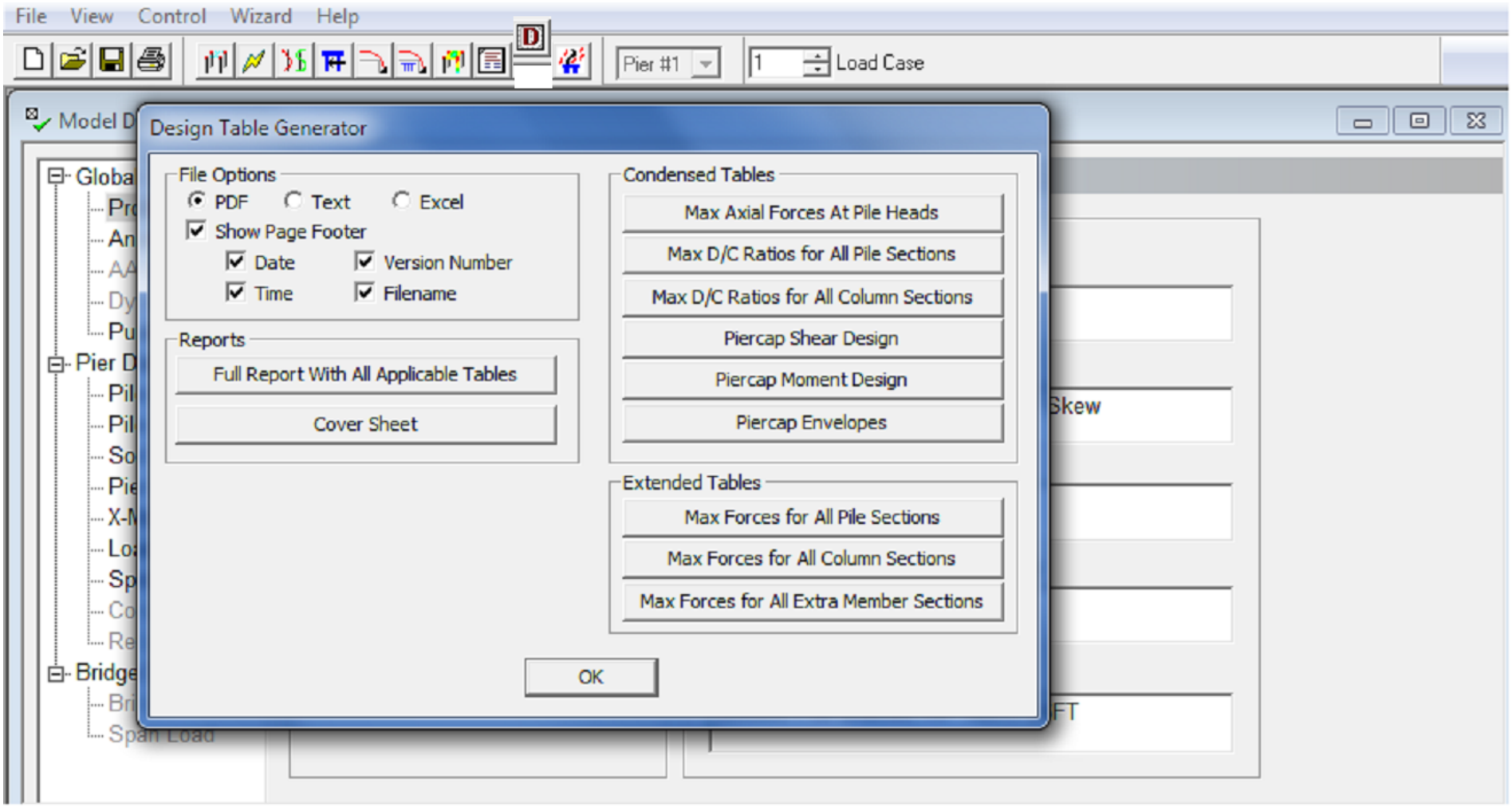


(b) Variation of the influence factors beneath the corner (red) and the center (blue)

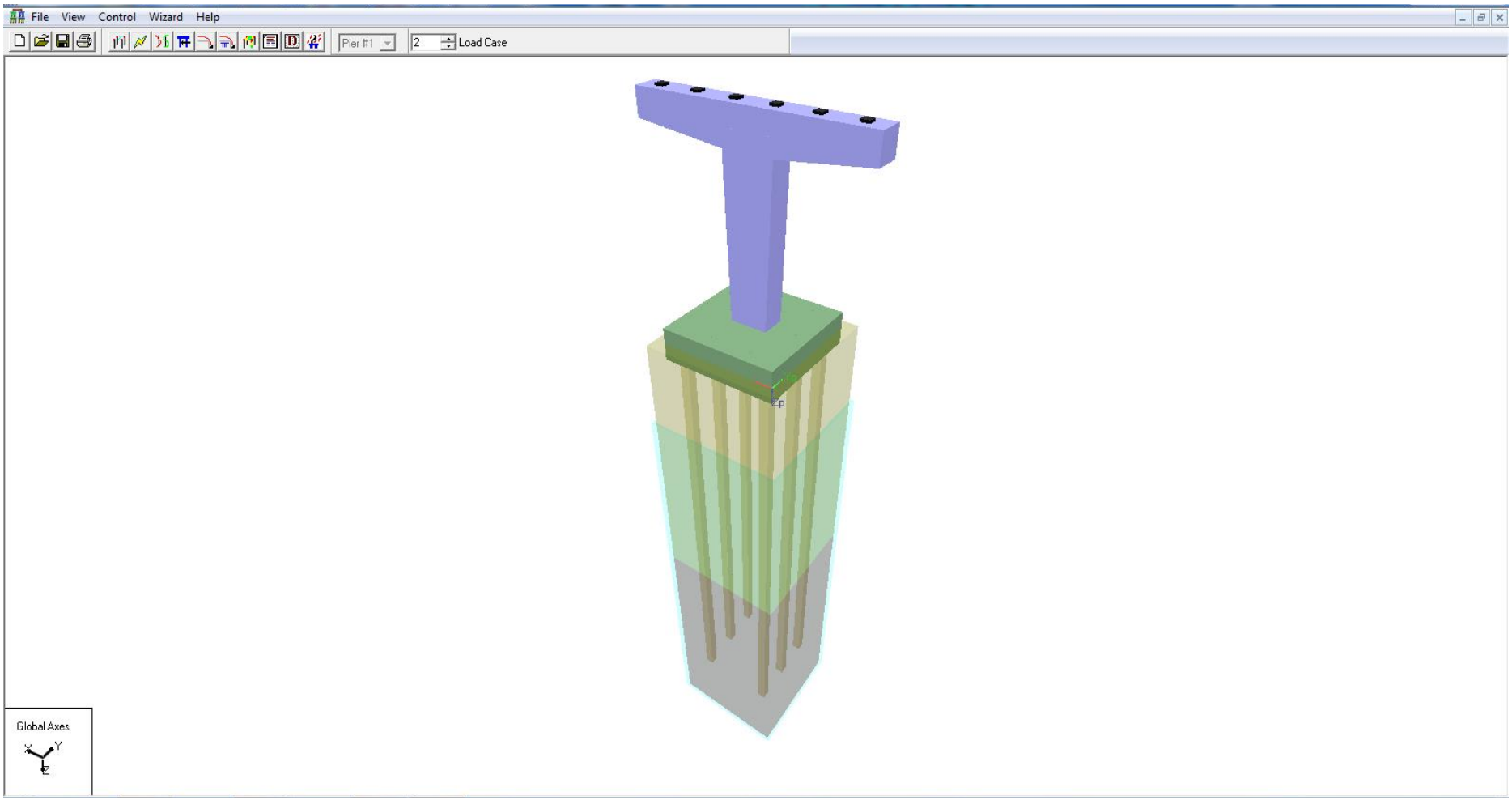
FB-MultiPier Update: Part 2
Use of Design Tables and Model Showcase



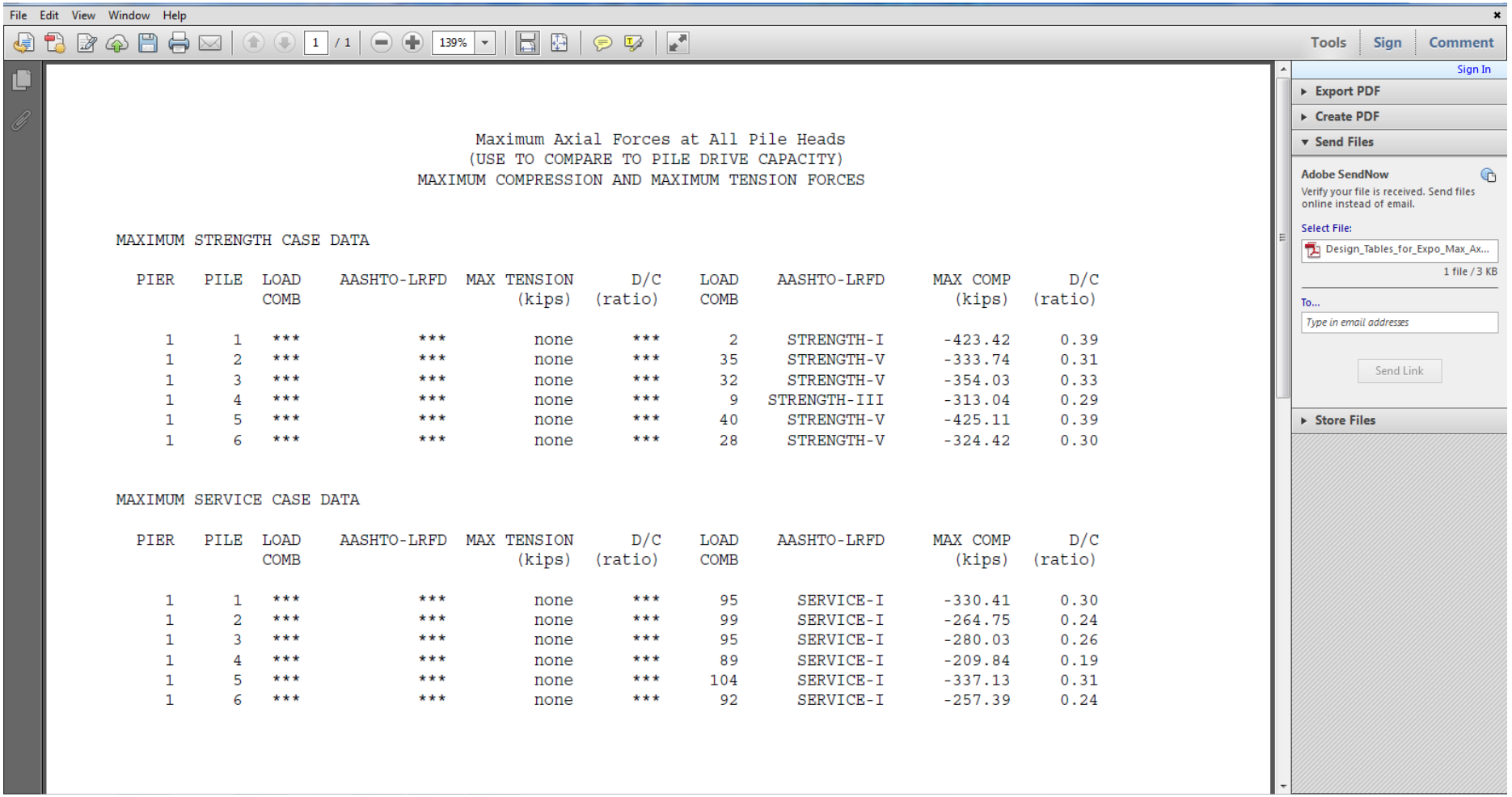
Design Tables



Example Pier for Design Tables



Pile Axial Forces



Maximum Axial Forces at All Pile Heads
(USE TO COMPARE TO PILE DRIVE CAPACITY)
MAXIMUM COMPRESSION AND MAXIMUM TENSION FORCES

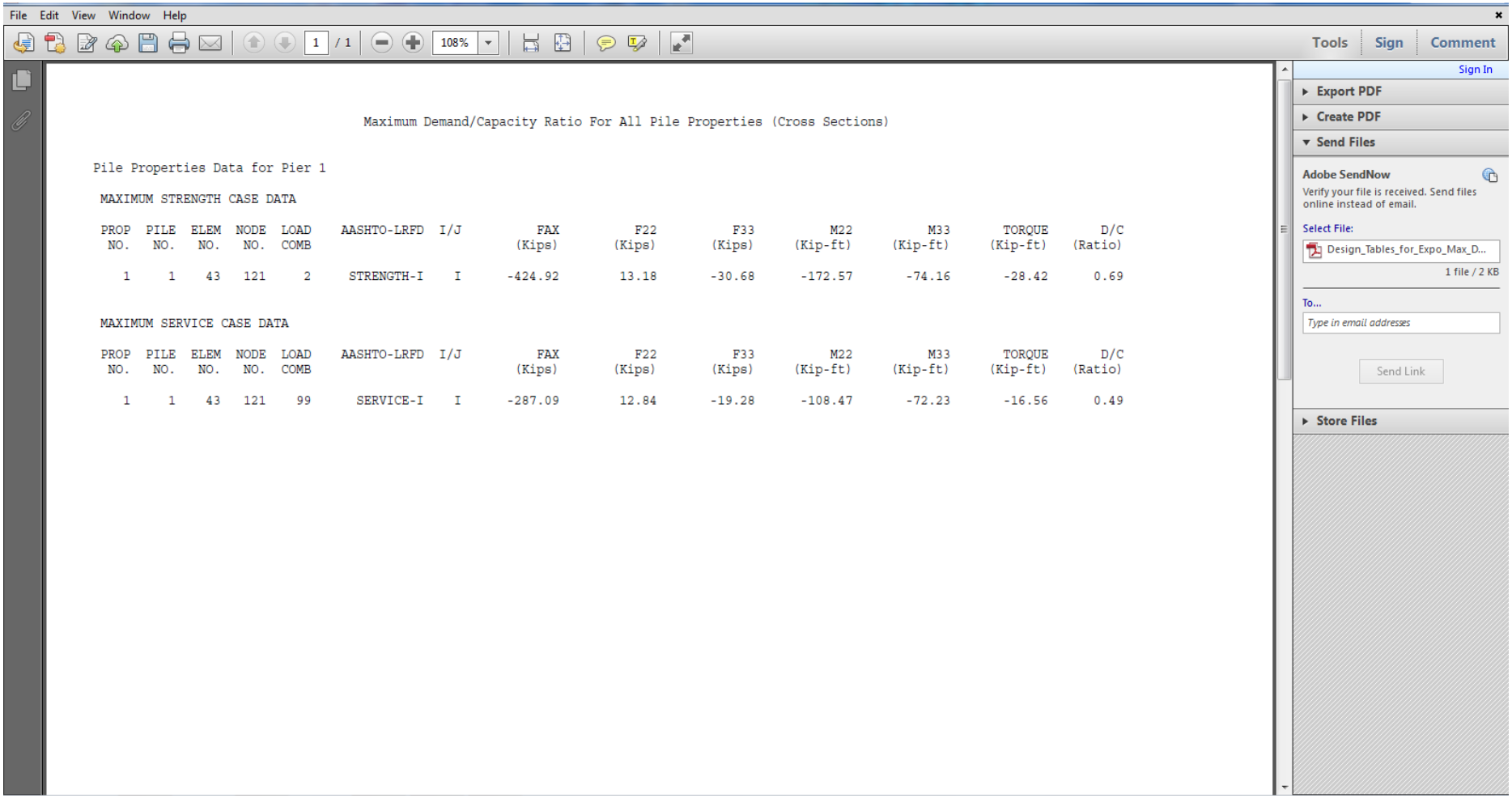
MAXIMUM STRENGTH CASE DATA

PIER	PILE	LOAD COMB	AASHTO-LRFD	MAX TENSION (kips)	D/C (ratio)	LOAD COMB	AASHTO-LRFD	MAX COMP (kips)	D/C (ratio)
1	1	***	***	none	***	2	STRENGTH-I	-423.42	0.39
1	2	***	***	none	***	35	STRENGTH-V	-333.74	0.31
1	3	***	***	none	***	32	STRENGTH-V	-354.03	0.33
1	4	***	***	none	***	9	STRENGTH-III	-313.04	0.29
1	5	***	***	none	***	40	STRENGTH-V	-425.11	0.39
1	6	***	***	none	***	28	STRENGTH-V	-324.42	0.30

MAXIMUM SERVICE CASE DATA

PIER	PILE	LOAD COMB	AASHTO-LRFD	MAX TENSION (kips)	D/C (ratio)	LOAD COMB	AASHTO-LRFD	MAX COMP (kips)	D/C (ratio)
1	1	***	***	none	***	95	SERVICE-I	-330.41	0.30
1	2	***	***	none	***	99	SERVICE-I	-264.75	0.24
1	3	***	***	none	***	95	SERVICE-I	-280.03	0.26
1	4	***	***	none	***	89	SERVICE-I	-209.84	0.19
1	5	***	***	none	***	104	SERVICE-I	-337.13	0.31
1	6	***	***	none	***	92	SERVICE-I	-257.39	0.24

Max D/C in the Piles



Maximum Demand/Capacity Ratio For All Pile Properties (Cross Sections)

Pile Properties Data for Pier 1

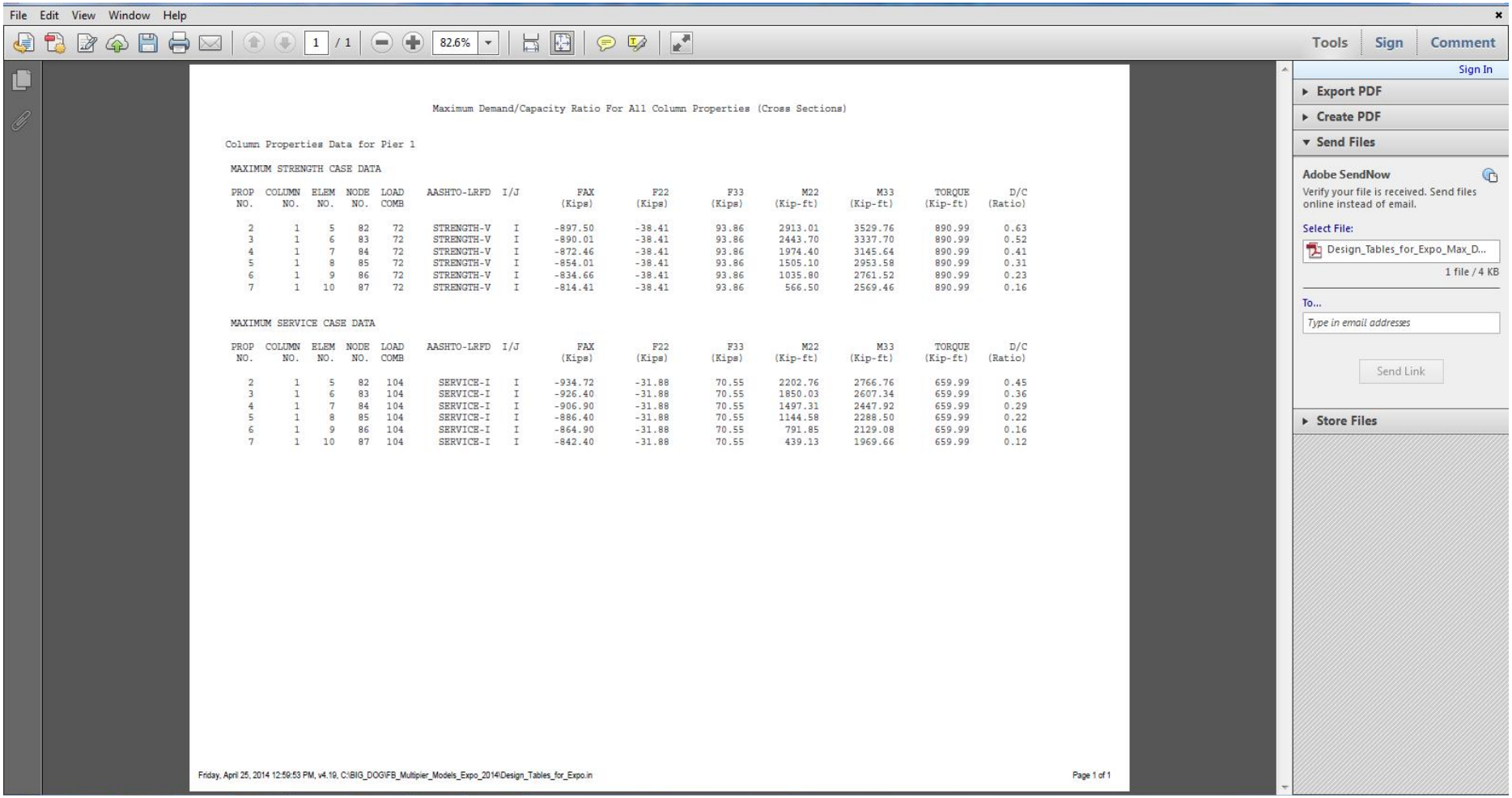
MAXIMUM STRENGTH CASE DATA

PROP NO.	PILE NO.	ELEM NO.	NODE NO.	LOAD COMB	AASHTO-LRFD	I/J	FAX (Kips)	F22 (Kips)	F33 (Kips)	M22 (Kip-ft)	M33 (Kip-ft)	TORQUE (Kip-ft)	D/C (Ratio)
1	1	43	121	2	STRENGTH-I	I	-424.92	13.18	-30.68	-172.57	-74.16	-28.42	0.69

MAXIMUM SERVICE CASE DATA

PROP NO.	PILE NO.	ELEM NO.	NODE NO.	LOAD COMB	AASHTO-LRFD	I/J	FAX (Kips)	F22 (Kips)	F33 (Kips)	M22 (Kip-ft)	M33 (Kip-ft)	TORQUE (Kip-ft)	D/C (Ratio)
1	1	43	121	99	SERVICE-I	I	-287.09	12.84	-19.28	-108.47	-72.23	-16.56	0.49

Max D/C in the Columns



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Maximum Demand/Capacity Ratio For All Column Properties (Cross Sections)

Column Properties Data for Pier 1

MAXIMUM STRENGTH CASE DATA

PROP NO.	COLUMN NO.	ELEM NO.	NODE NO.	LOAD COMB	AASHTO-LRFD	I/J	PAX (Kips)	F22 (Kips)	F33 (Kips)	M22 (Kip-ft)	M33 (Kip-ft)	TORQUE (Kip-ft)	D/C (Ratio)
2	1	5	82	72	STRENGTH-V	I	-897.50	-38.41	93.86	2913.01	3529.76	890.99	0.63
3	1	6	83	72	STRENGTH-V	I	-890.01	-38.41	93.86	2443.70	3337.70	890.99	0.52
4	1	7	84	72	STRENGTH-V	I	-872.46	-38.41	93.86	1974.40	3145.64	890.99	0.41
5	1	8	85	72	STRENGTH-V	I	-854.01	-38.41	93.86	1505.10	2953.58	890.99	0.31
6	1	9	86	72	STRENGTH-V	I	-834.66	-38.41	93.86	1035.80	2761.52	890.99	0.23
7	1	10	87	72	STRENGTH-V	I	-814.41	-38.41	93.86	566.50	2569.46	890.99	0.16

MAXIMUM SERVICE CASE DATA

PROP NO.	COLUMN NO.	ELEM NO.	NODE NO.	LOAD COMB	AASHTO-LRFD	I/J	PAX (Kips)	F22 (Kips)	F33 (Kips)	M22 (Kip-ft)	M33 (Kip-ft)	TORQUE (Kip-ft)	D/C (Ratio)
2	1	5	82	104	SERVICE-I	I	-934.72	-31.88	70.55	2202.76	2766.76	659.99	0.45
3	1	6	83	104	SERVICE-I	I	-926.40	-31.88	70.55	1850.03	2607.34	659.99	0.36
4	1	7	84	104	SERVICE-I	I	-906.90	-31.88	70.55	1497.31	2447.92	659.99	0.29
5	1	8	85	104	SERVICE-I	I	-886.40	-31.88	70.55	1144.58	2288.50	659.99	0.22
6	1	9	86	104	SERVICE-I	I	-864.90	-31.88	70.55	791.85	2129.08	659.99	0.16
7	1	10	87	104	SERVICE-I	I	-842.40	-31.88	70.55	439.13	1969.66	659.99	0.12

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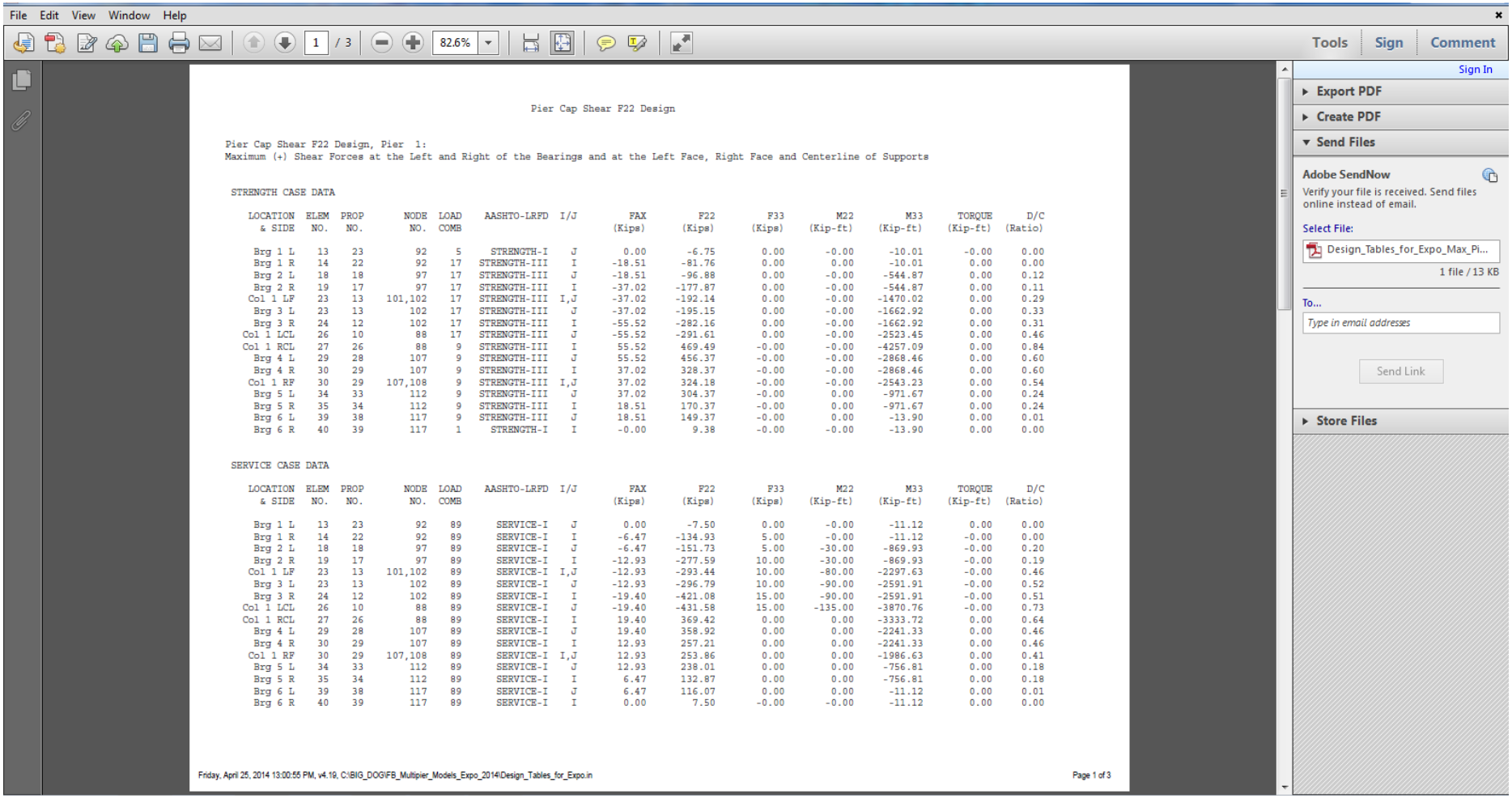
Pier Cap Shear Design Data



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Pier Cap Shear F22 Design

Pier Cap Shear F22 Design, Pier 1:
Maximum (+) Shear Forces at the Left and Right of the Bearings and at the Left Face, Right Face and Centerline of Supports

STRENGTH CASE DATA

LOCATION & SIDE	ELEM NO.	PROP NO.	NODE NO.	LOAD COMB	AASHTO-LRFD	I/J	FAX (Kips)	F22 (Kips)	F33 (Kips)	M22 (Kip-ft)	M33 (Kip-ft)	TORQUE (Kip-ft)	D/C (Ratio)
Brg 1 L	13	23	92	5	STRENGTH-I	J	0.00	-6.75	0.00	-0.00	-10.01	-0.00	0.00
Brg 1 R	14	22	92	17	STRENGTH-III	I	-18.51	-81.76	0.00	0.00	-10.01	0.00	0.00
Brg 2 L	18	18	97	17	STRENGTH-III	J	-18.51	-96.88	0.00	-0.00	-544.87	0.00	0.12
Brg 2 R	19	17	97	17	STRENGTH-III	I	-37.02	-177.87	0.00	-0.00	-544.87	0.00	0.11
Col 1 LF	23	13	101,102	17	STRENGTH-III	I,J	-37.02	-192.14	0.00	-0.00	-1470.02	0.00	0.29
Brg 3 L	23	13	102	17	STRENGTH-III	J	-37.02	-195.15	0.00	-0.00	-1662.92	0.00	0.33
Brg 3 R	24	12	102	17	STRENGTH-III	I	-55.52	-282.16	0.00	-0.00	-1662.92	0.00	0.31
Col 1 LCL	26	10	88	17	STRENGTH-III	J	-55.52	-291.61	0.00	-0.00	-2523.45	0.00	0.46
Col 1 RCL	27	26	88	9	STRENGTH-III	I	55.52	469.49	-0.00	-0.00	-4257.09	0.00	0.84
Brg 4 L	29	28	107	9	STRENGTH-III	J	55.52	456.37	-0.00	-0.00	-2868.46	0.00	0.60
Brg 4 R	30	29	107	9	STRENGTH-III	I	37.02	328.37	-0.00	-0.00	-2868.46	0.00	0.60
Col 1 RF	30	29	107,108	9	STRENGTH-III	I,J	37.02	324.18	-0.00	-0.00	-2543.23	0.00	0.54
Brg 5 L	34	33	112	9	STRENGTH-III	J	37.02	304.37	-0.00	0.00	-971.67	0.00	0.24
Brg 5 R	35	34	112	9	STRENGTH-III	I	18.51	170.37	-0.00	0.00	-971.67	0.00	0.24
Brg 6 L	39	38	117	9	STRENGTH-III	J	18.51	149.37	-0.00	0.00	-13.90	0.00	0.01
Brg 6 R	40	39	117	1	STRENGTH-I	I	-0.00	9.38	-0.00	-0.00	-13.90	0.00	0.00

SERVICE CASE DATA

LOCATION & SIDE	ELEM NO.	PROP NO.	NODE NO.	LOAD COMB	AASHTO-LRFD	I/J	FAX (Kips)	F22 (Kips)	F33 (Kips)	M22 (Kip-ft)	M33 (Kip-ft)	TORQUE (Kip-ft)	D/C (Ratio)
Brg 1 L	13	23	92	89	SERVICE-I	J	0.00	-7.50	0.00	-0.00	-11.12	0.00	0.00
Brg 1 R	14	22	92	89	SERVICE-I	I	-6.47	-134.93	5.00	-0.00	-11.12	-0.00	0.00
Brg 2 L	18	18	97	89	SERVICE-I	J	-6.47	-151.73	5.00	-30.00	-869.93	-0.00	0.20
Brg 2 R	19	17	97	89	SERVICE-I	I	-12.93	-277.59	10.00	-30.00	-869.93	-0.00	0.19
Col 1 LF	23	13	101,102	89	SERVICE-I	I,J	-12.93	-293.44	10.00	-80.00	-2297.63	-0.00	0.46
Brg 3 L	23	13	102	89	SERVICE-I	J	-12.93	-296.79	10.00	-90.00	-2591.91	-0.00	0.52
Brg 3 R	24	12	102	89	SERVICE-I	I	-19.40	-421.08	15.00	-90.00	-2591.91	-0.00	0.51
Col 1 LCL	26	10	88	89	SERVICE-I	J	-19.40	-431.58	15.00	-135.00	-3870.76	-0.00	0.73
Col 1 RCL	27	26	88	89	SERVICE-I	I	19.40	369.42	0.00	0.00	-3333.72	0.00	0.64
Brg 4 L	29	28	107	89	SERVICE-I	J	19.40	358.92	0.00	0.00	-2241.33	0.00	0.46
Brg 4 R	30	29	107	89	SERVICE-I	I	12.93	257.21	0.00	0.00	-2241.33	0.00	0.46
Col 1 RF	30	29	107,108	89	SERVICE-I	I,J	12.93	253.86	0.00	0.00	-1986.63	0.00	0.41
Brg 5 L	34	33	112	89	SERVICE-I	J	12.93	238.01	0.00	0.00	-756.81	0.00	0.18
Brg 5 R	35	34	112	89	SERVICE-I	I	6.47	132.87	0.00	0.00	-756.81	0.00	0.18
Brg 6 L	39	38	117	89	SERVICE-I	J	6.47	116.07	0.00	0.00	-11.12	0.00	0.01
Brg 6 R	40	39	117	89	SERVICE-I	I	0.00	7.50	-0.00	-0.00	-11.12	0.00	0.00

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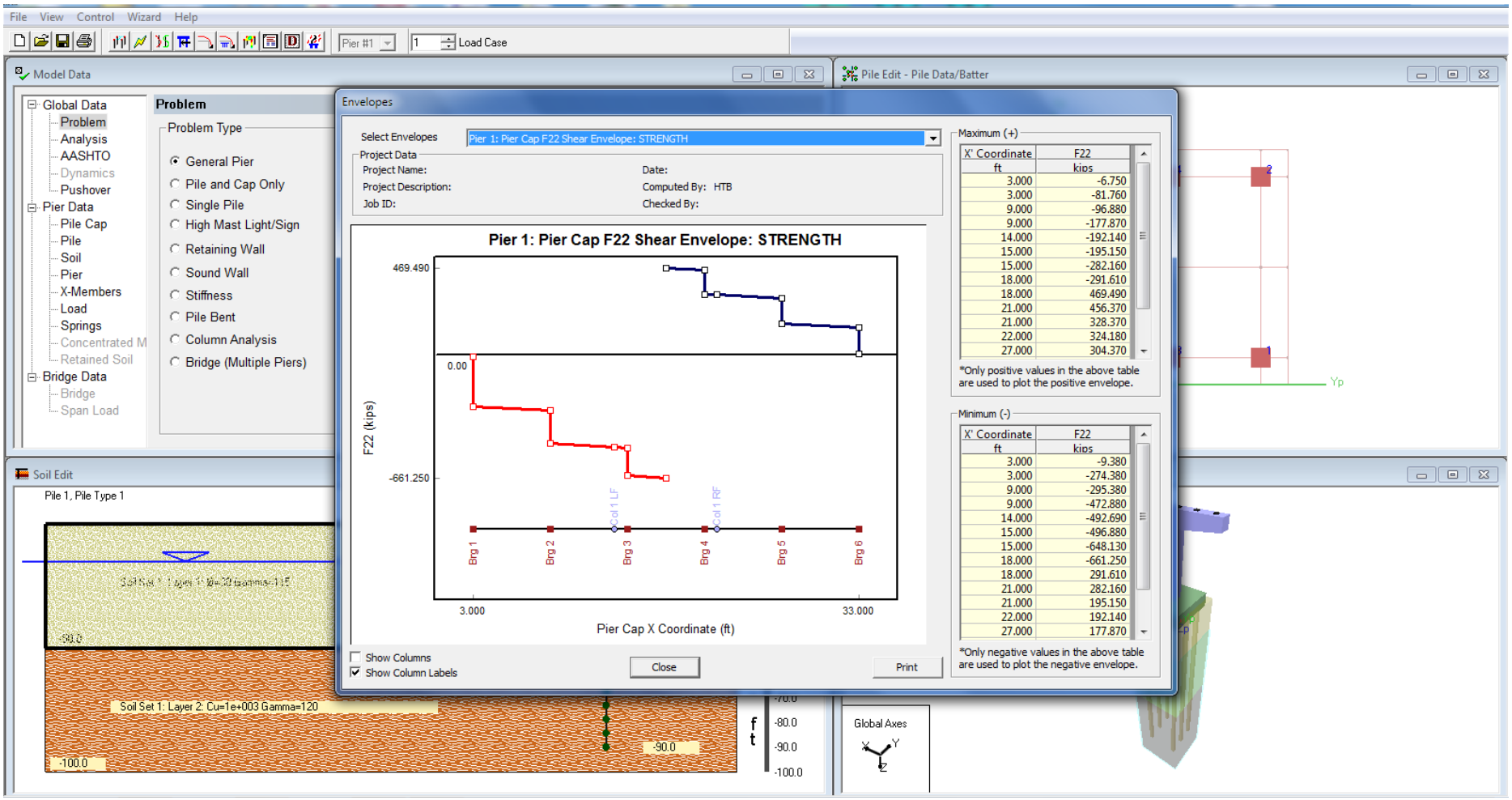
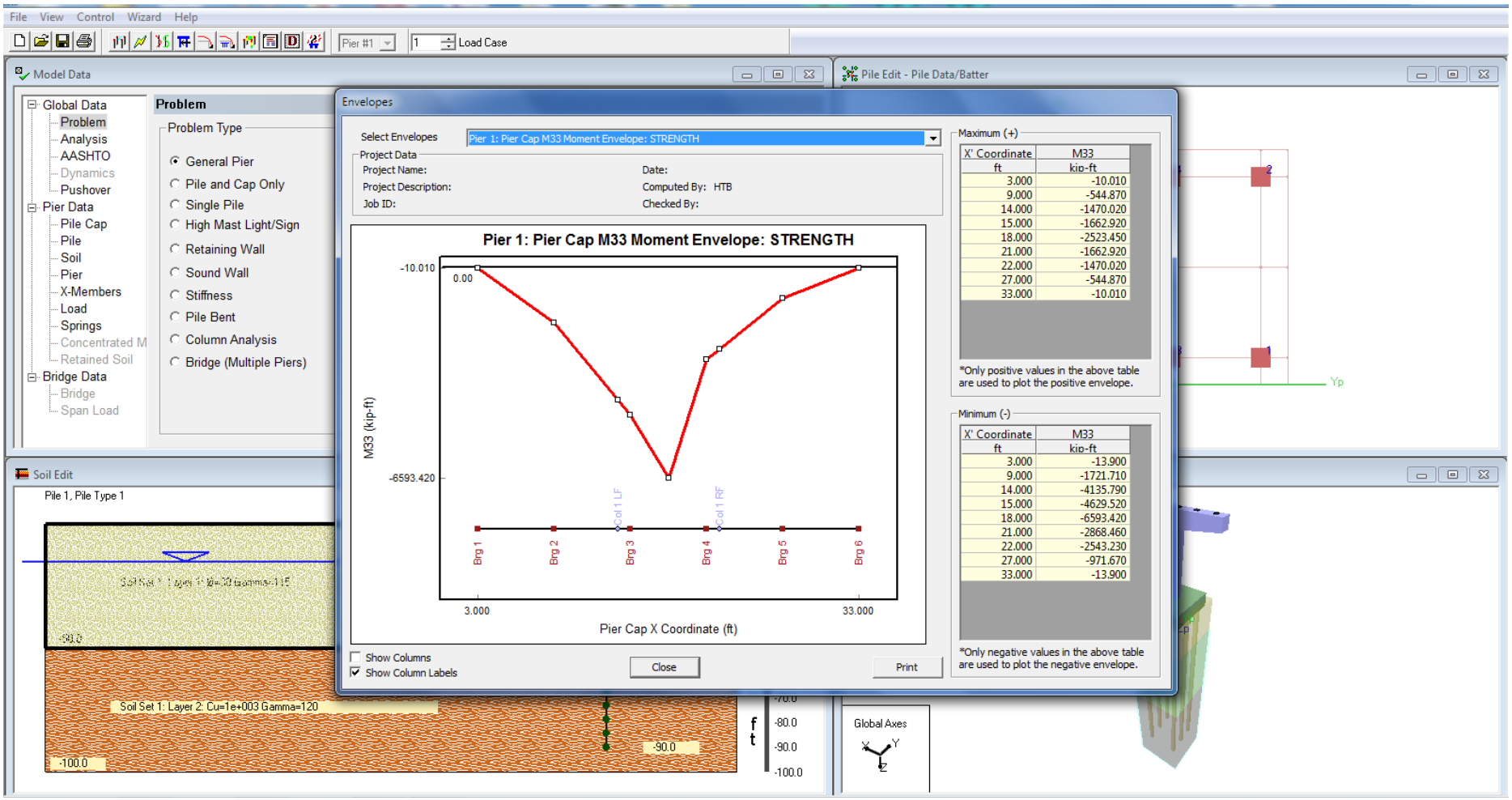
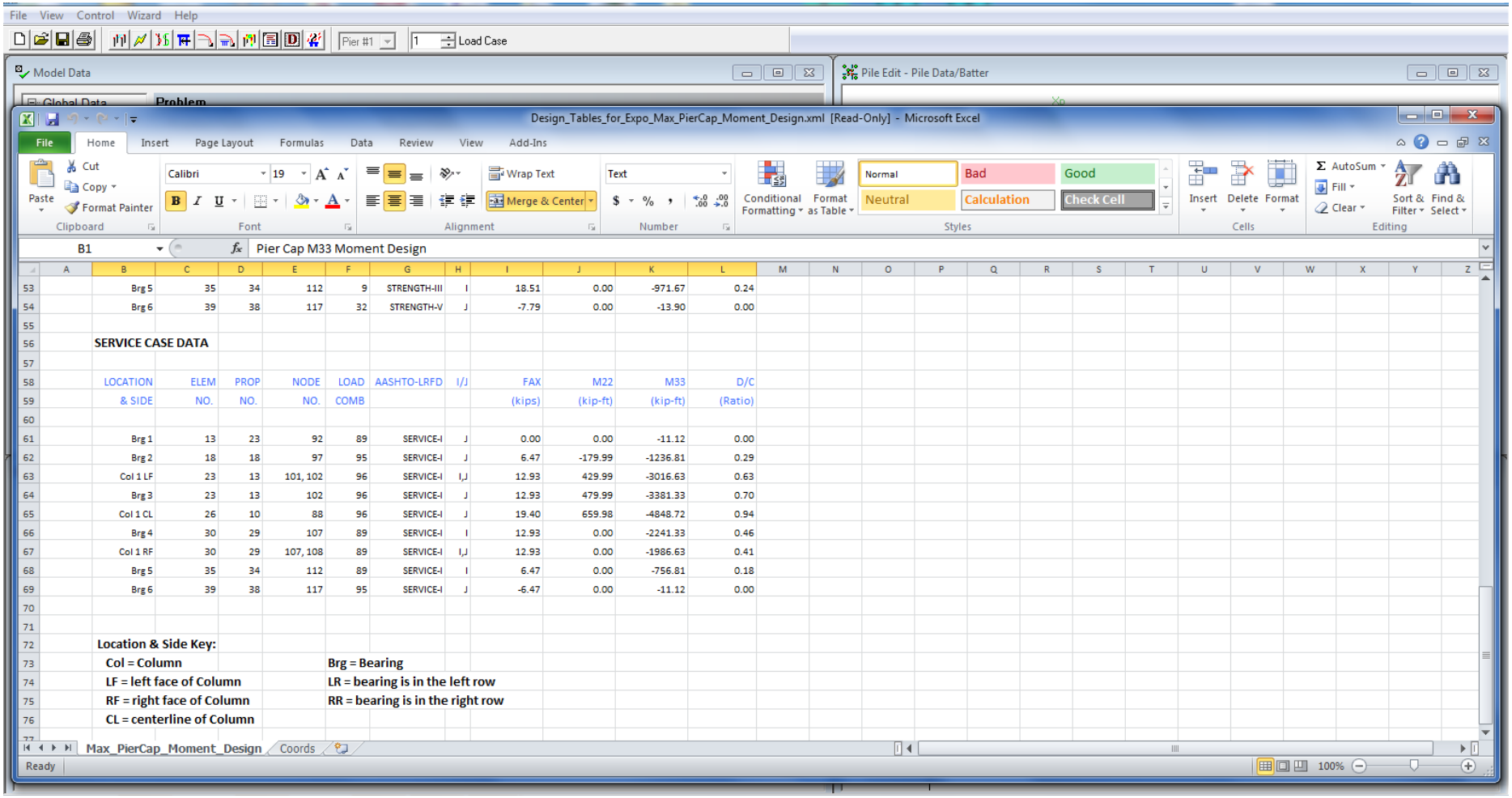
Shear Envelope



Moment Envelope



Data Exporting



53	Brg 5	35	34	112	9	STRENGTH-III	I	18.51	0.00	-971.67	0.24
54	Brg 6	39	38	117	32	STRENGTH-V	J	-7.79	0.00	-13.90	0.00
55											
56	**SERVICE CASE DATA**										
57											
58	LOCATION	ELEM	PROP	NODE	LOAD	AASHTO-LRFD	I/J	FAX	M22	M33	D/C
59	& SIDE	NO.	NO.	NO.	COMB			(kips)	(kip-ft)	(kip-ft)	(Ratio)
60											
61	Brg 1	13	23	92	89	SERVICE-I	J	0.00	0.00	-11.12	0.00
62	Brg 2	18	18	97	95	SERVICE-I	J	6.47	-179.99	-1236.81	0.29
63	Col 1 LF	23	13	101, 102	96	SERVICE-I	I,J	12.93	429.99	-3016.63	0.63
64	Brg 3	23	13	102	96	SERVICE-I	J	12.93	479.99	-3381.33	0.70
65	Col 1 CL	26	10	88	96	SERVICE-I	J	19.40	659.98	-4848.72	0.94
66	Brg 4	30	29	107	89	SERVICE-I	I	12.93	0.00	-2241.33	0.46
67	Col 1 RF	30	29	107, 108	89	SERVICE-I	I,J	12.93	0.00	-1986.63	0.41
68	Brg 5	35	34	112	89	SERVICE-I	I	6.47	0.00	-756.81	0.18
69	Brg 6	39	38	117	95	SERVICE-I	J	-6.47	0.00	-11.12	0.00
70											
71											
72	**Location & Side Key:**										
73	**Col = Column**				**Brg = Bearing**						
74	**LF = left face of Column**				**LR = bearing is in the left row**						
75	**RF = right face of Column**				**RR = bearing is in the right row**						
76	**CL = centerline of Column**										

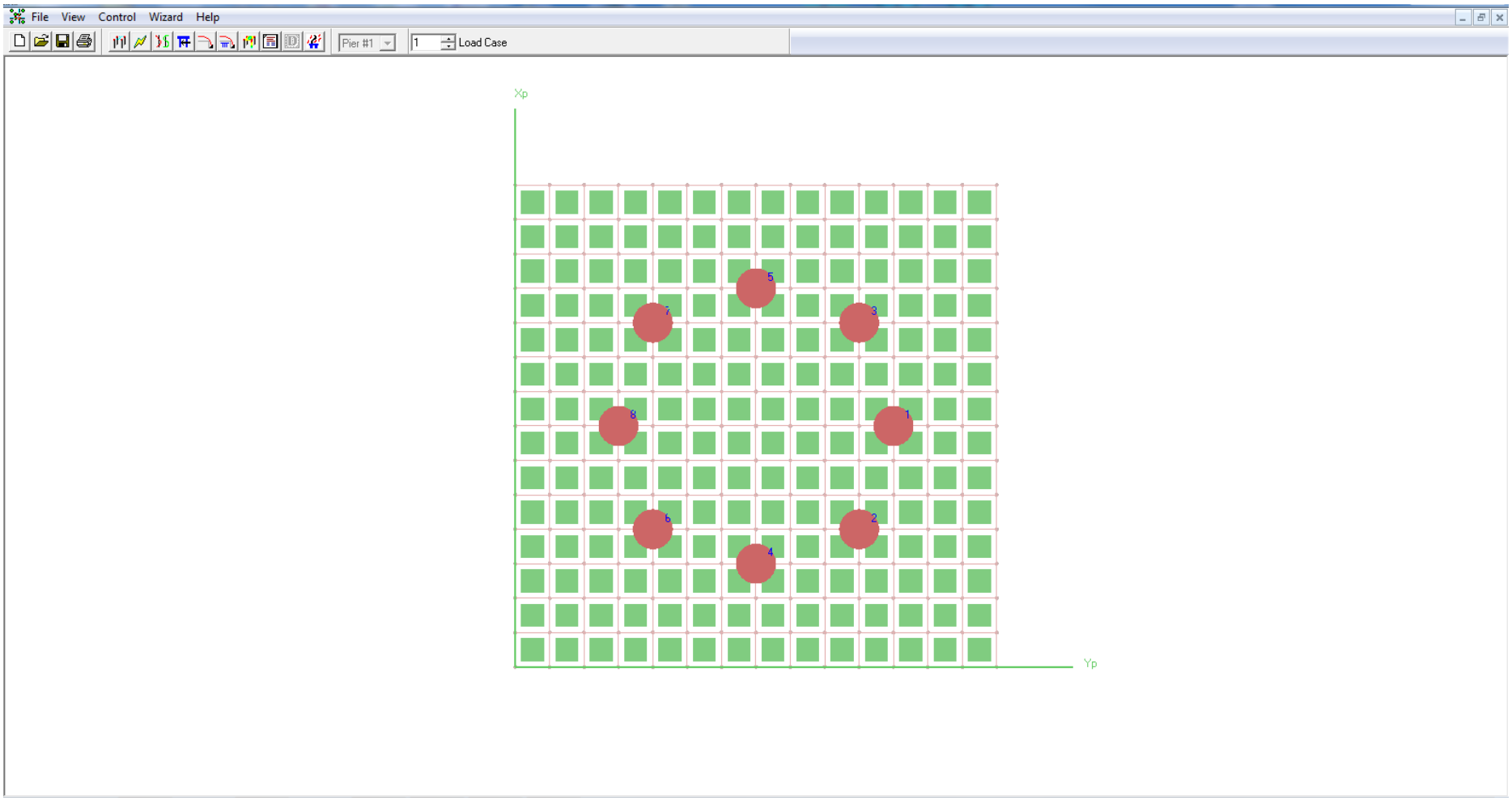
Agenda

- Use of Design Tables
- **Model Showcase**
- Summary

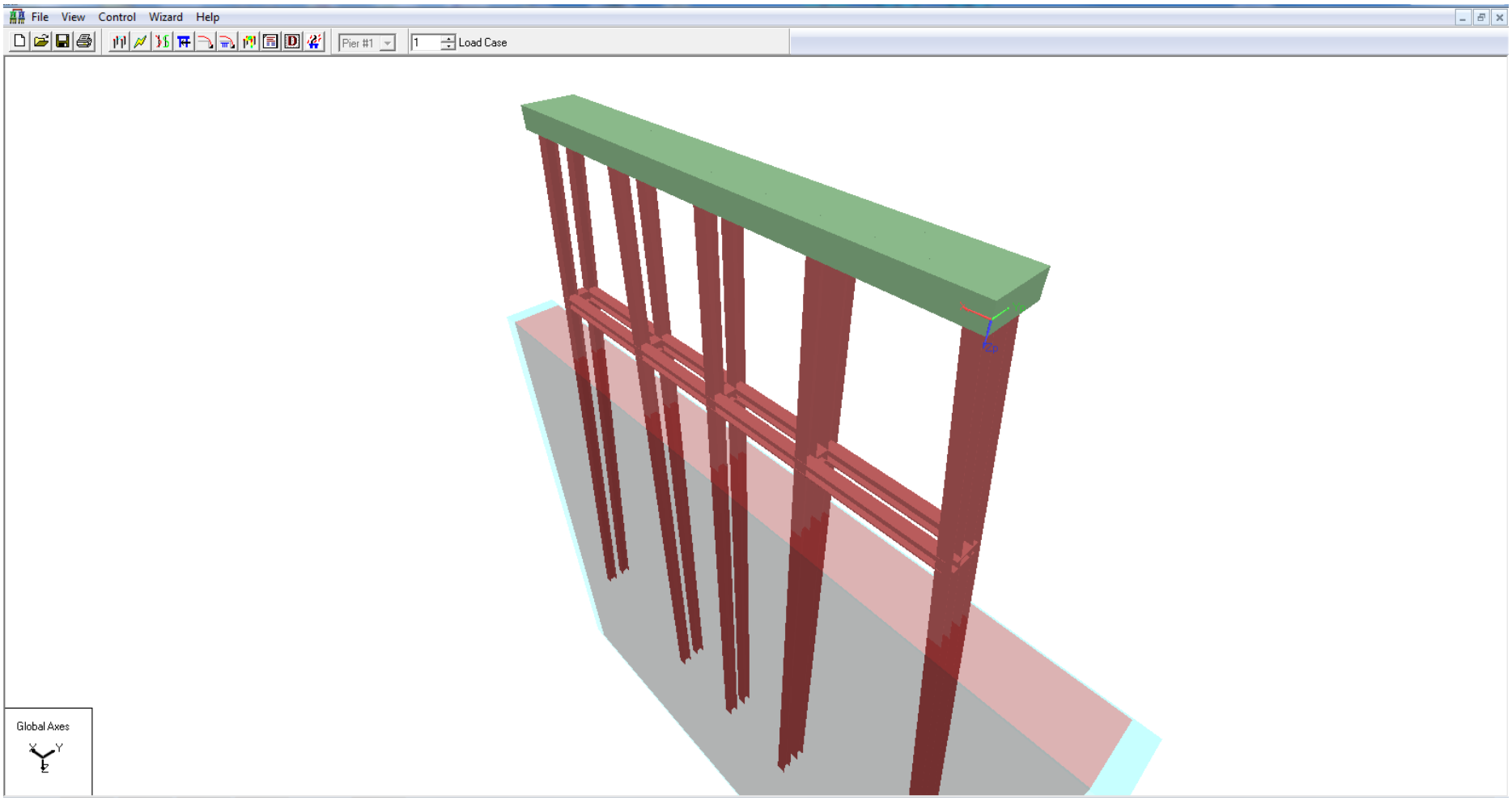
FB-Multipier Models

YOU MADE THESE!!!!!

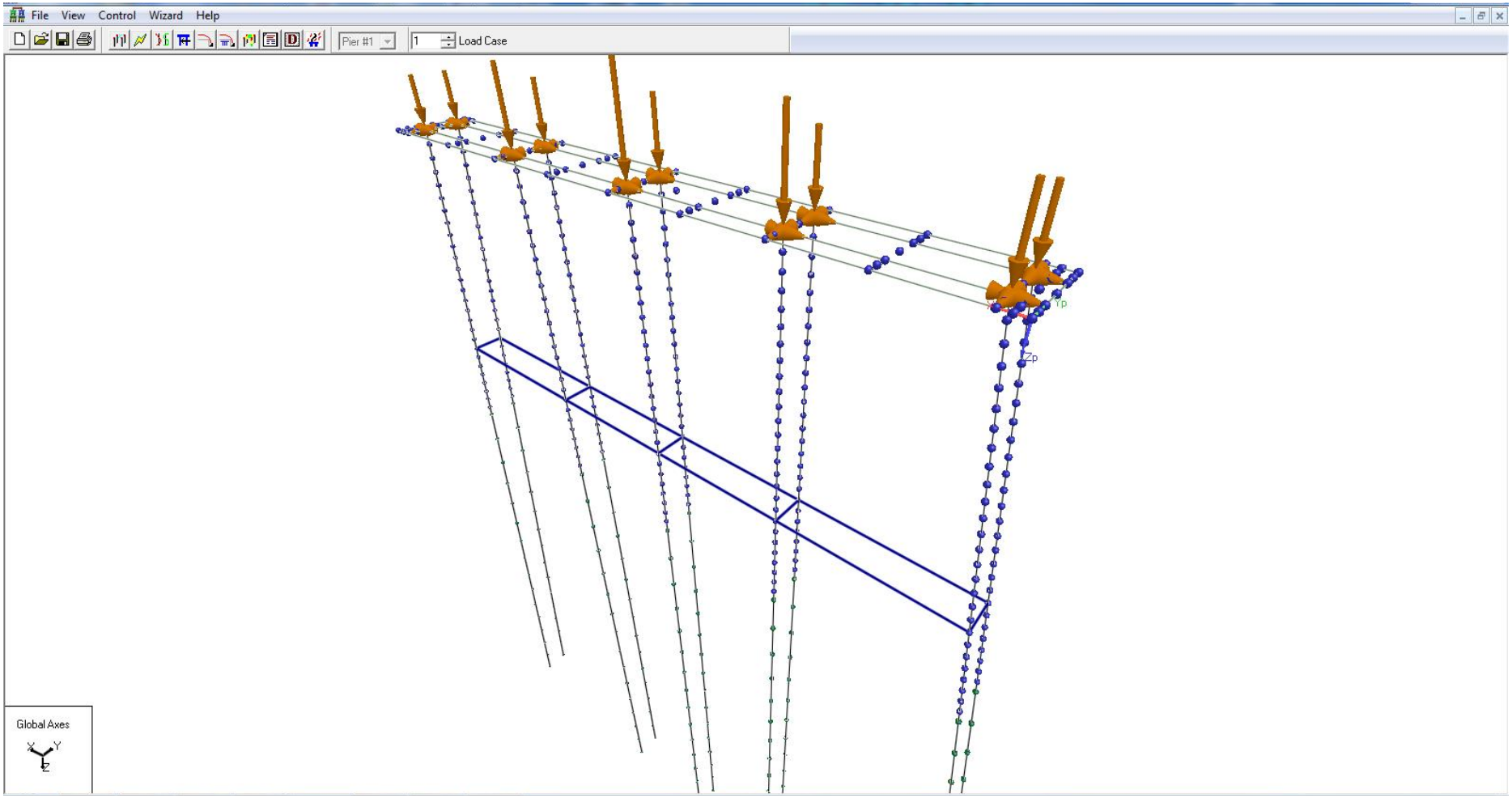
Any Pile Layout



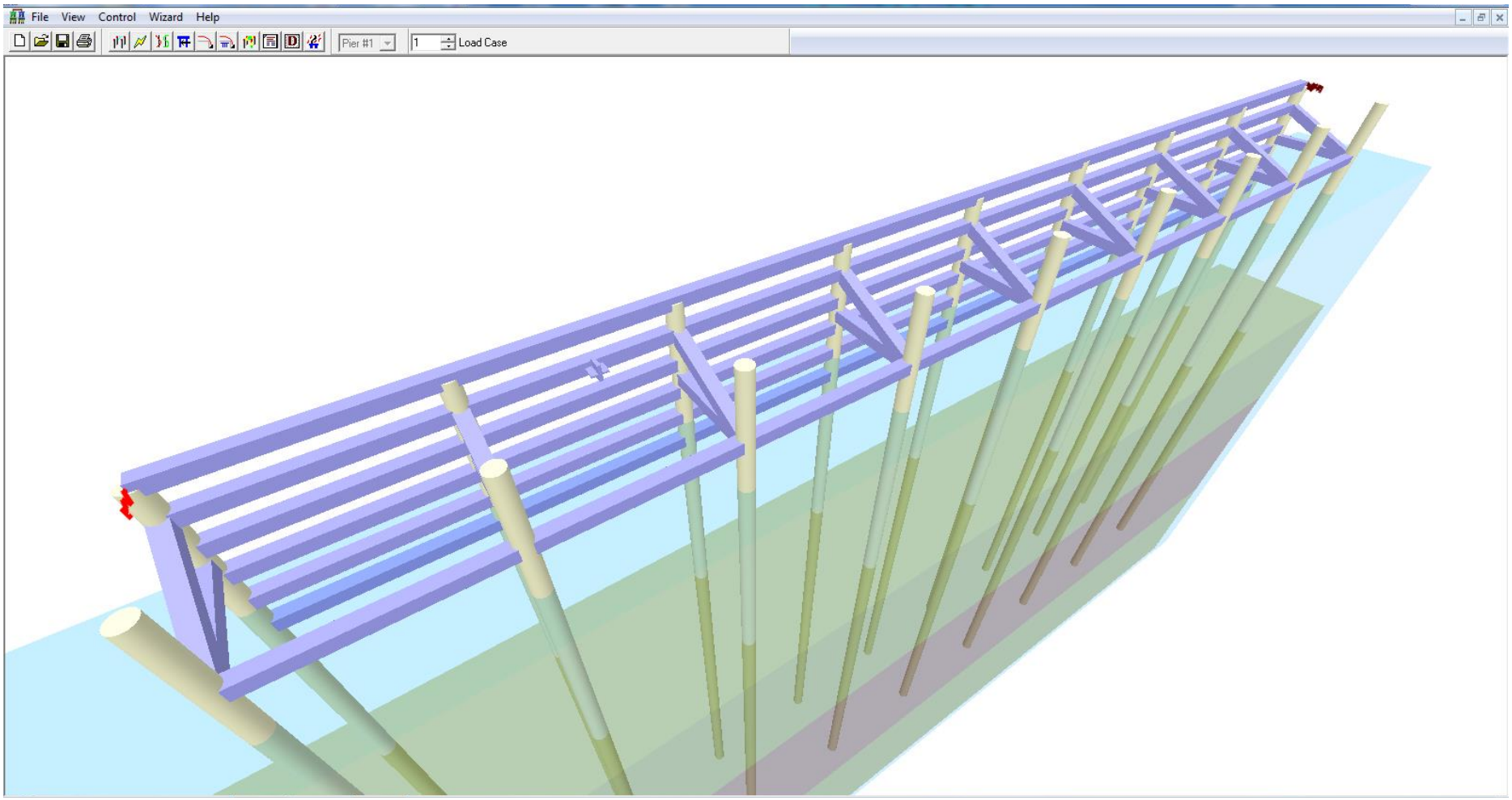
Steel H-Piles and Bracing



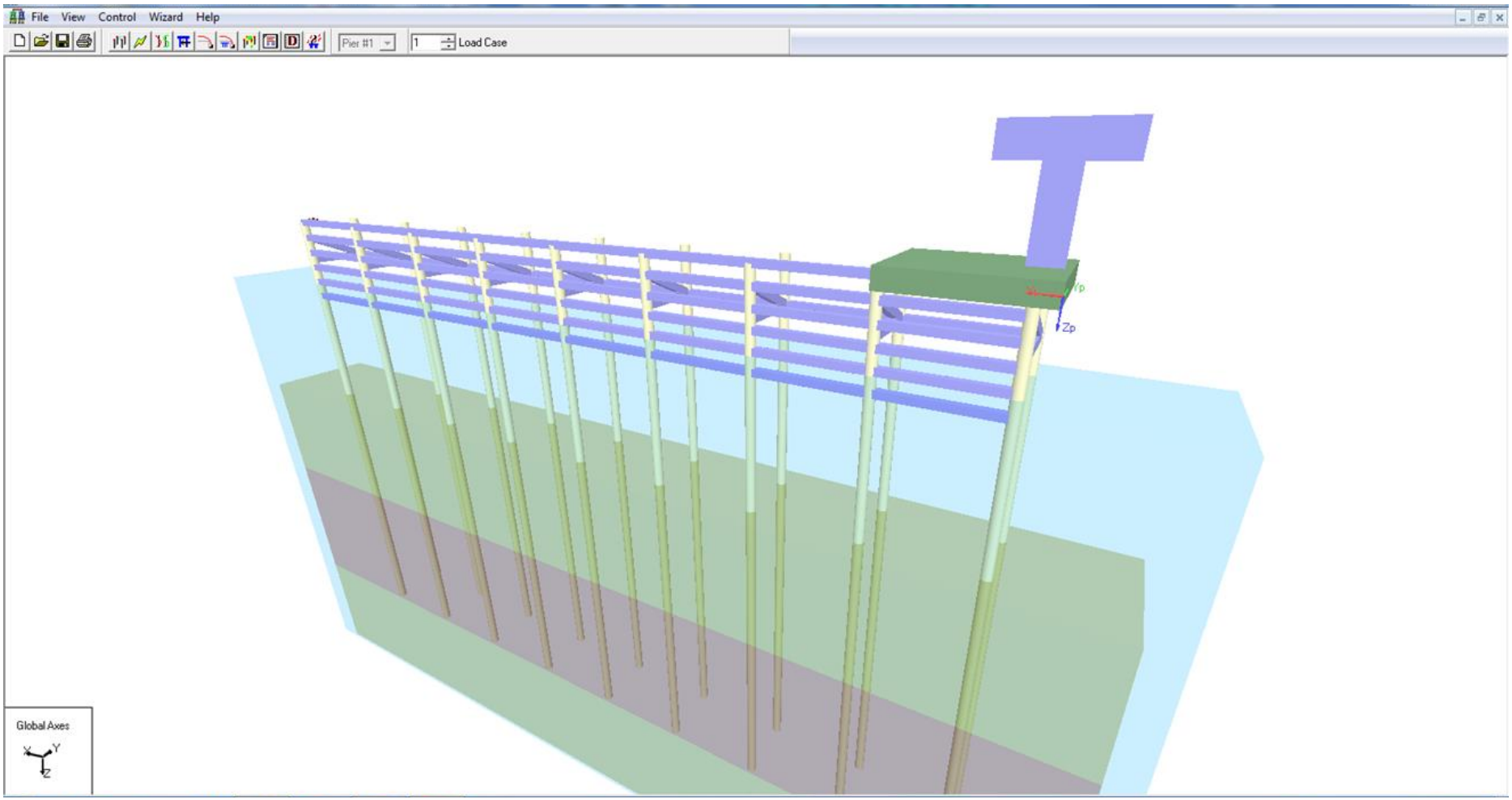
“Thin View” Extra Member Bracing



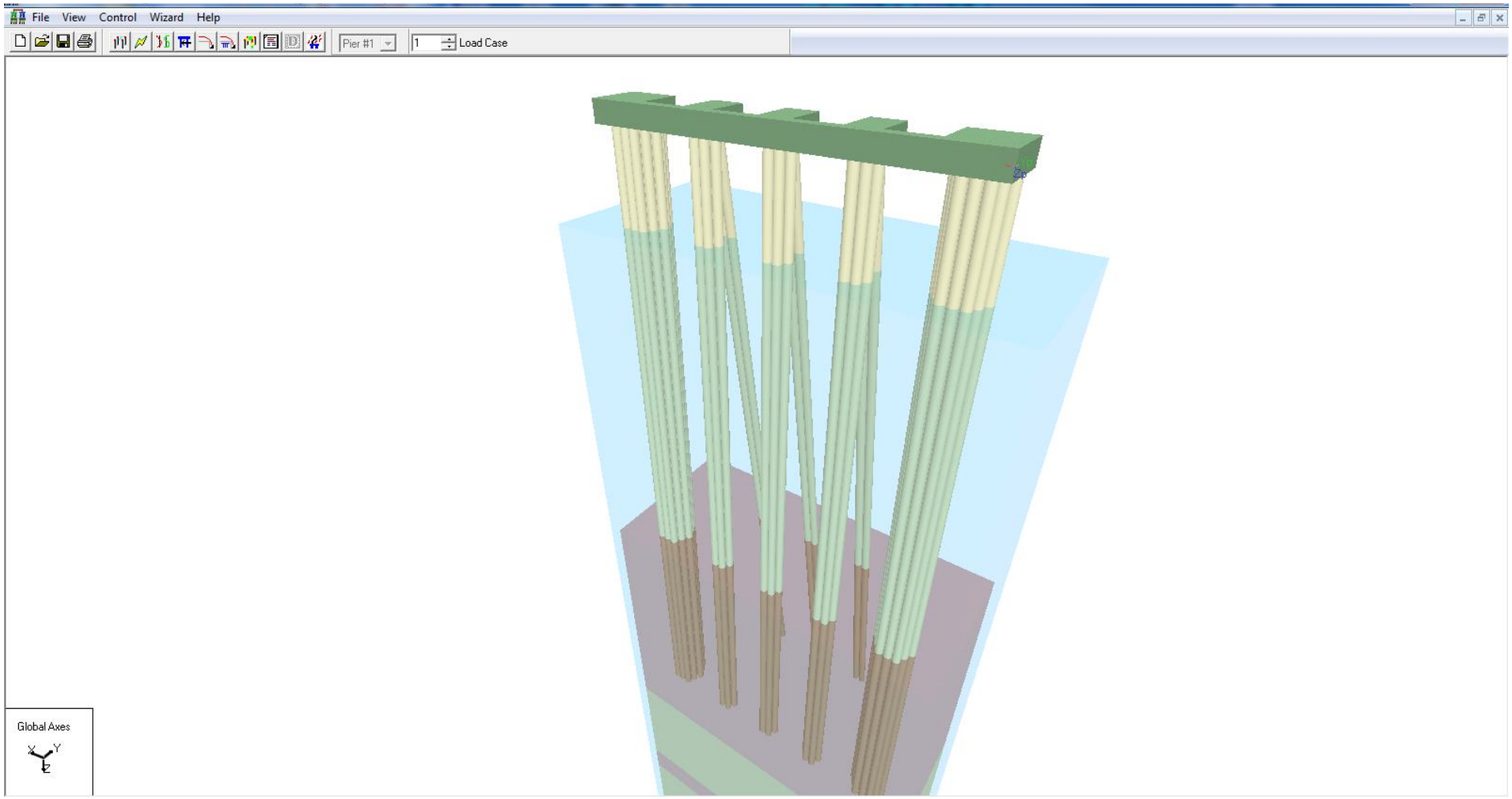
Barge Fender at Port Canaveral



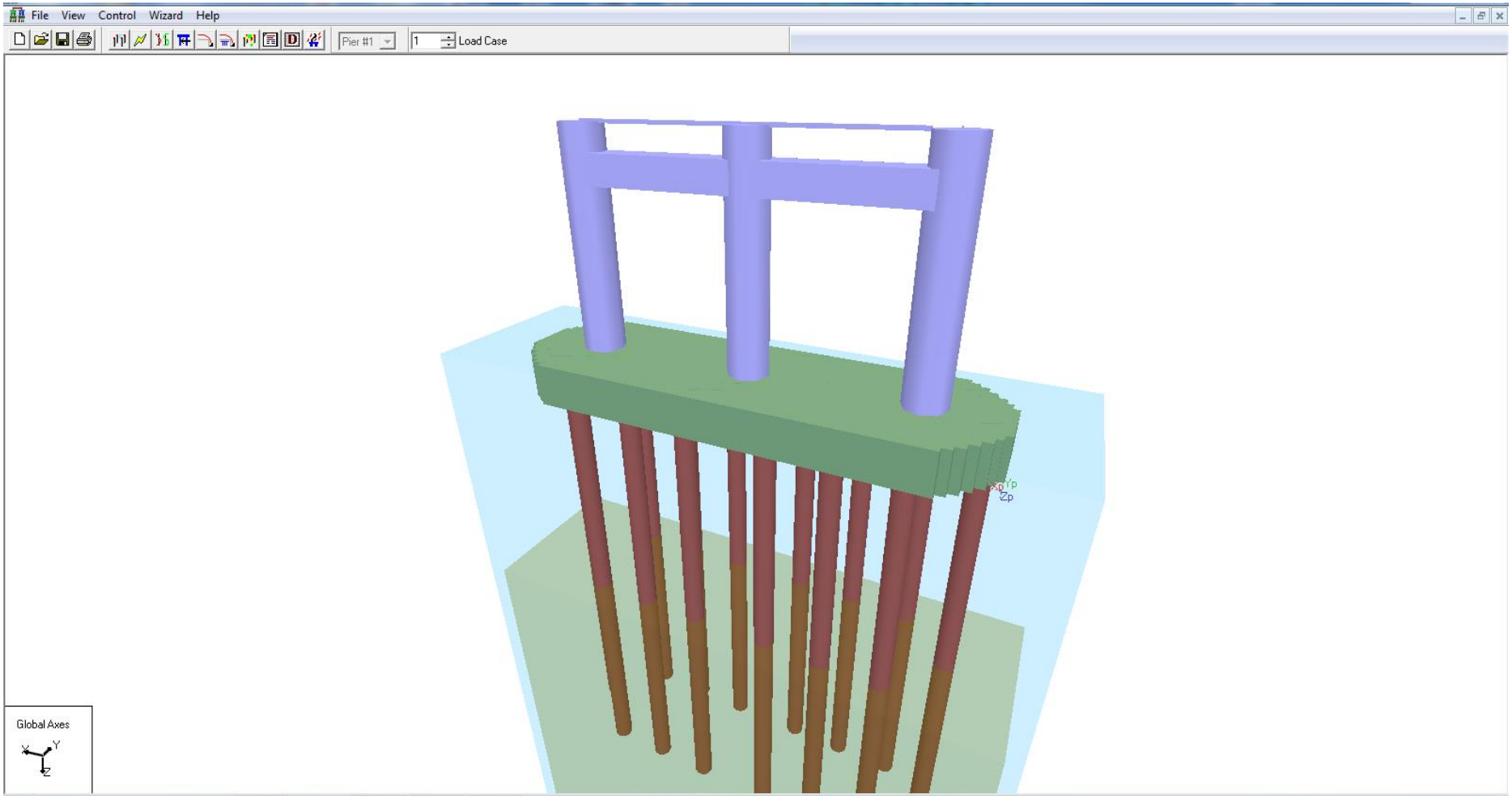
Edited General Pier Model



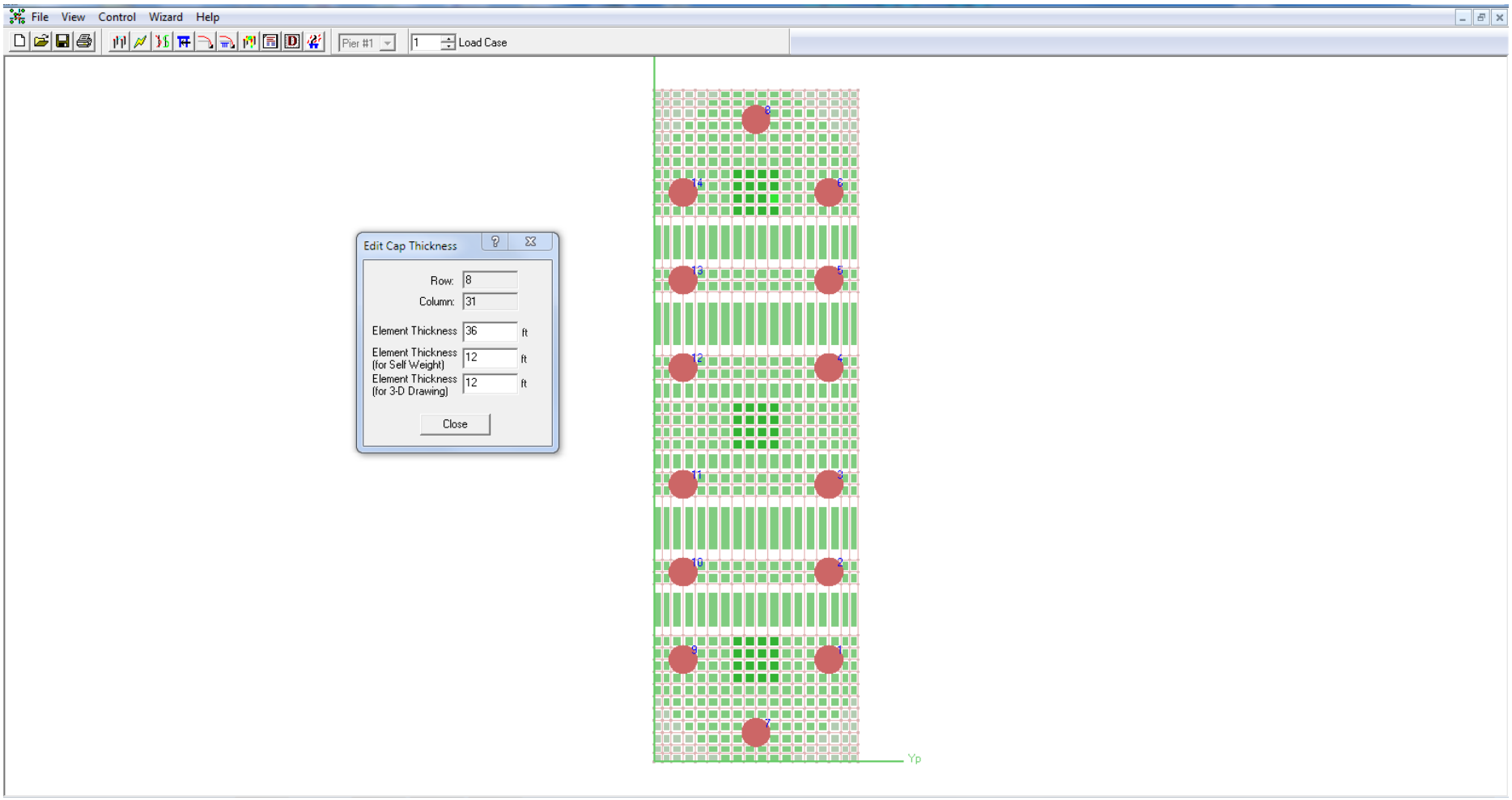
Multiple Timber Pile Clusters



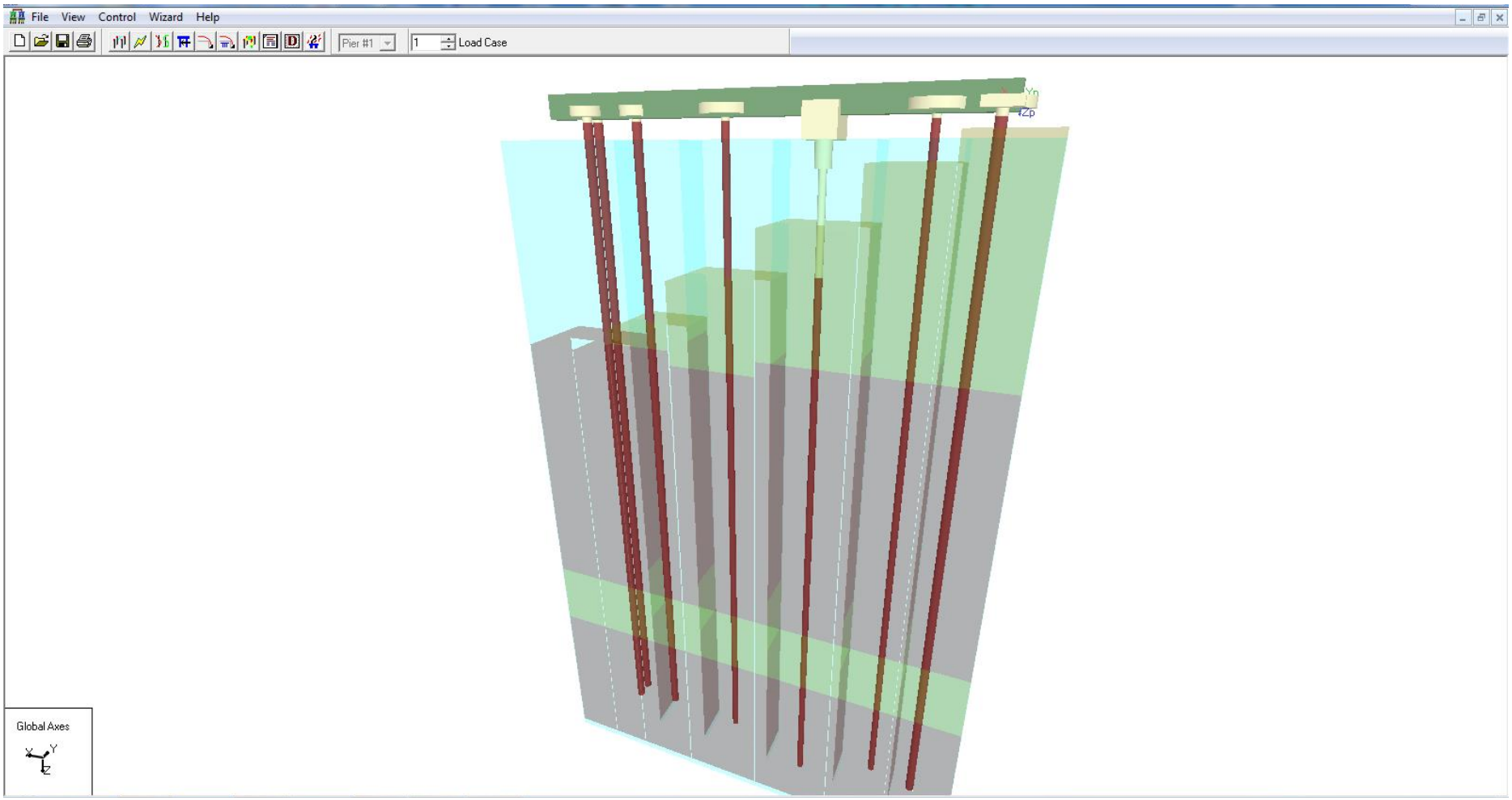
Pipe Piles, Strut, Reduced Pier Cap Stiffness



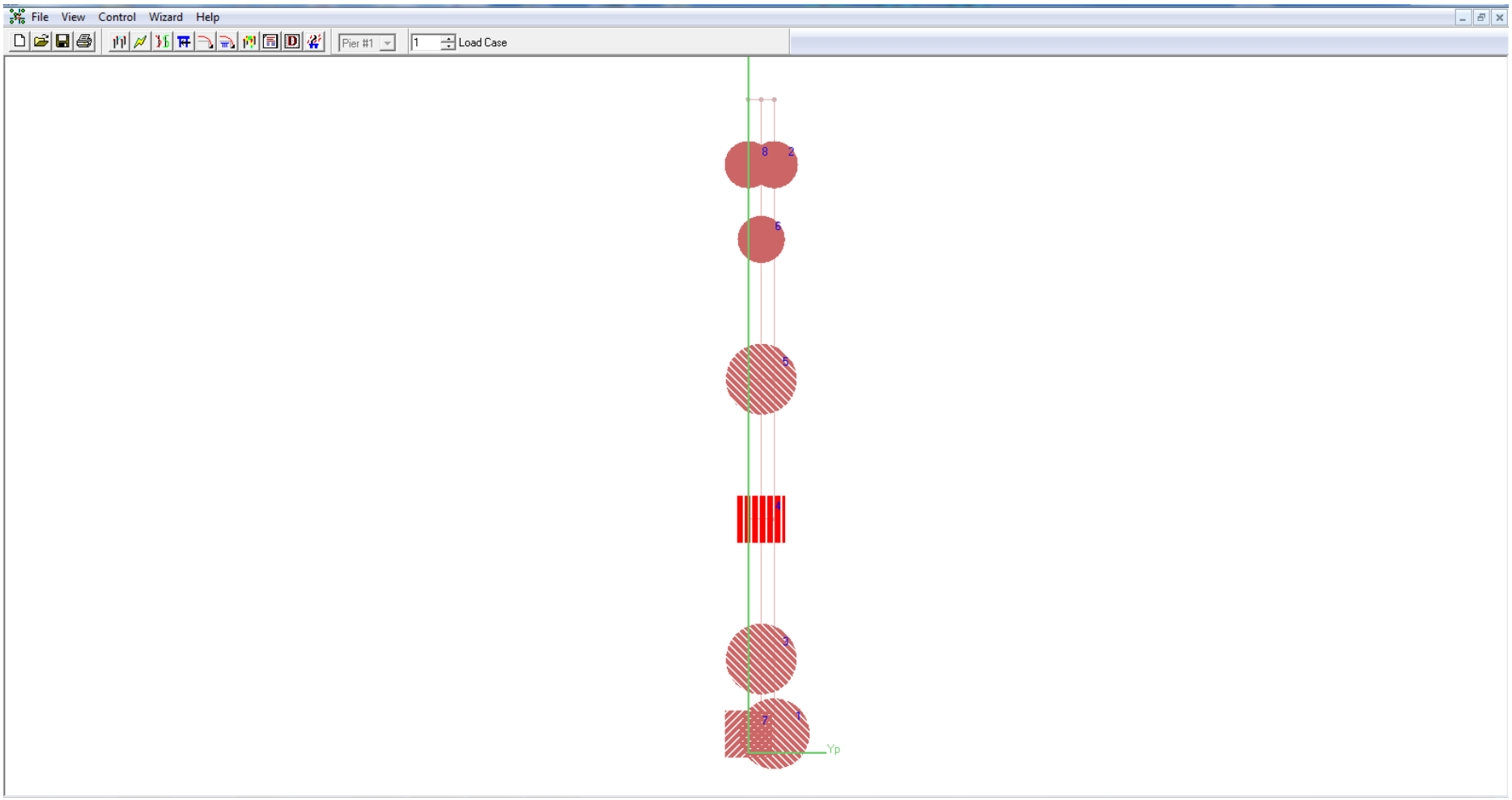
Cap Thickened and Some Elements Removed



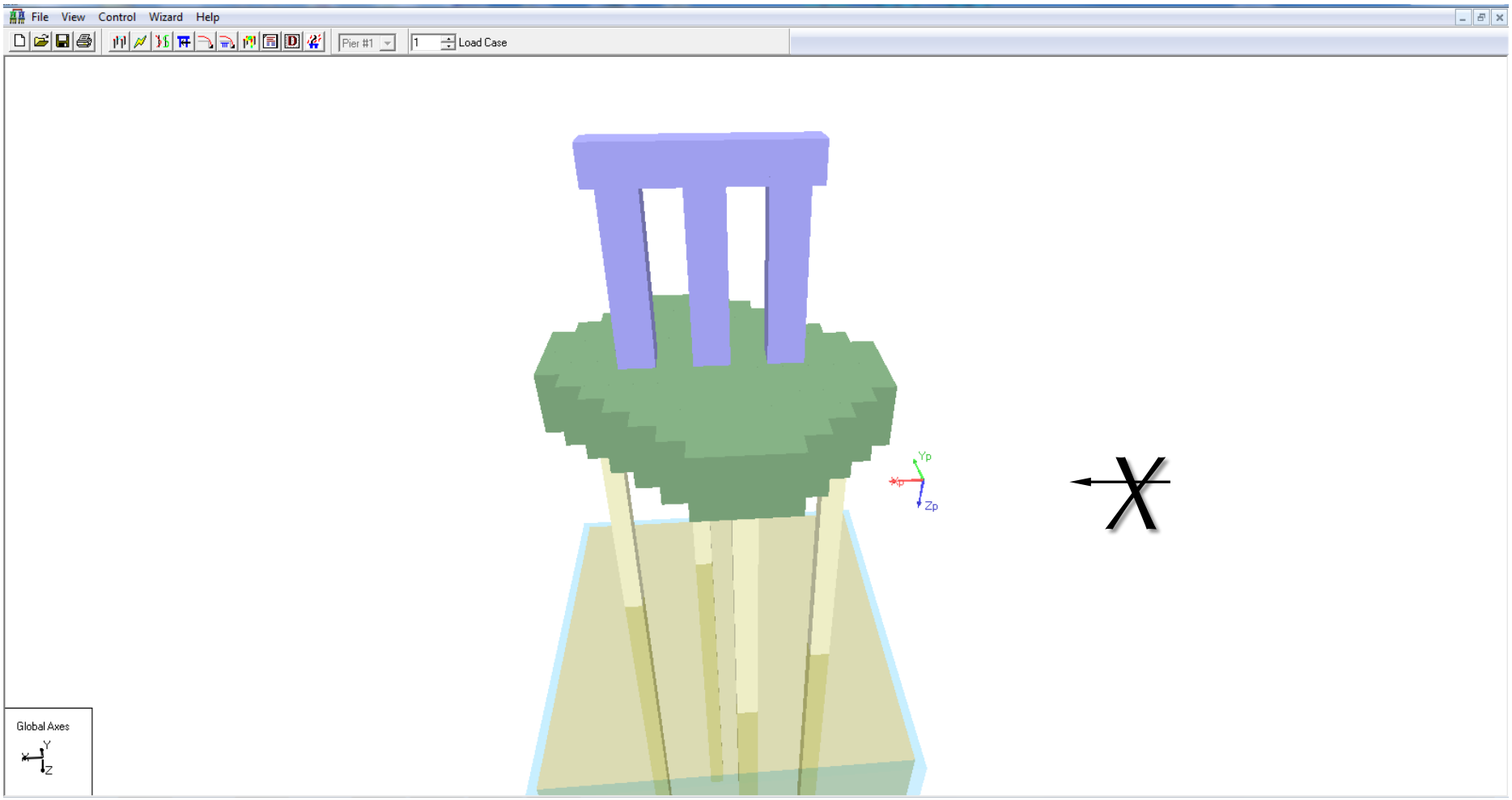
6 Soil Sets and 4 Pile Types



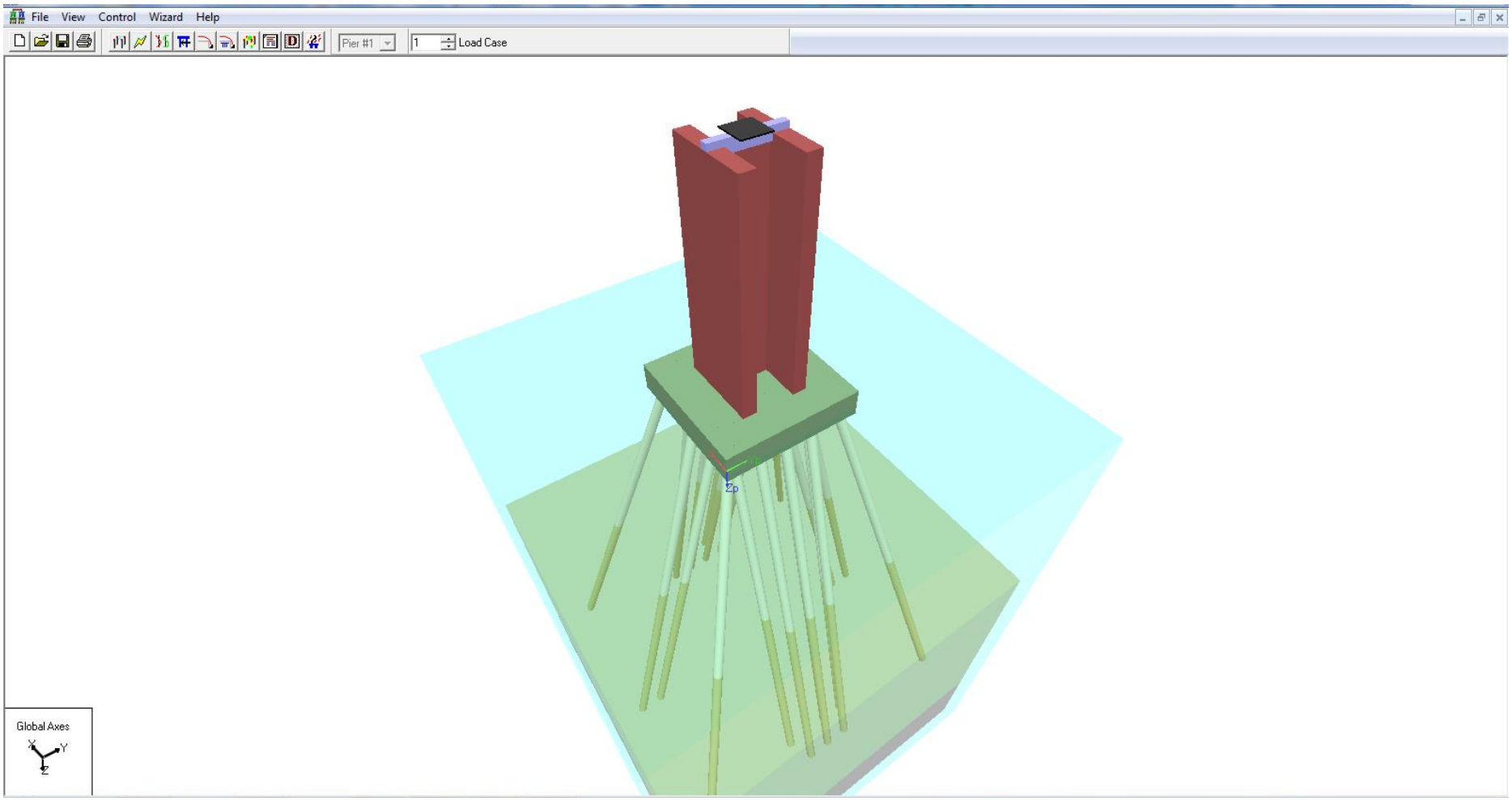
4 Pile Types



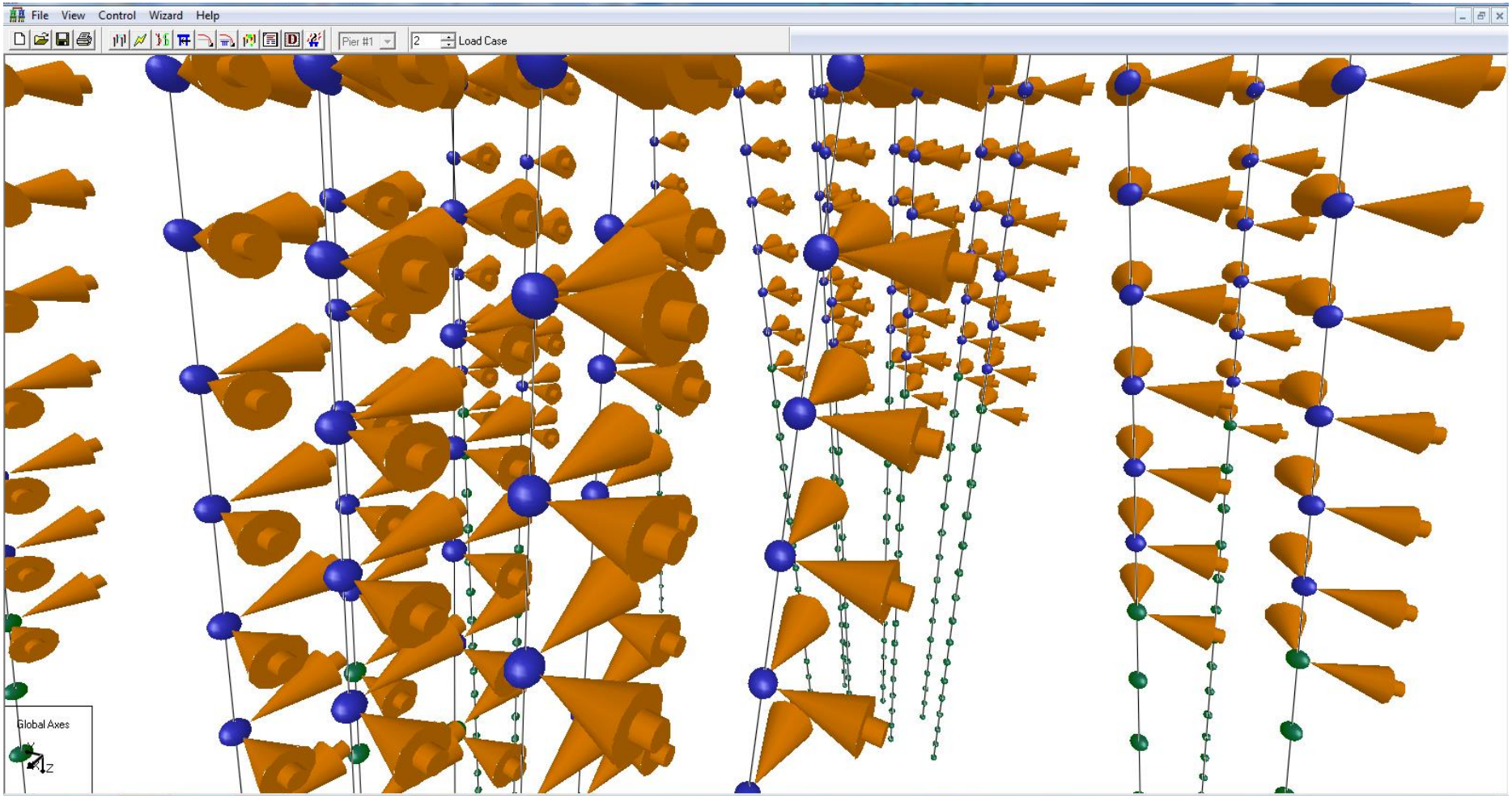
Cap Skewed to Pier



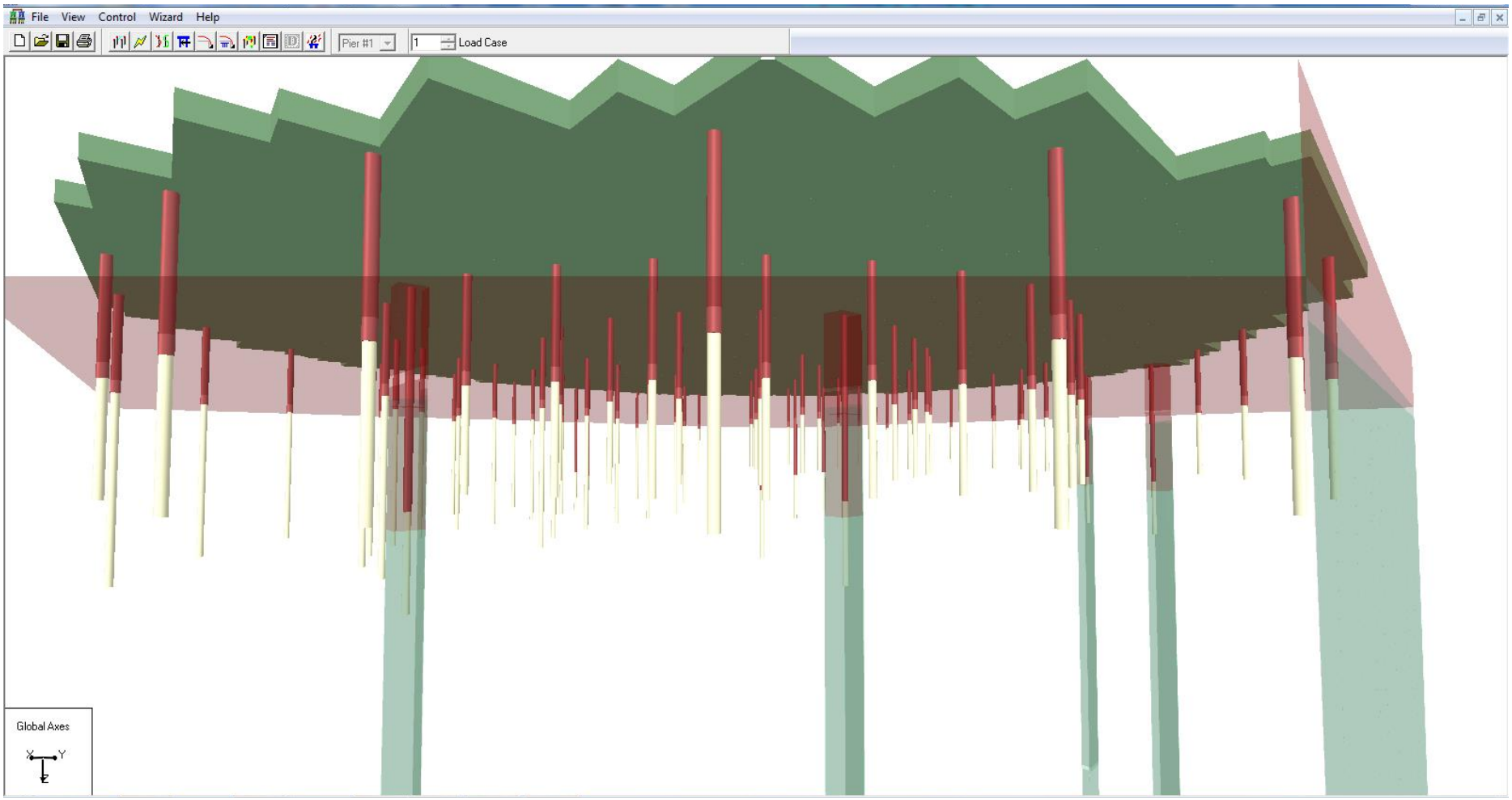
Bonner Bridge (H-Pile Pier)



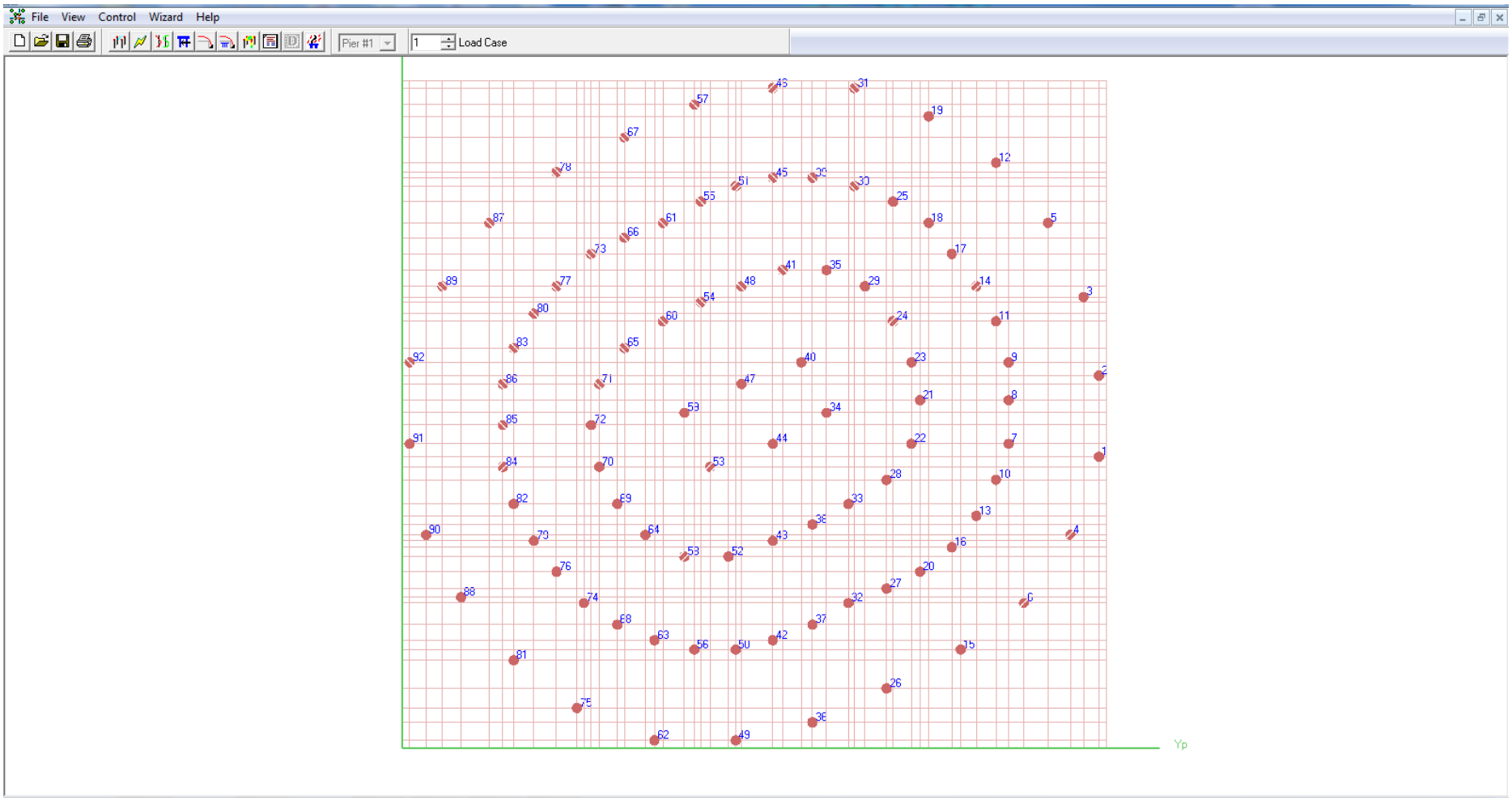
X and Y Loads at Every Pile Node



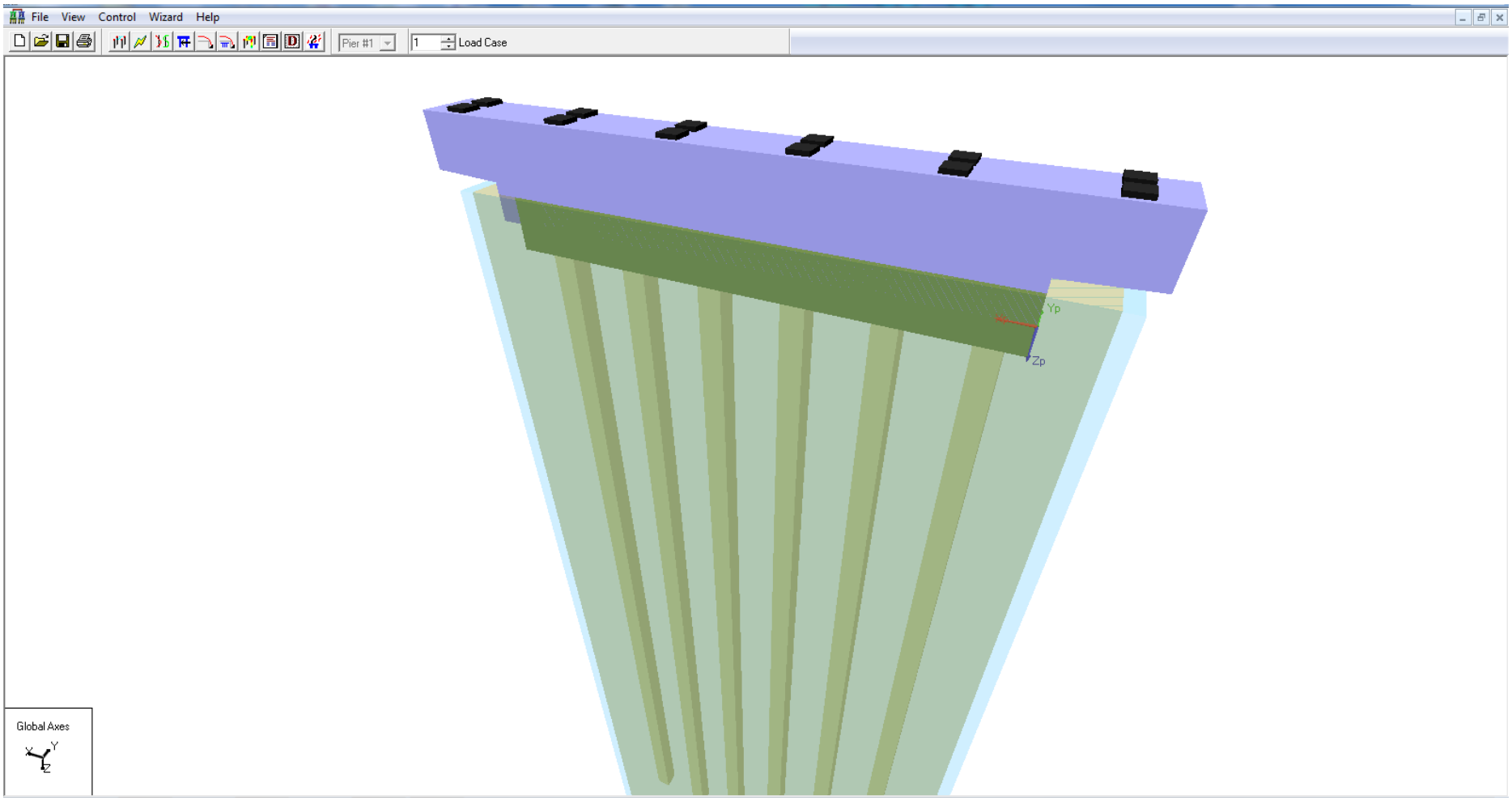
Oxidation Basin



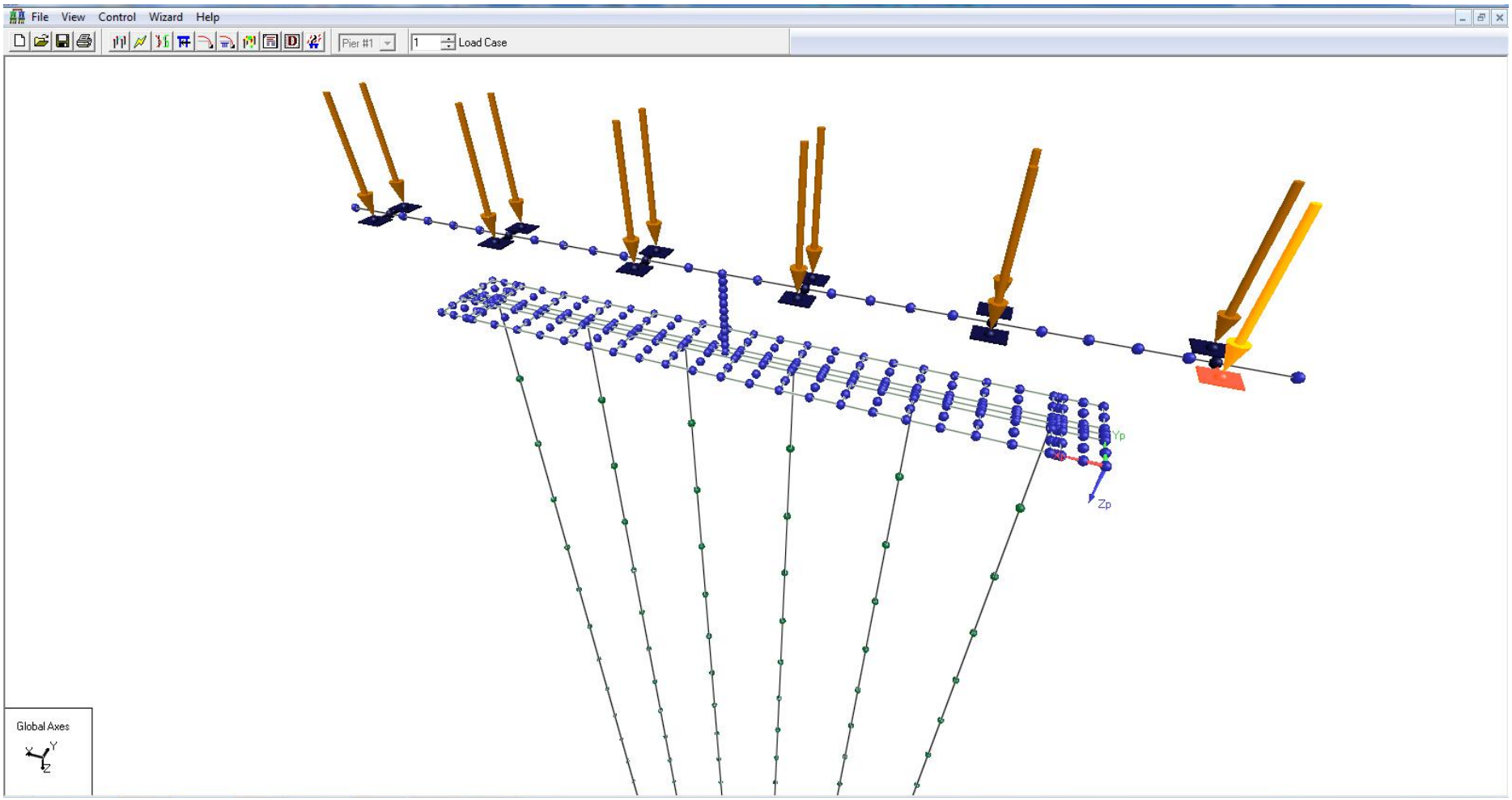
Oxidation Basin (Plan View)



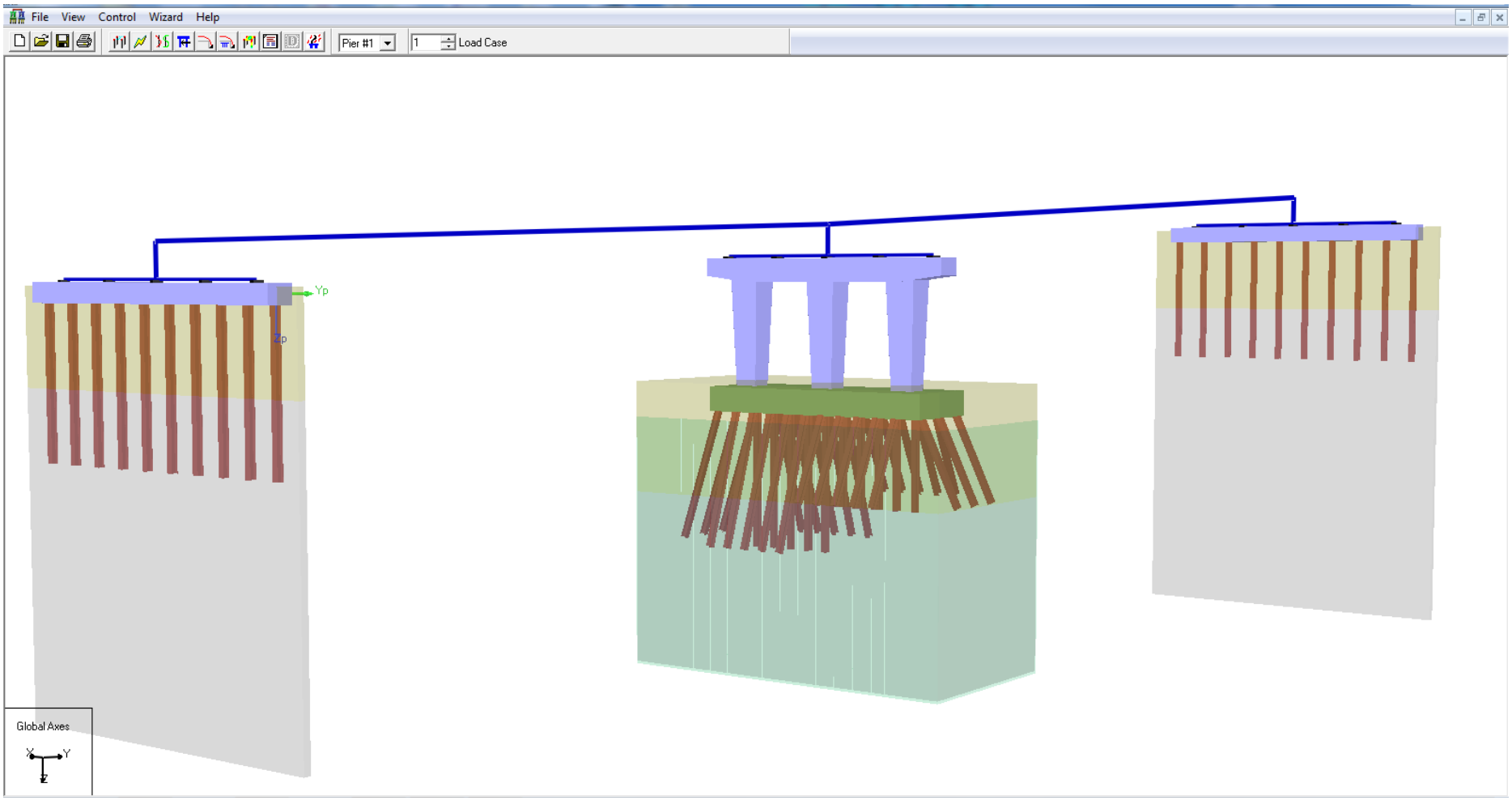
General Pier



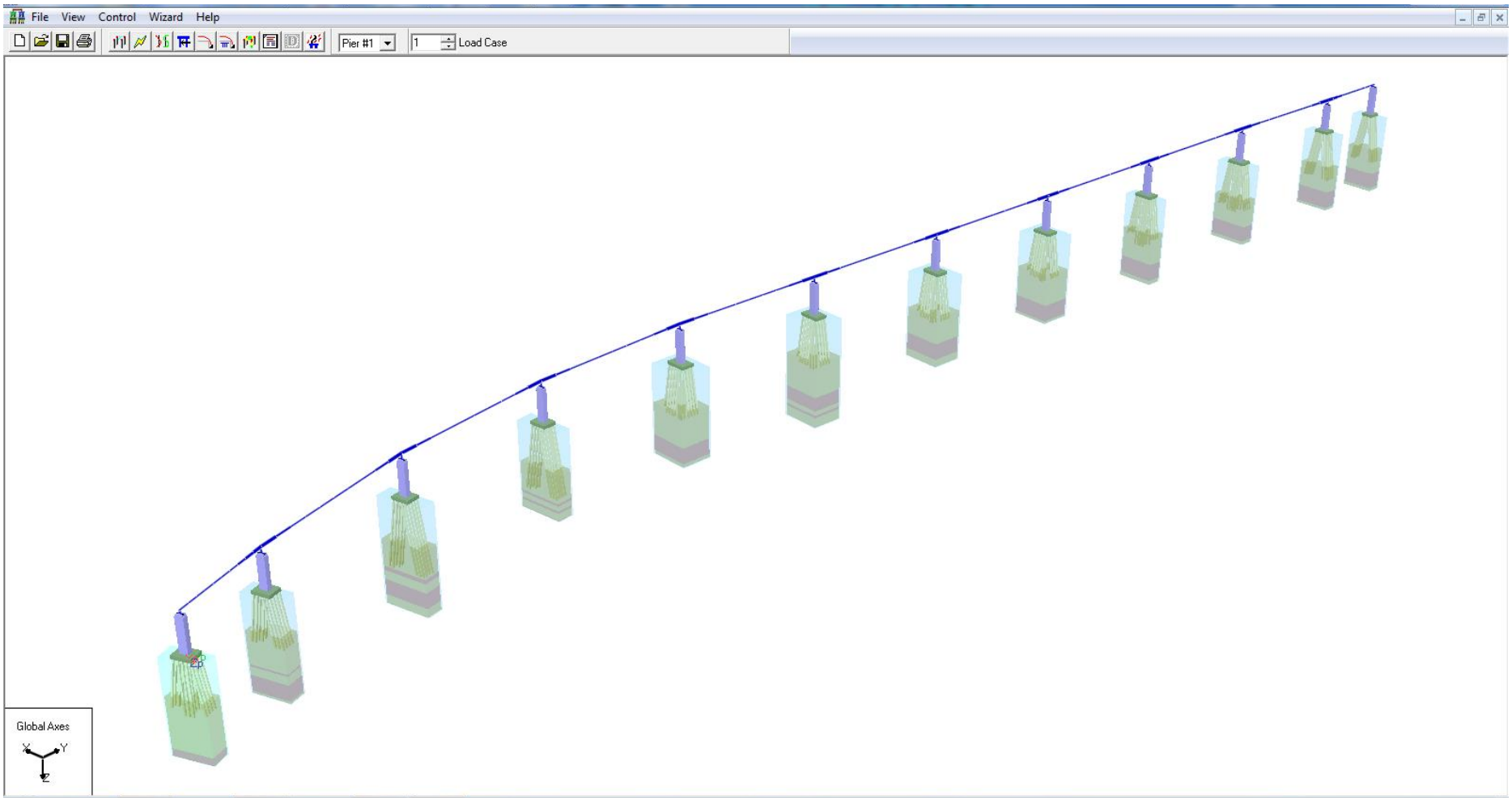
“Thin View”



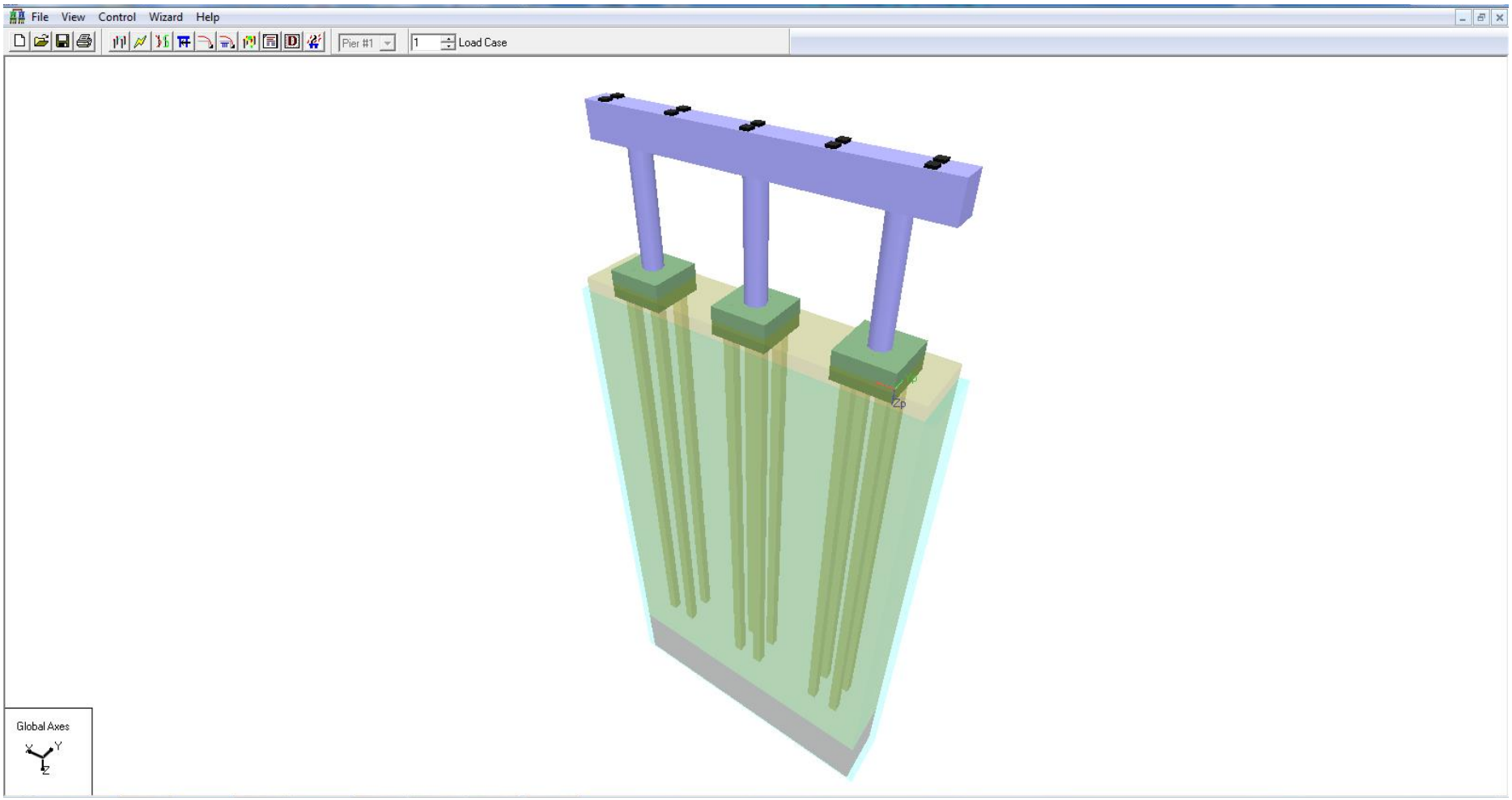
Two-Span Bridge



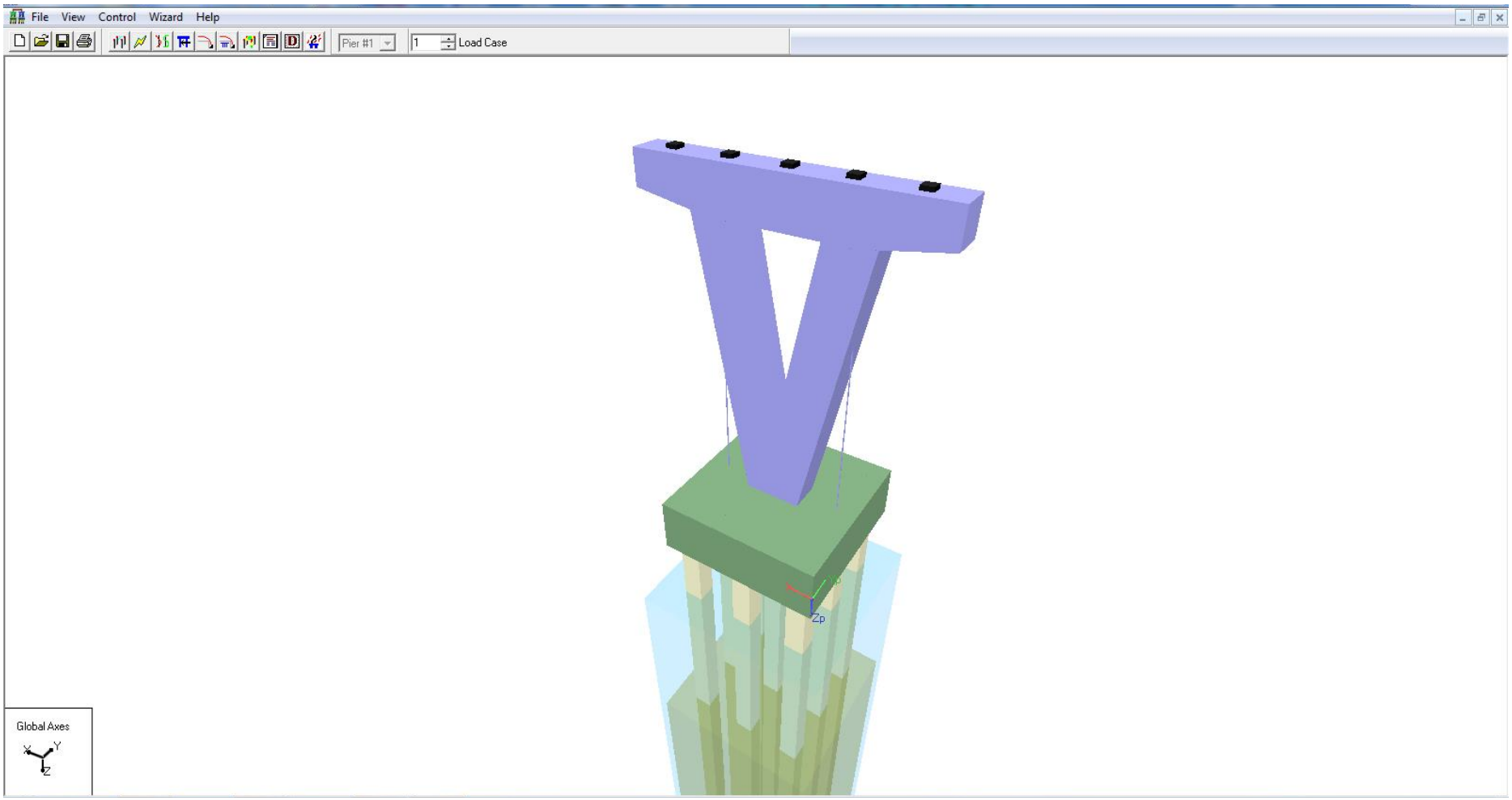
Eleven-Span Bridge (Curved)



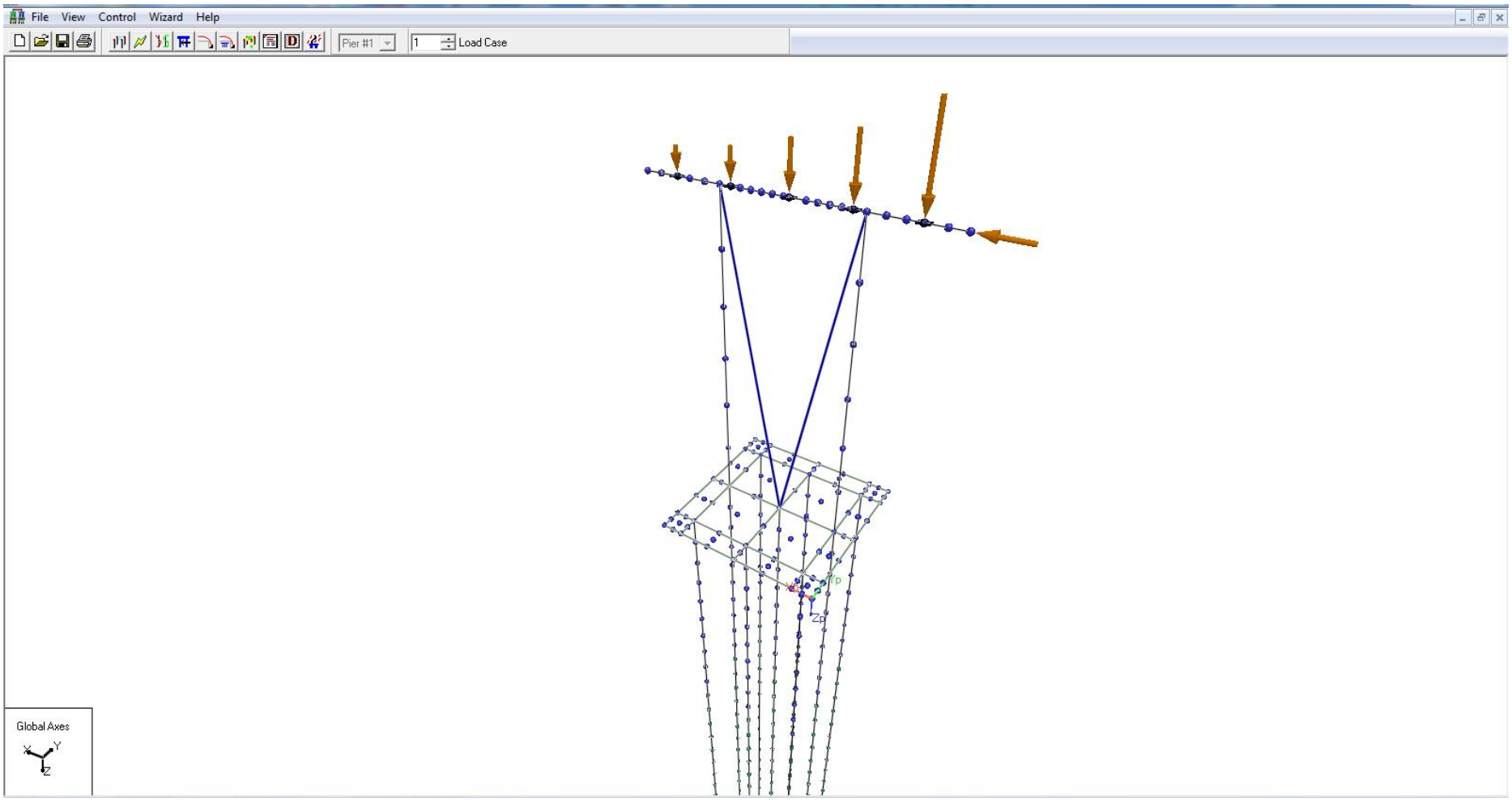
Typical Pier



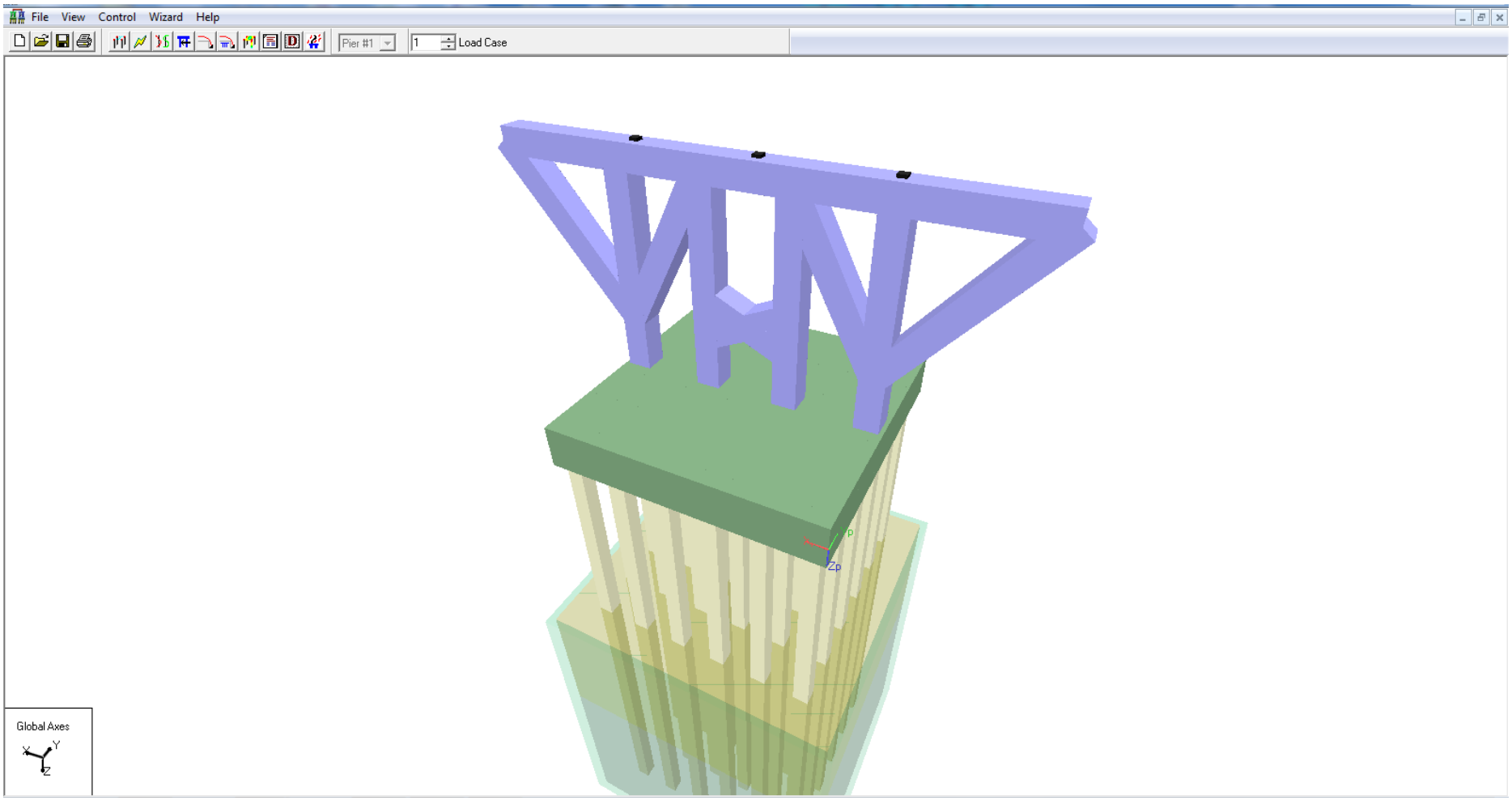
V-Pier



V-pier (Thin View)



Interesting…Hmmmm



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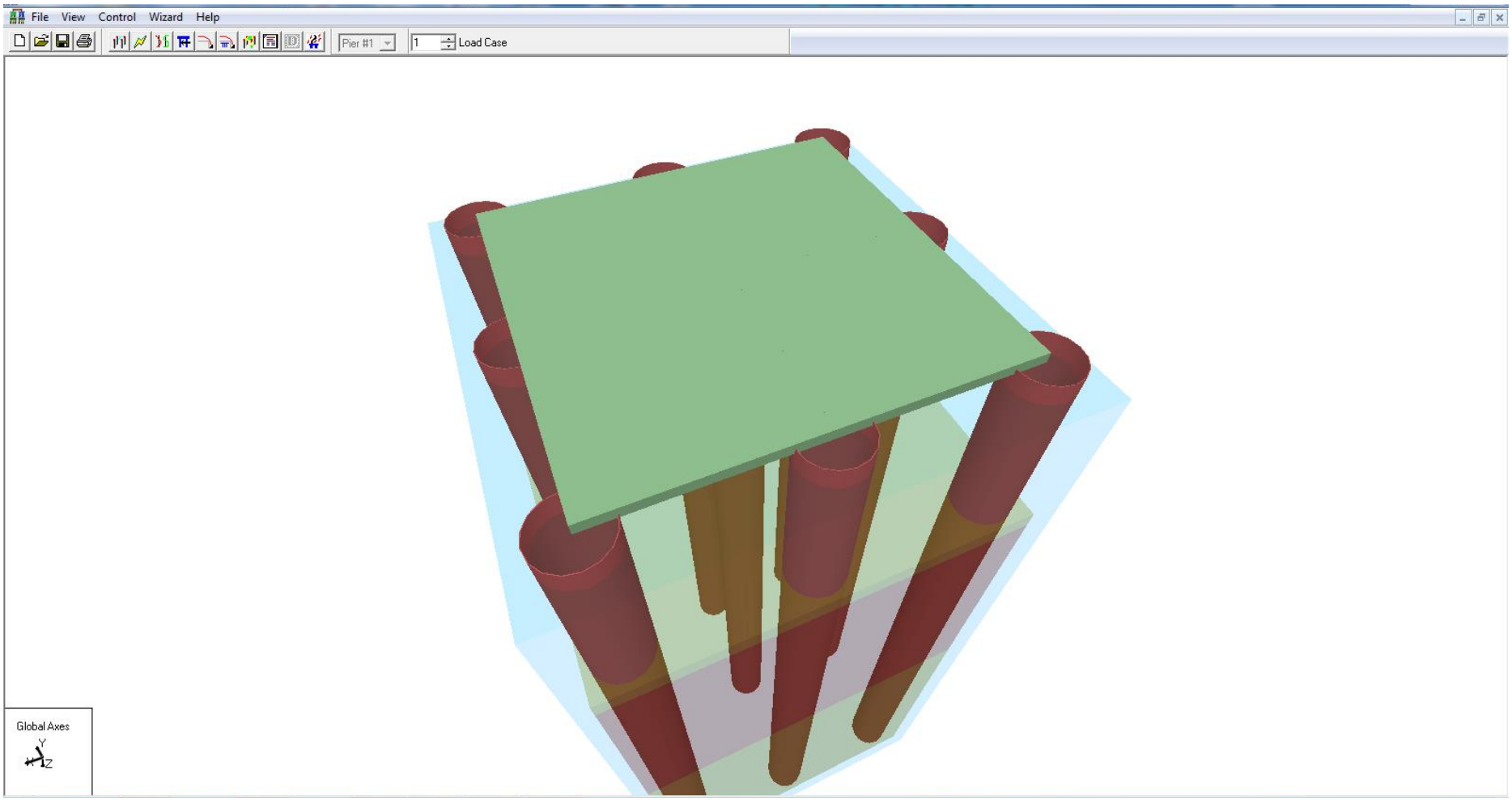
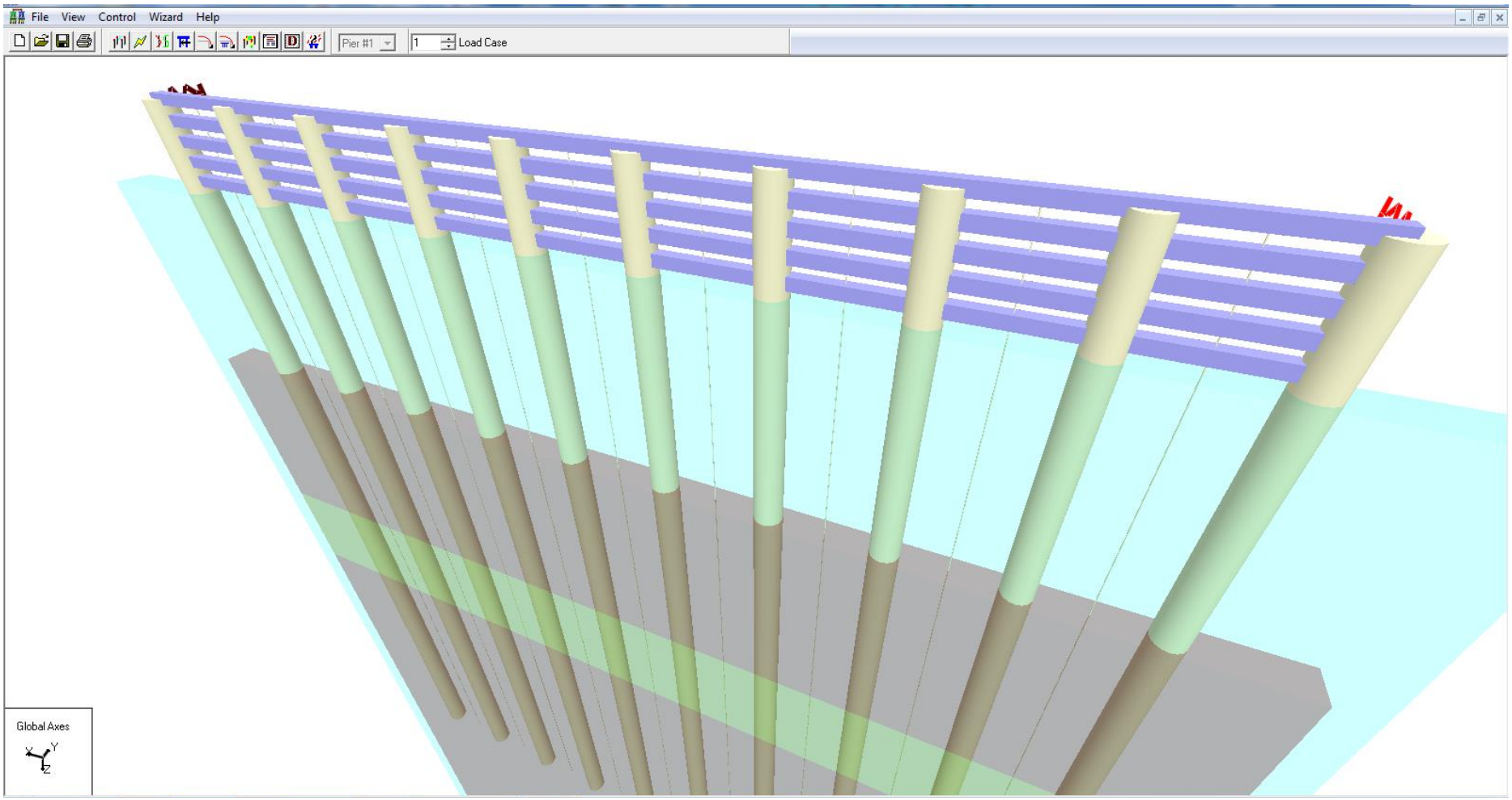
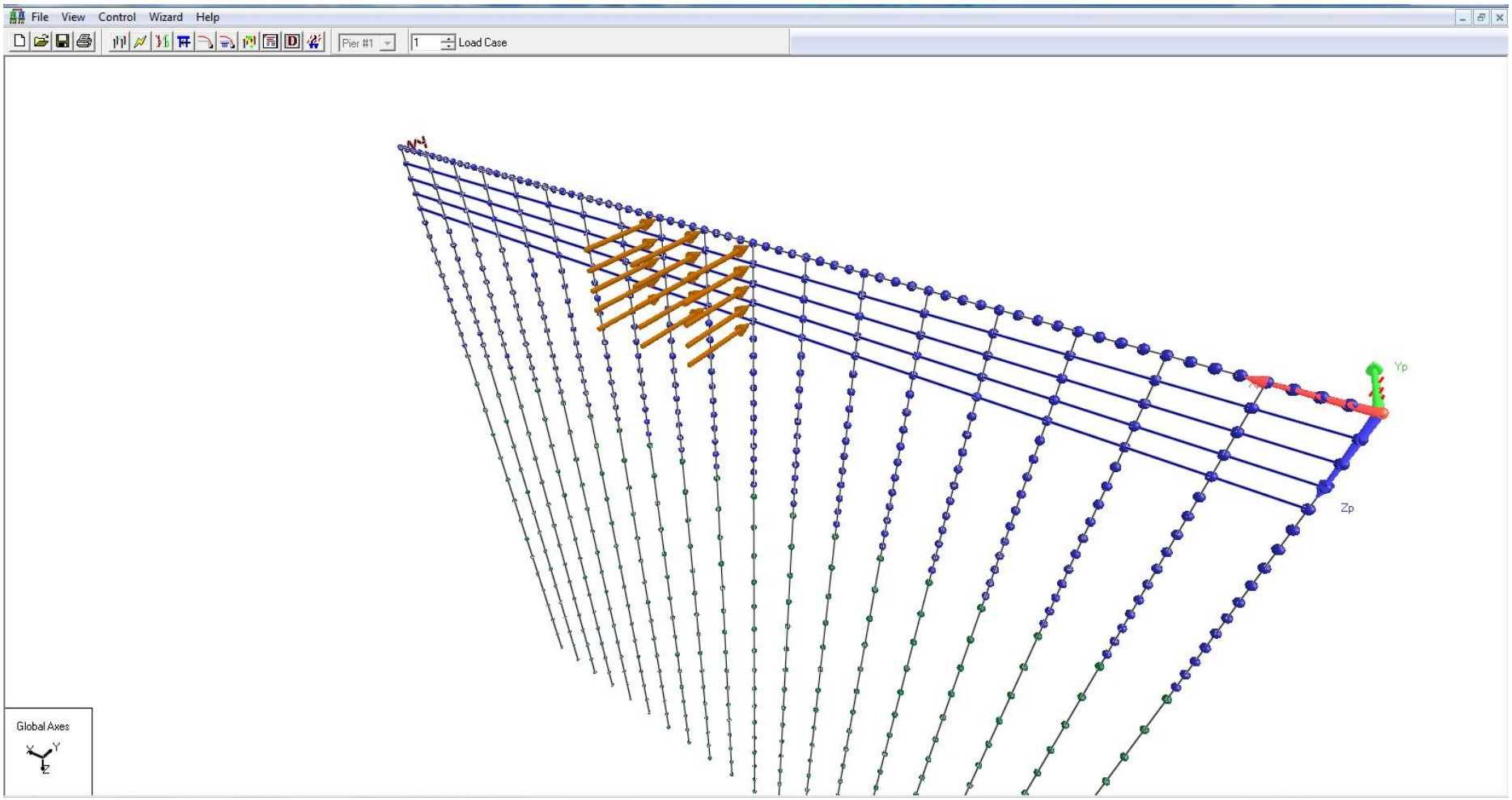


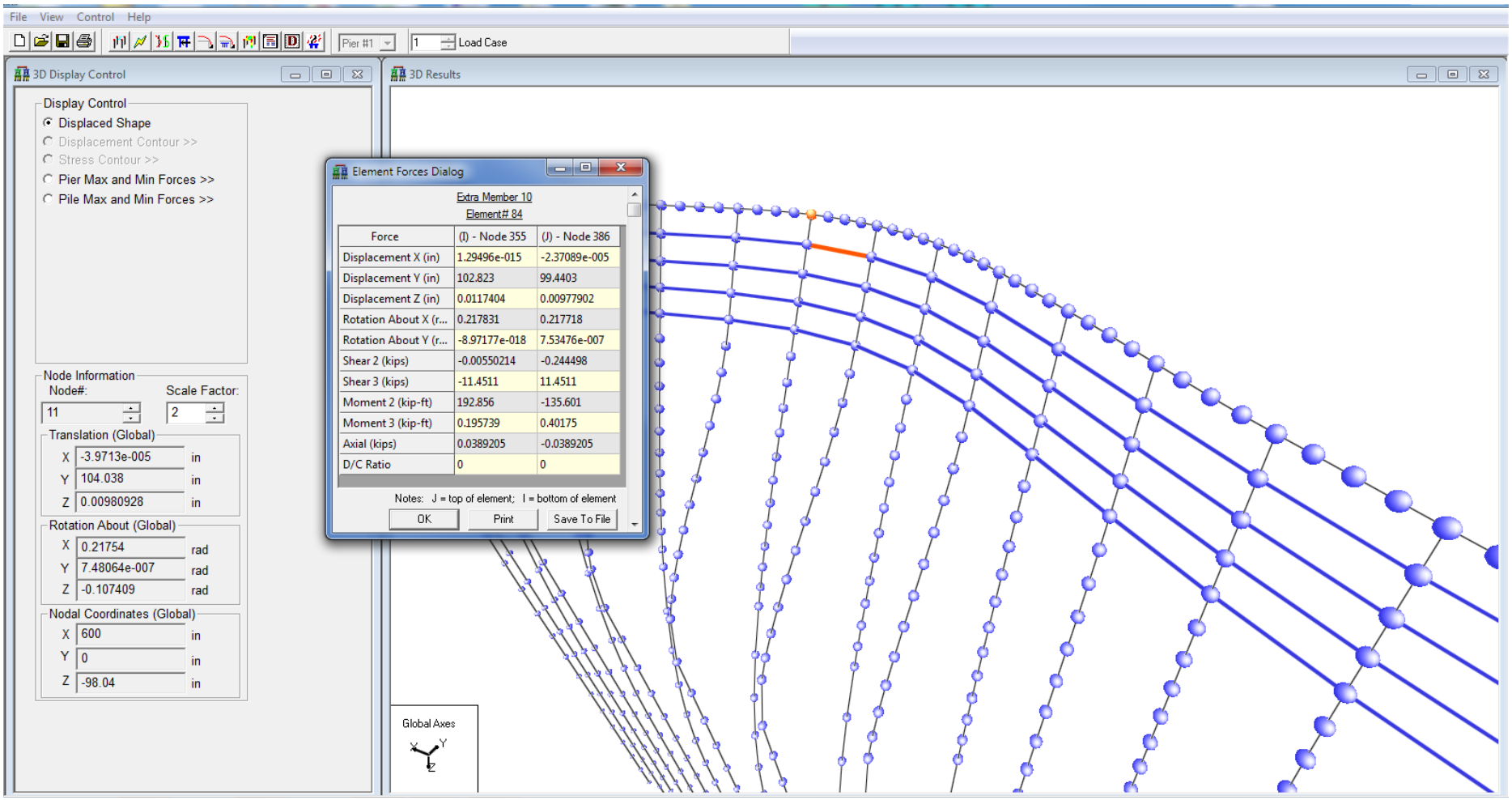
Fender Dummy Piles



Loading Dummy Piles



3D Results Window



Summary

- Design Tables
  - Conveniently Report Design Forces and Envelopes
- Model Showcase
  - Endless Possibilities

Acknowledgements

Bridge engineers (you!)

Thank you for your time!