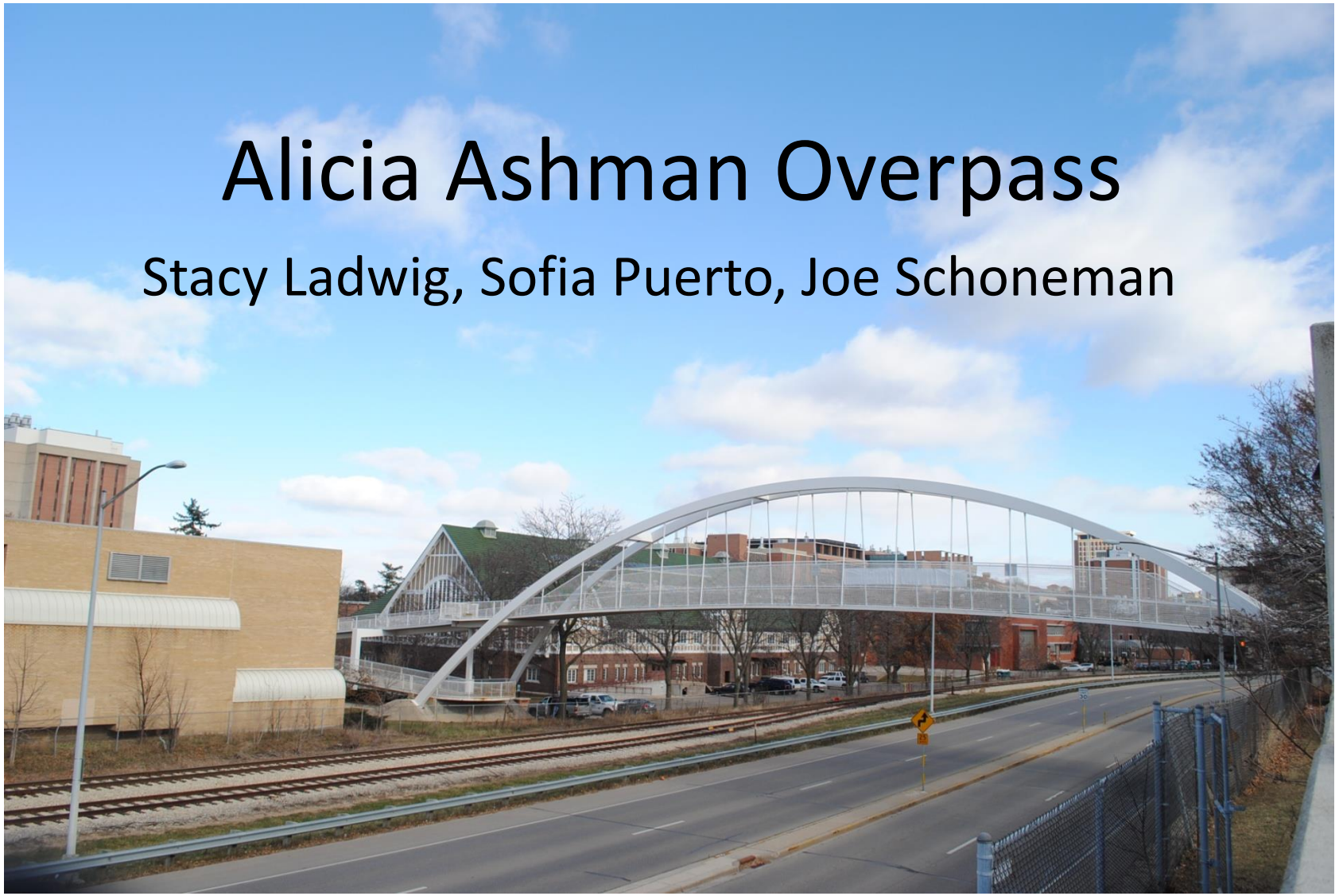
Alicia Ashman Overpass

Stacy Ladwig, Sofia Puerto, Joe Schoneman



Overview

- About Overpass
- Motivation
- SAP Model
- Experimental Setup
- Procedure
- Experimental Results
- Comparison with SAP Model
- Conclusion

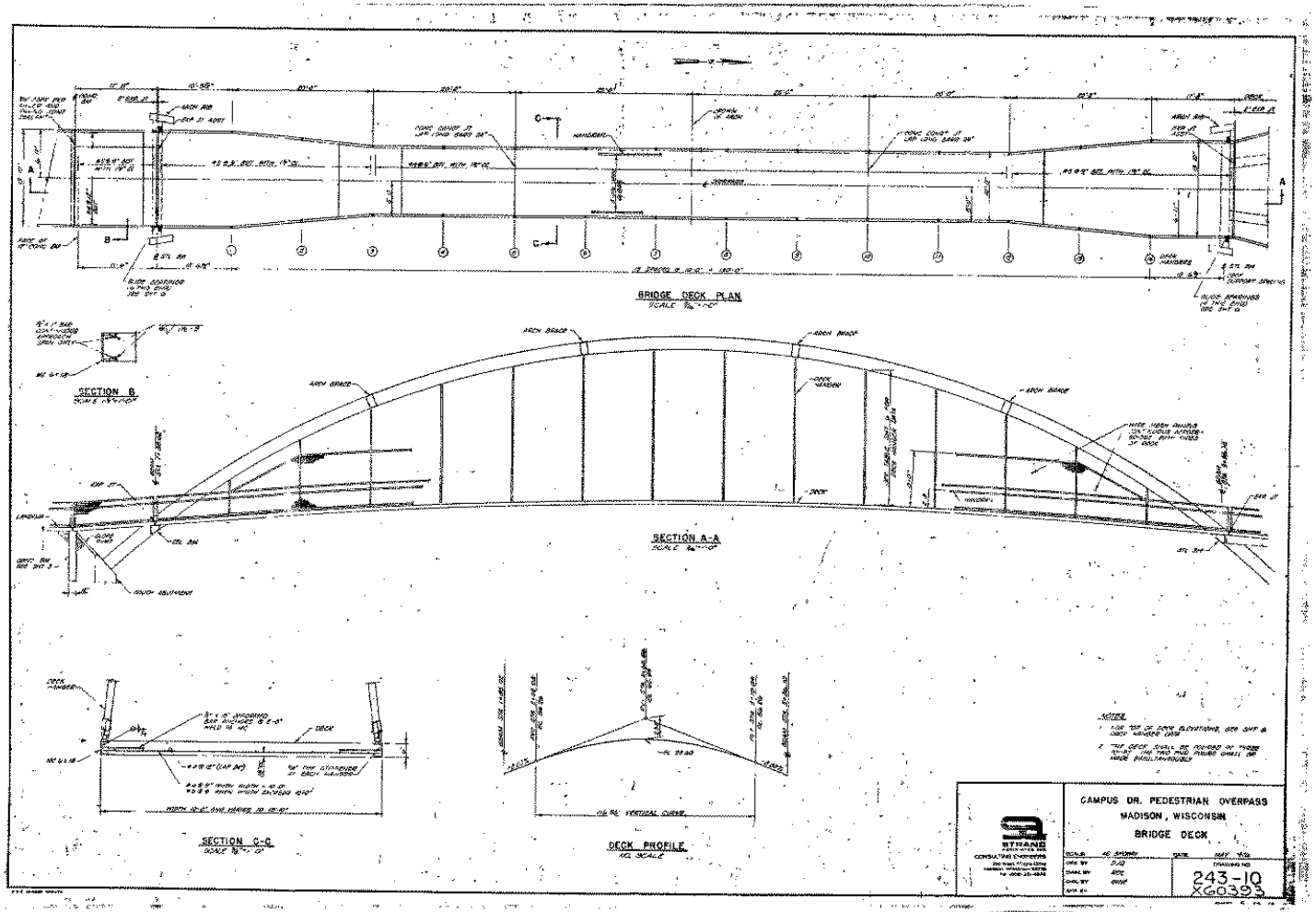
About Overpass

- Named after:
  - Alderman Alicia Ashman
- Built in 1977
- Materials:
  - Concrete
  - Steel
- Bridge Geometry:
  - Arch Span: 180 x 10 ft
  - Ramp: 200 ft

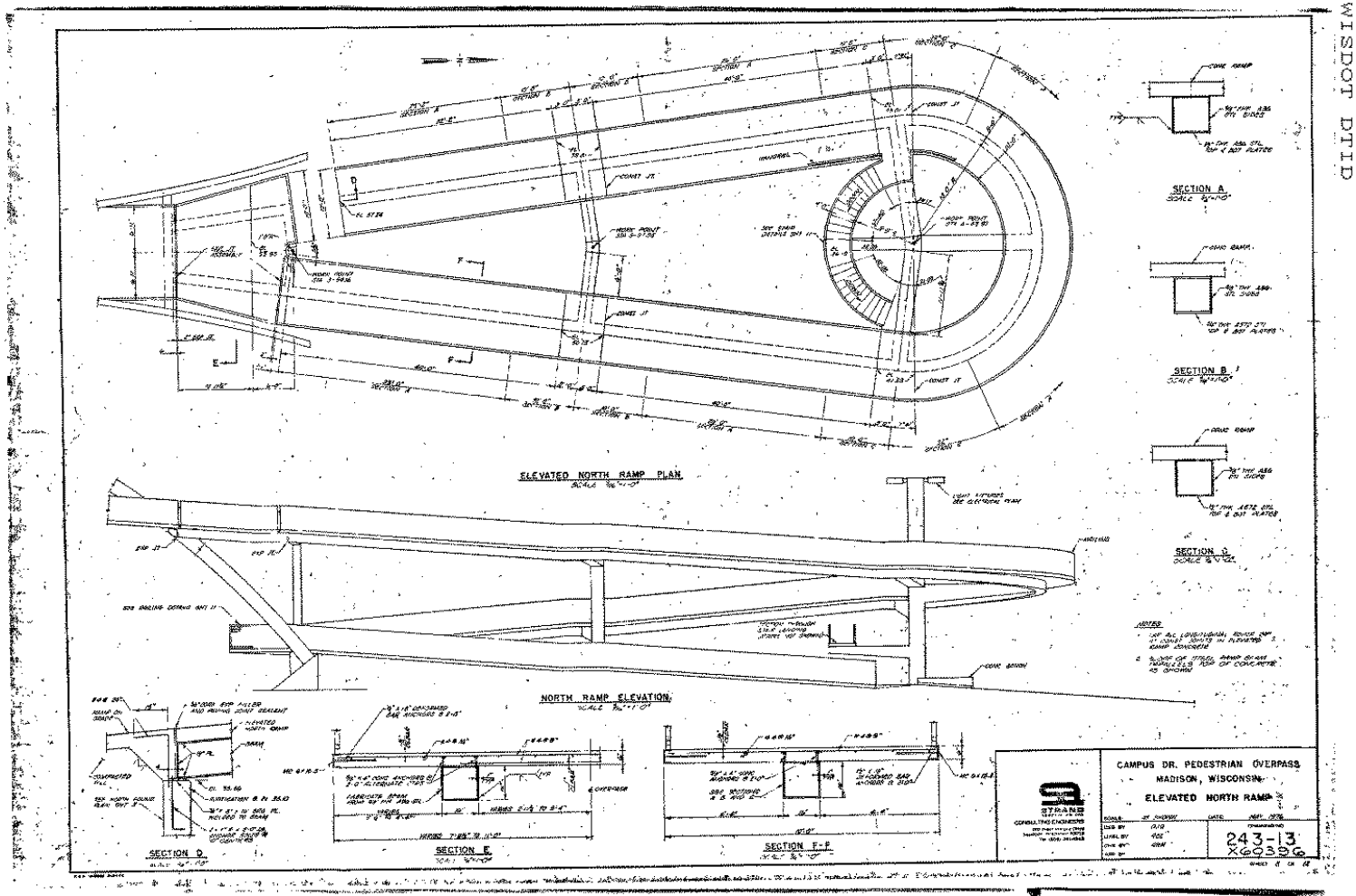
Motivation

- High amounts of deflection cause users to feel unsafe even when bridge is structurally sound
- Apply OMA concepts
- Compare results with a SAP2000 Model generated during CEE 744

Campus Dr. Pederstrian Overpass
P-13-769

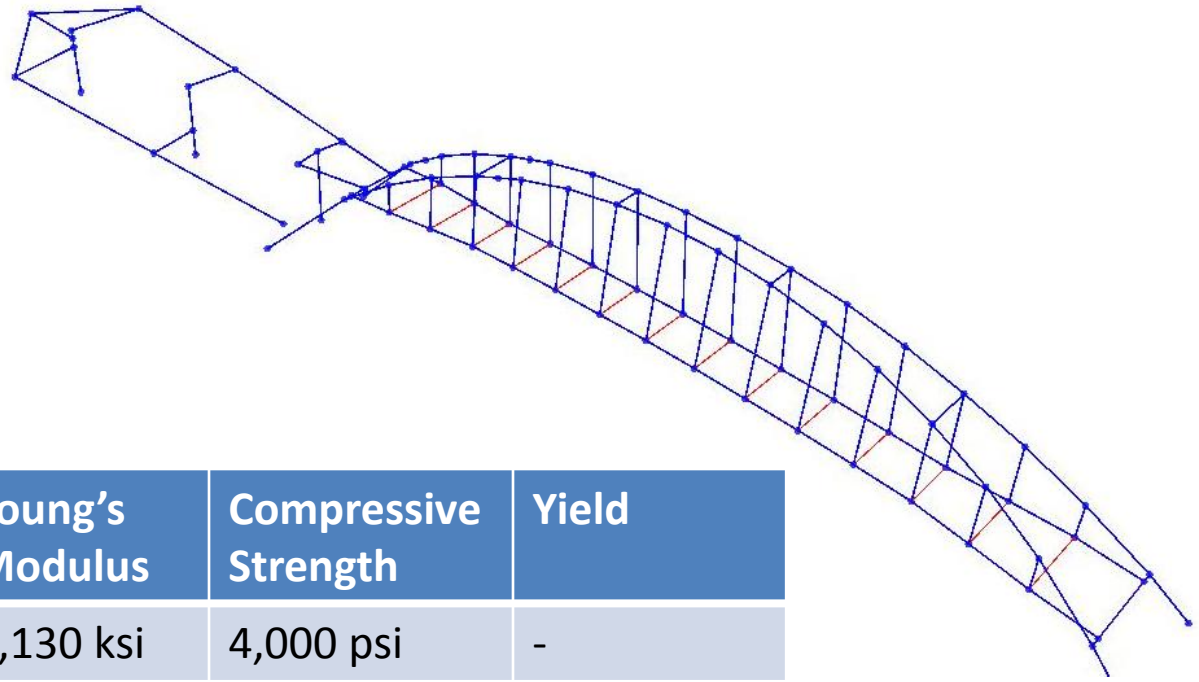


Campus Dr. Pederstrian Overpass
P-13-769



P-13-769
1977

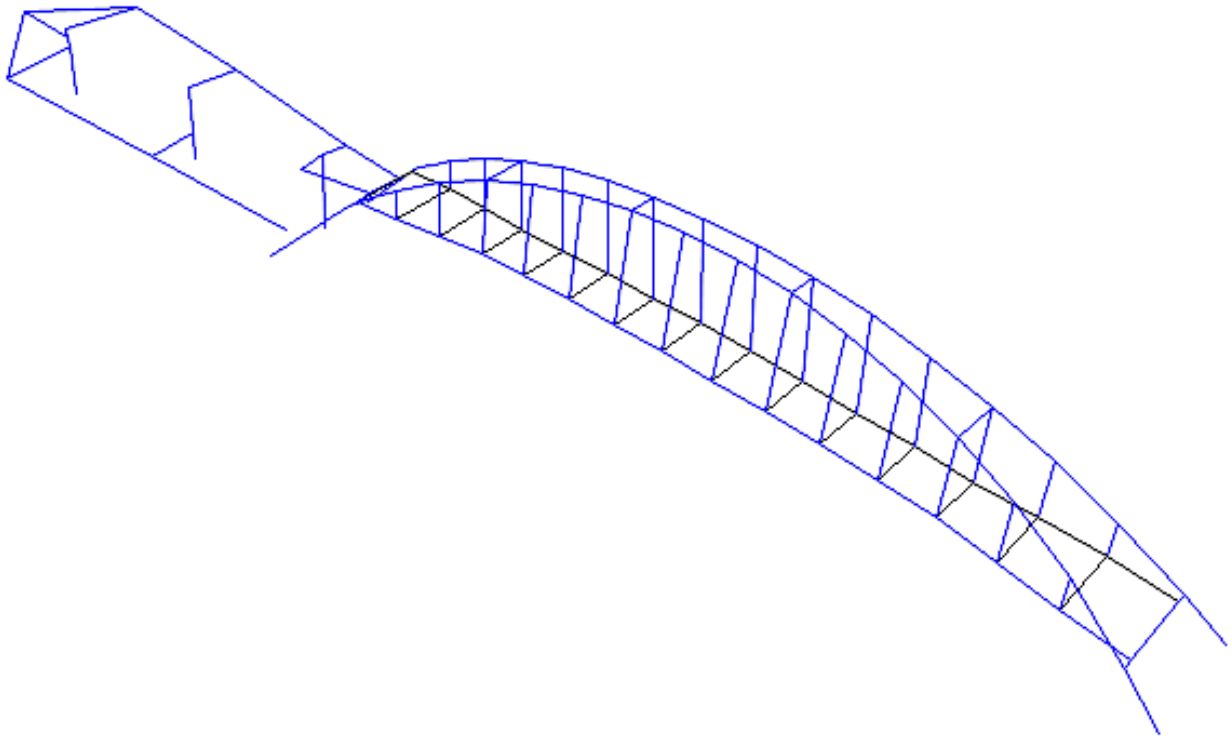
SAP2000 Model Given



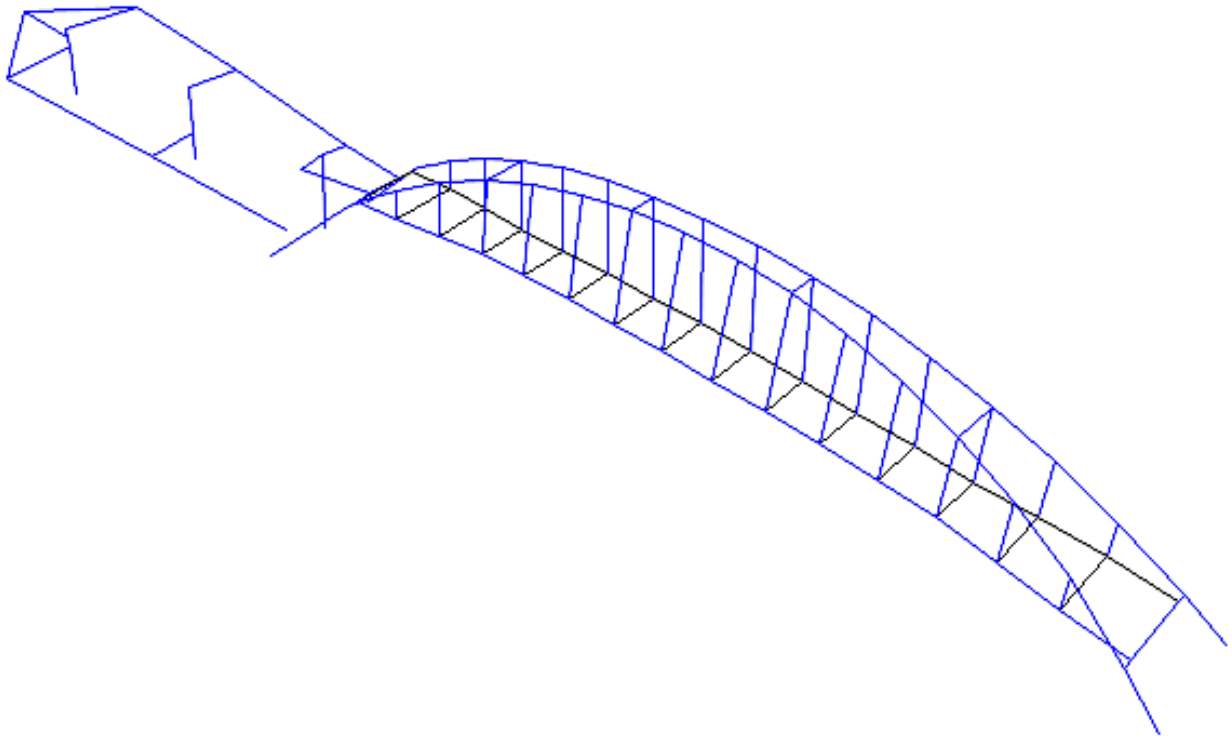
Material	Young's Modulus	Compressive Strength	Yield
Concrete	3,130 ksi	4,000 psi	-
Steel	29,000 ksi		36,000 psi

- Frame elements used to model hangers, arch, beams and columns
- Shell elements to represent concrete slab

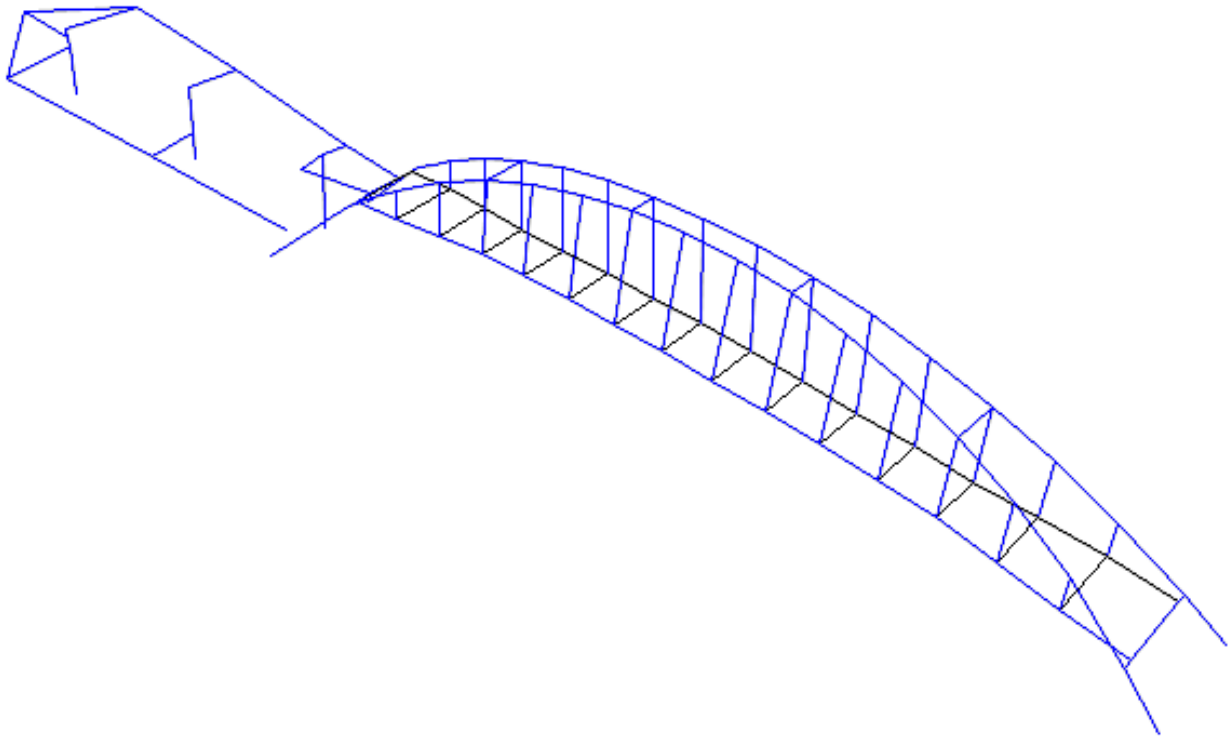
Dynamic Behavior of Model Provided Mode 1



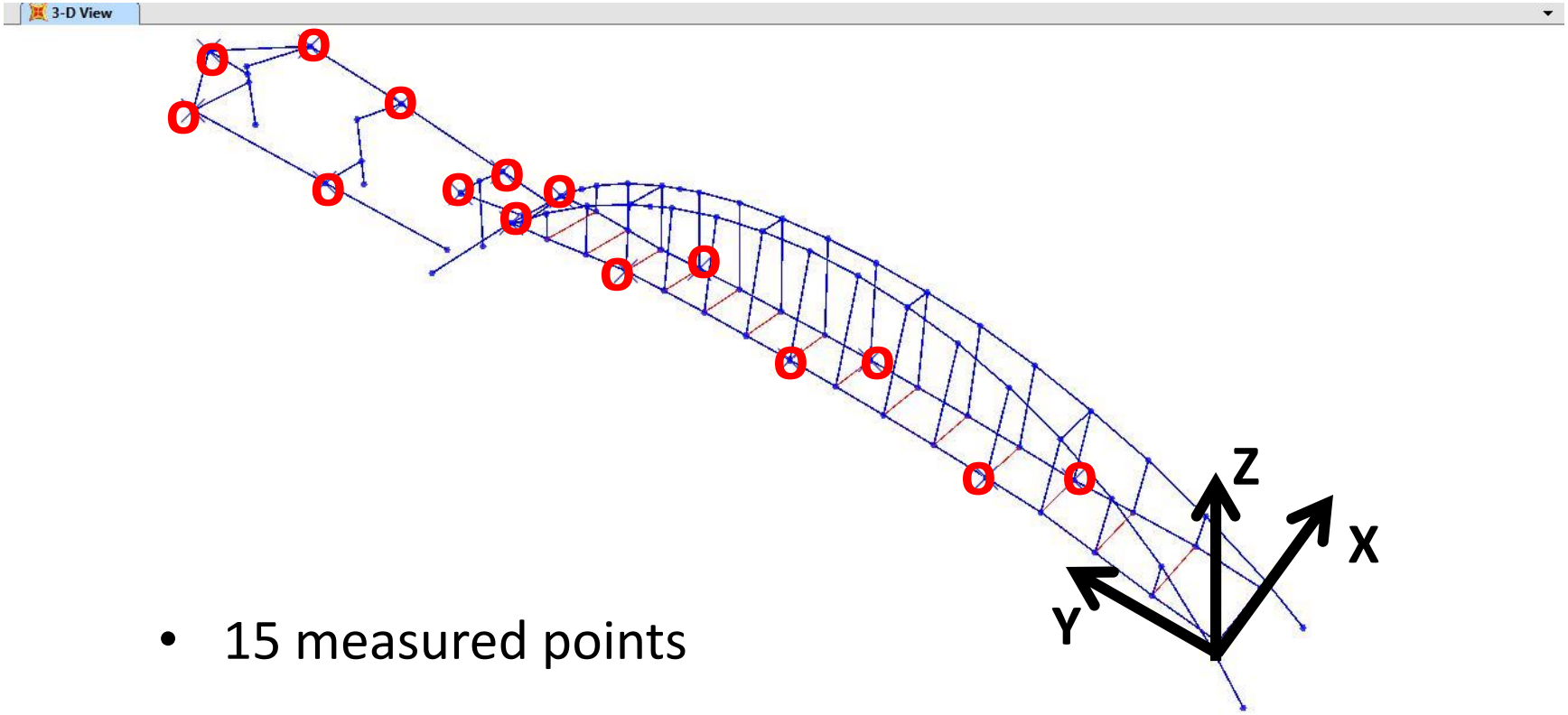
Dynamic Behavior of Model Provided Mode 3



Dynamic Behavior of Model Provided Mode 7



Measured Points
Based on Modal Shapes



- 15 measured points

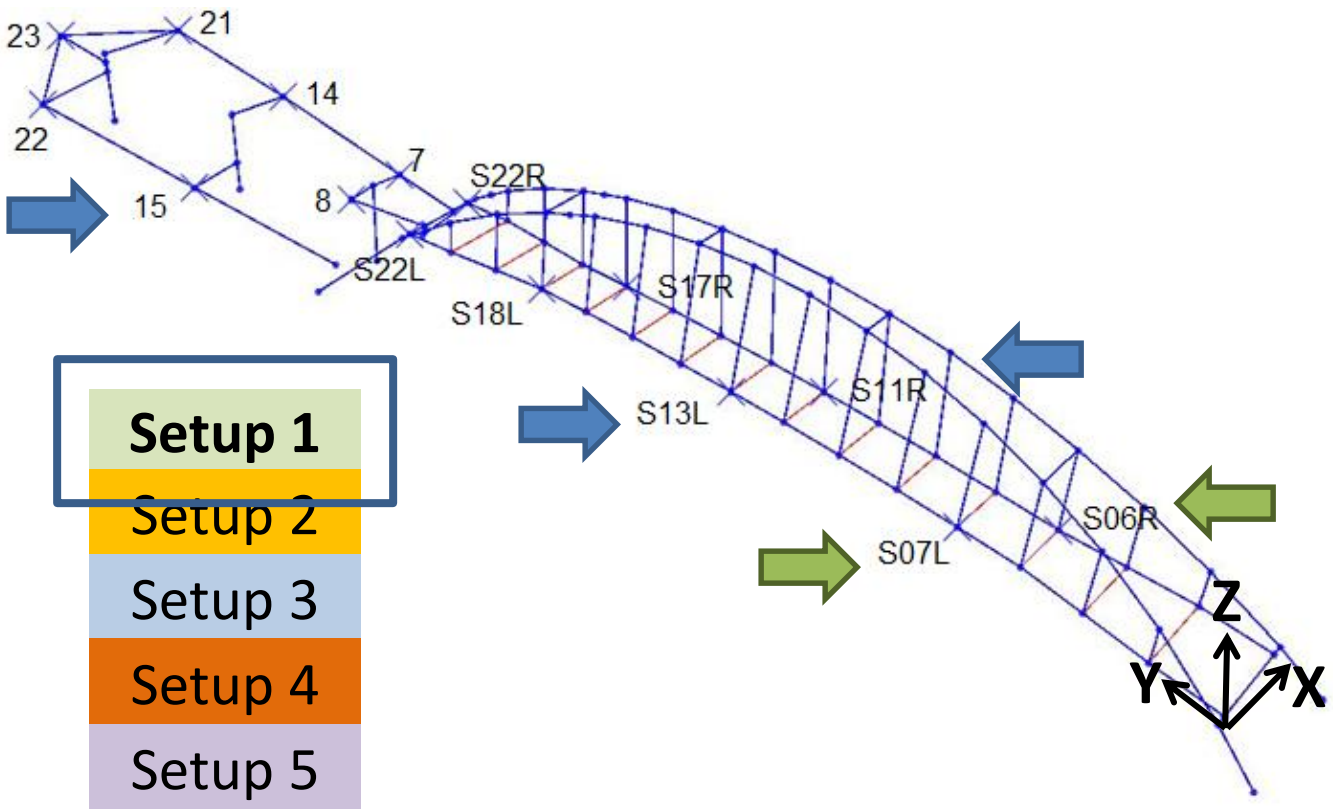
Measurement Set Up

- Five X-Y-Z accelerometers were used to collect data
- Only X and Z directions were recorded

Measurement set up

Reference Points

Pulse	SAP2000 Joint
1	**S06R**
2	**S07L**
3	S11R
4	S13L
5	S17R
6	S18L
7	S22R
8	S22L
9	7
10	8
11	14
12	21
13	22
14	15
15	23



Setup 1

Setup 2

Setup 3

Setup 4

Setup 5

Measurement set up

Reference Points

Pulse	SAP2000 Joint
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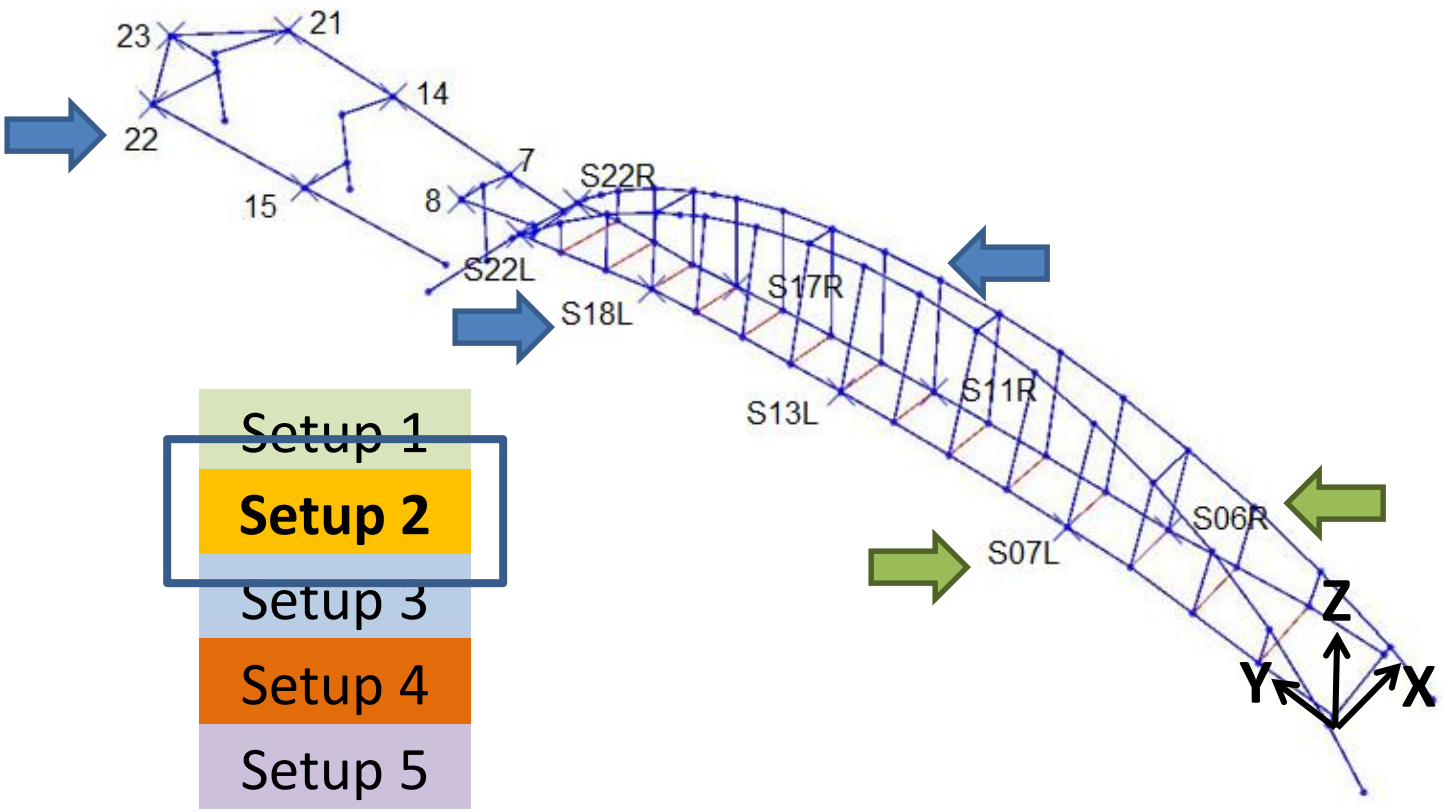
13	22
14	15
15	23



Setup 1

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Measurement set up

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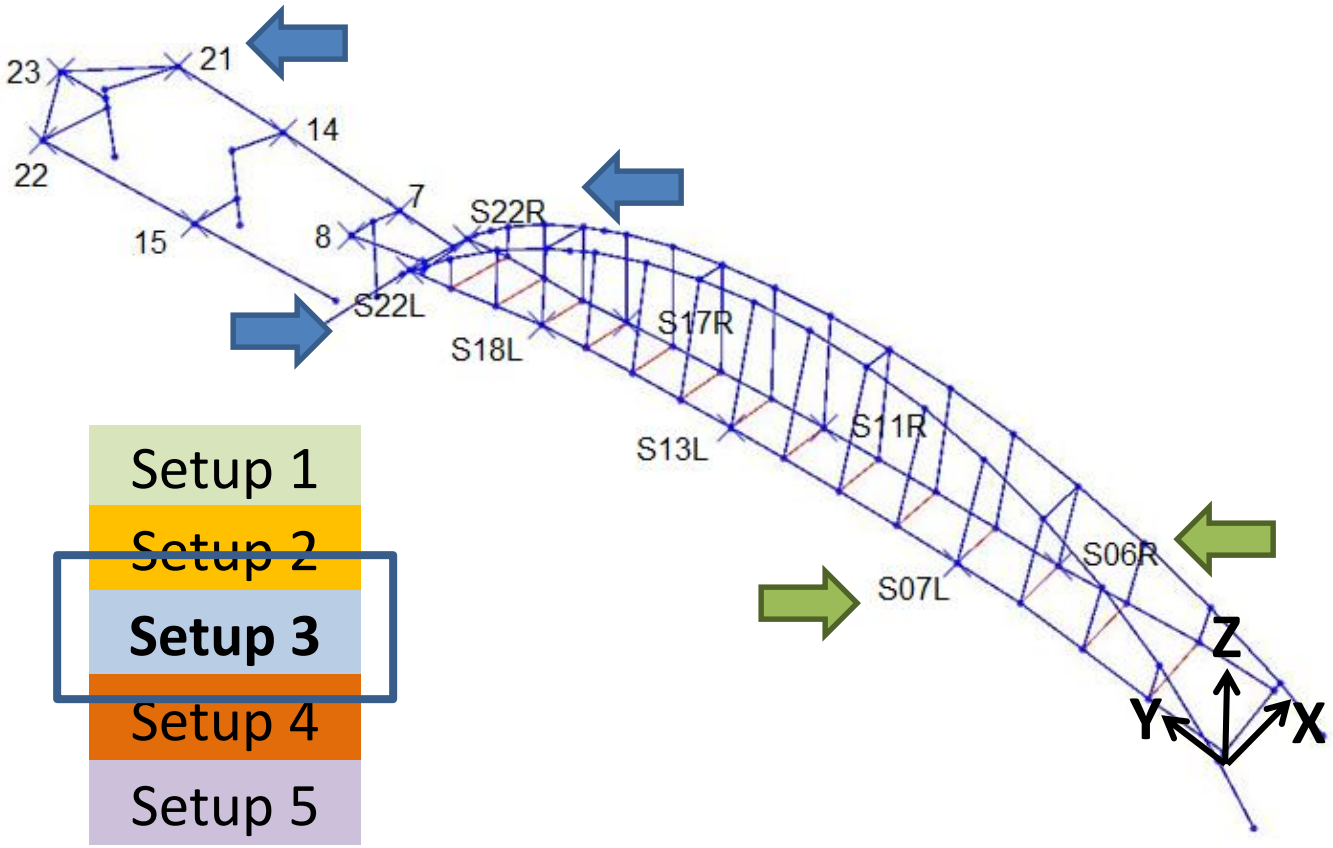
14	15
15	23



Setup 1
Setup 2
Setup 3
Setup 4
Setup 5

Measurement set up

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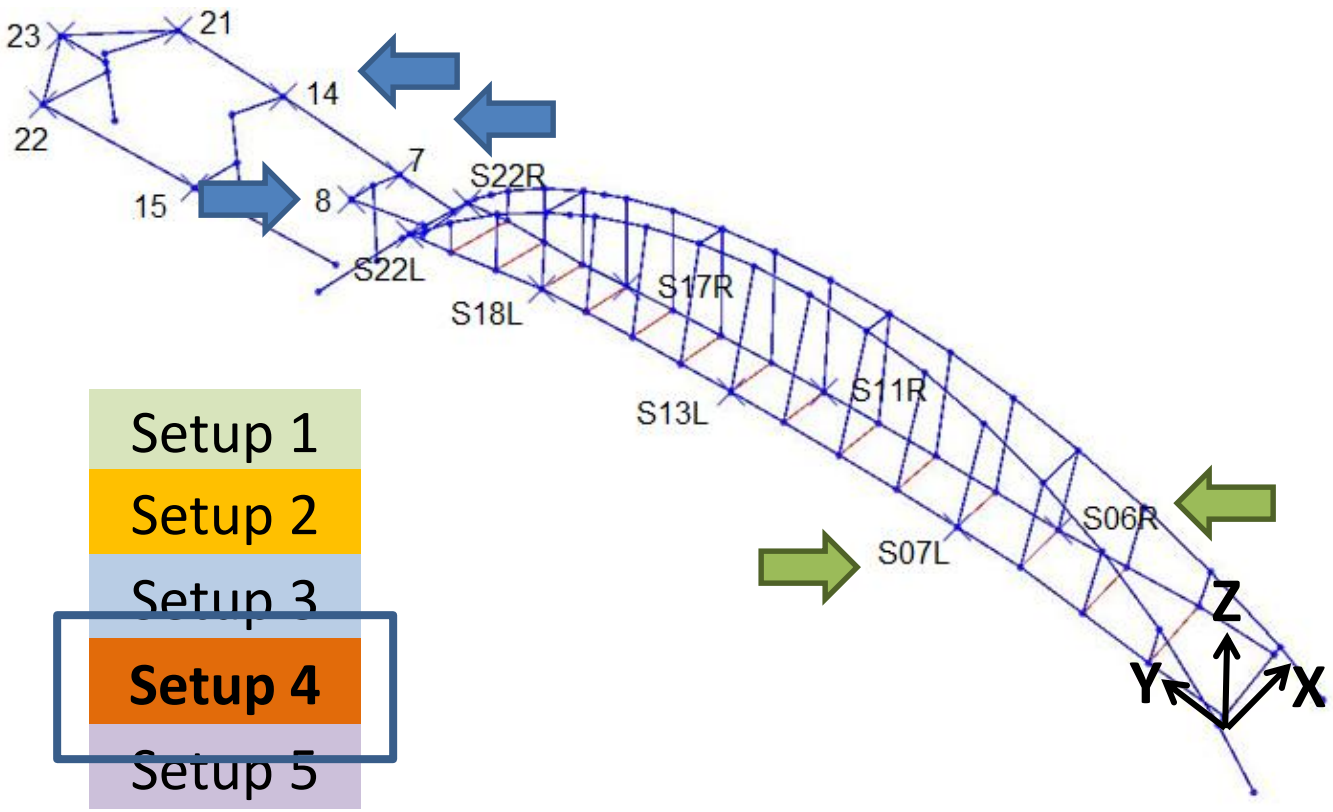
14	15
15	23



Setup 1

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Measurement set up

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14	15
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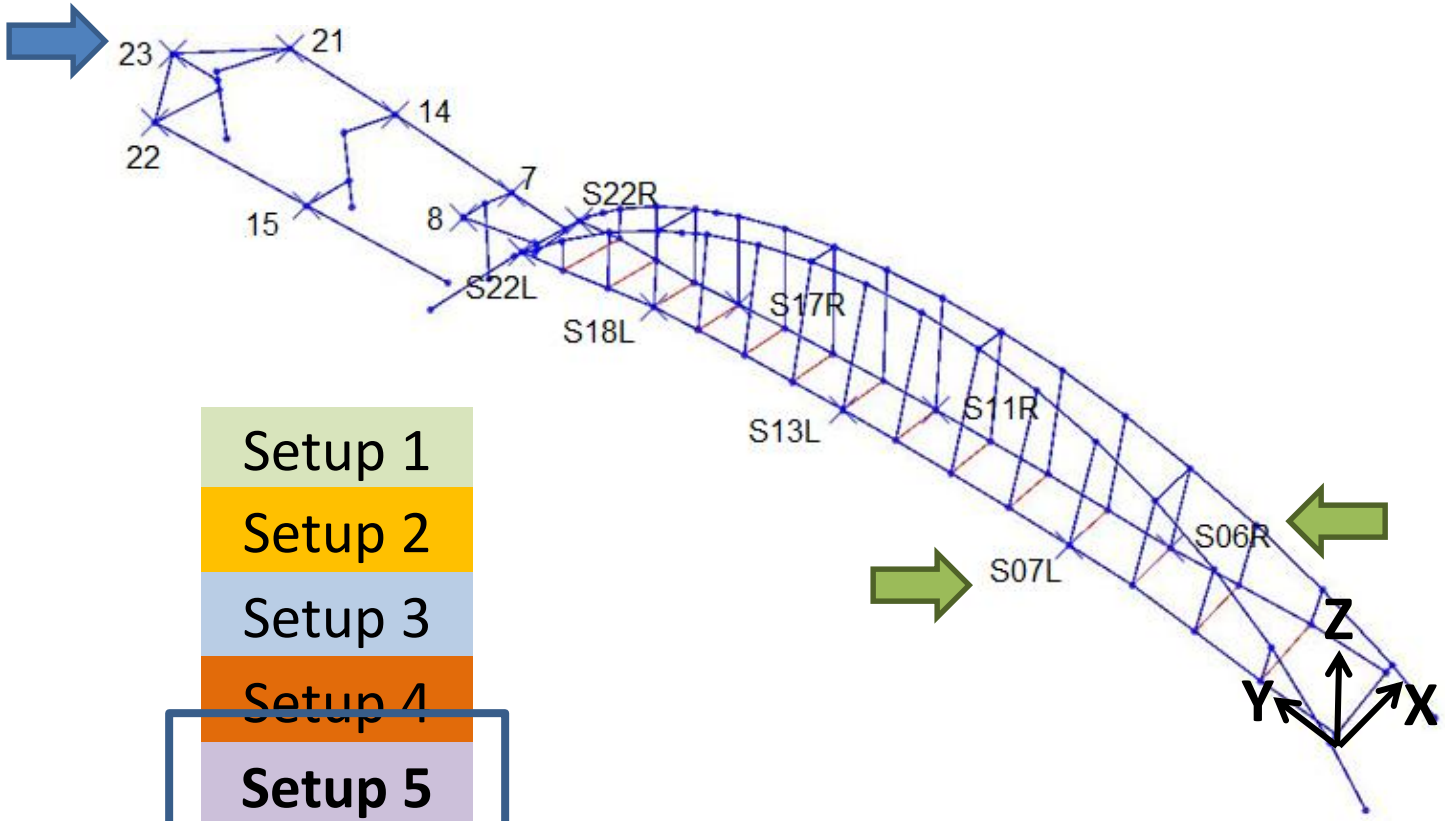
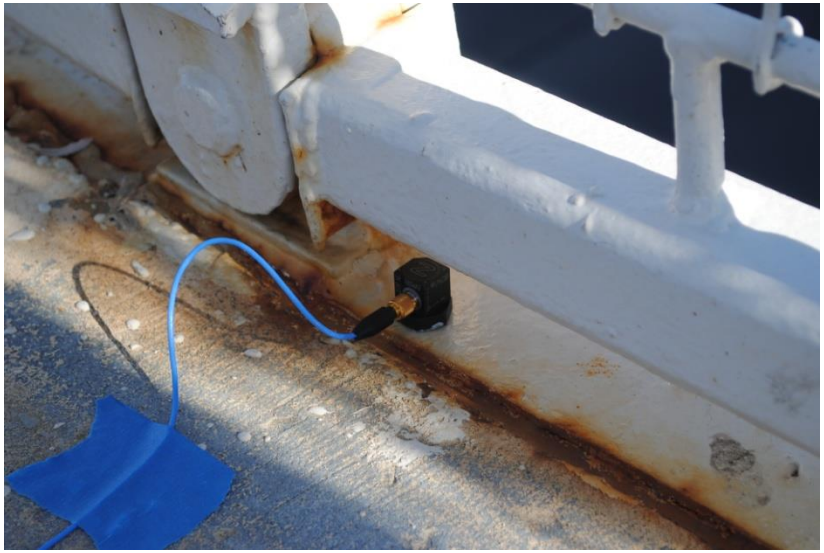


Setup 1
Setup 2
Setup 3
Setup 4
Setup 5

Procedure

- Randomly excite bridge by walking and jumping on structure
- Used 30 averages per set up to determine dynamic response up to 25 Hz

Measurement Day

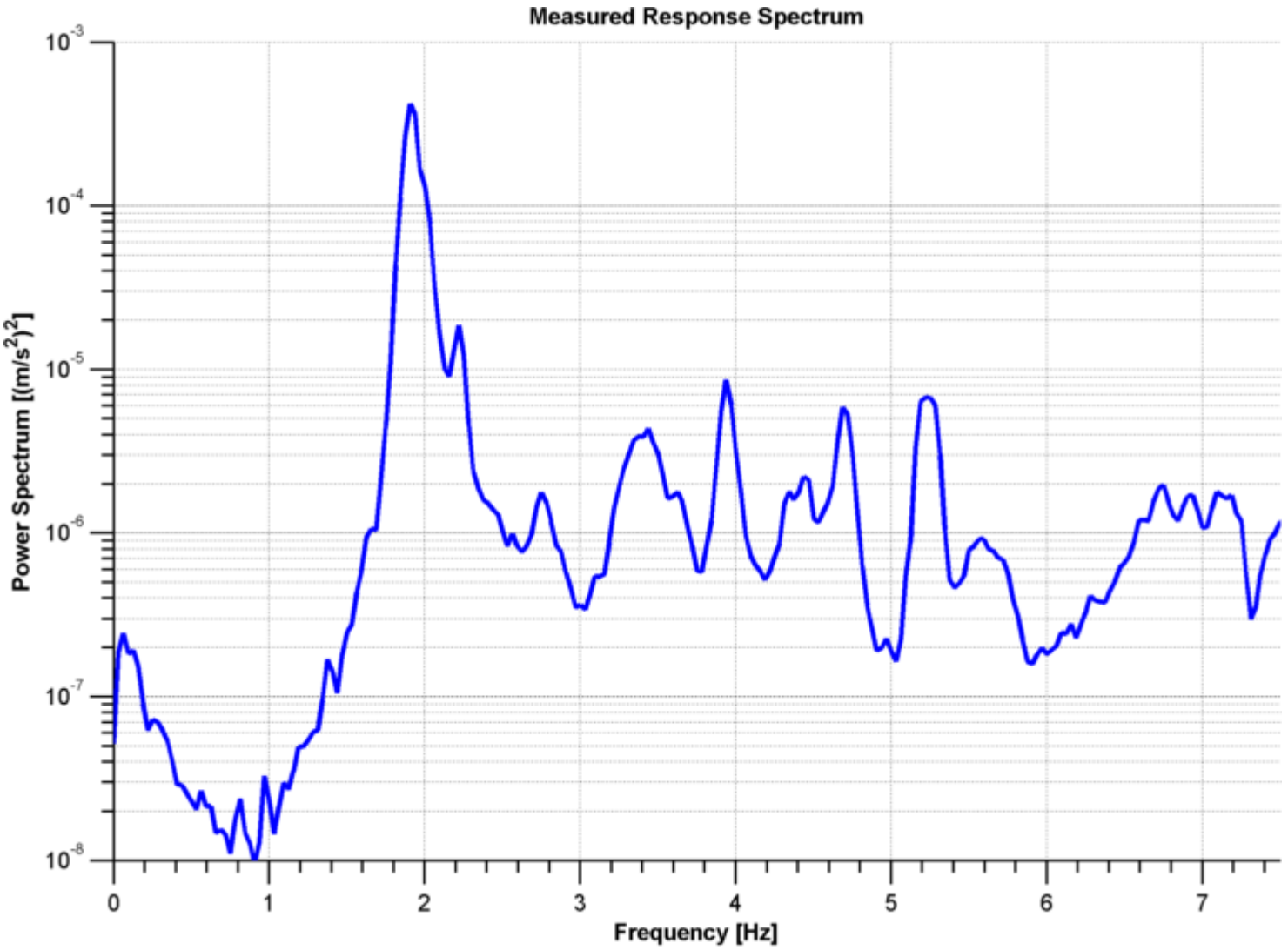


Measurement Day

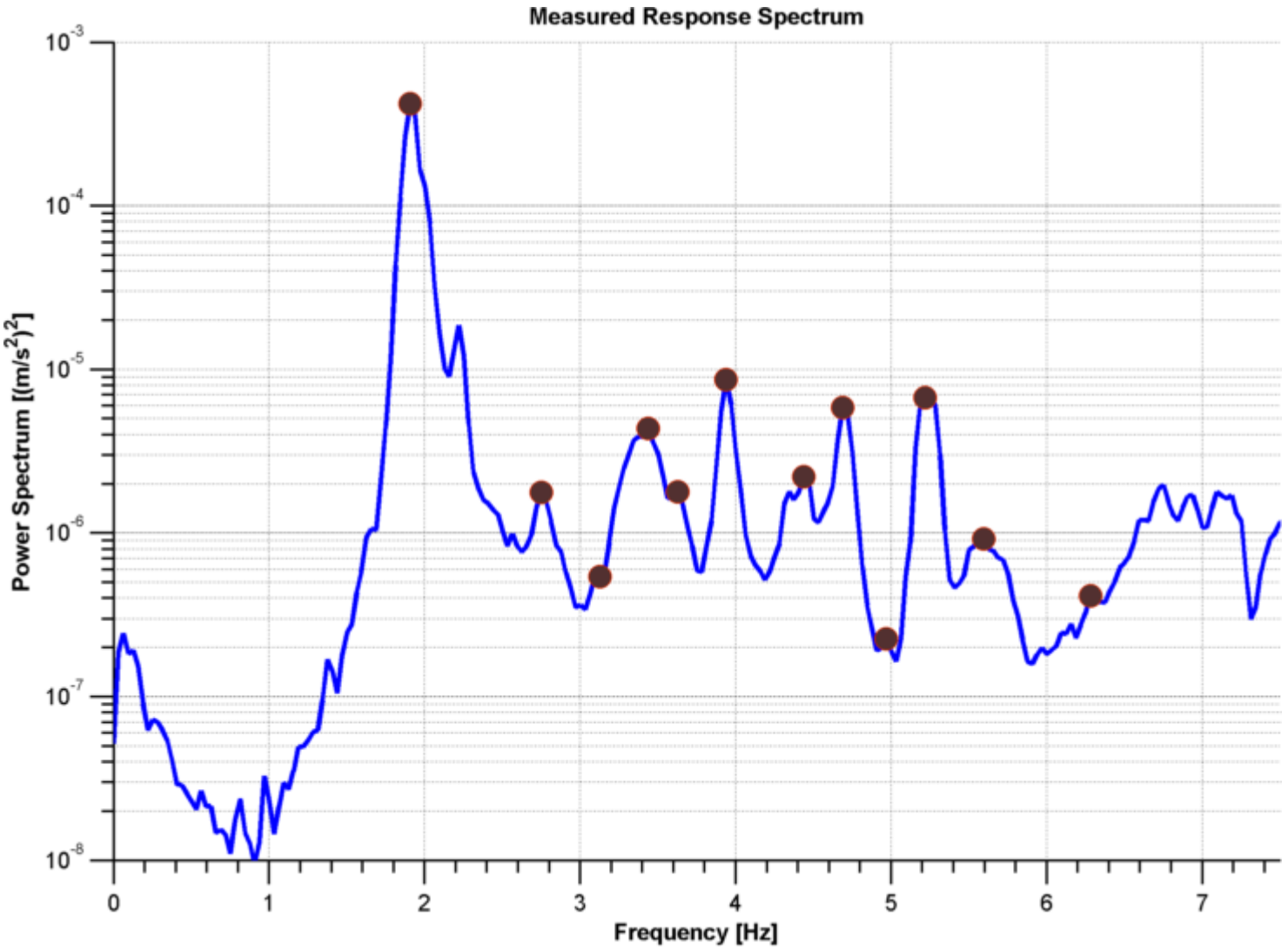
Experimental Results - Processing

- Output from Pulse as 5 ‘.uff’ files
- FRF generation: Combine results into average FRF curve
- Modeshape comparison: For each set of results, divide through by z-reference for uniform scaling

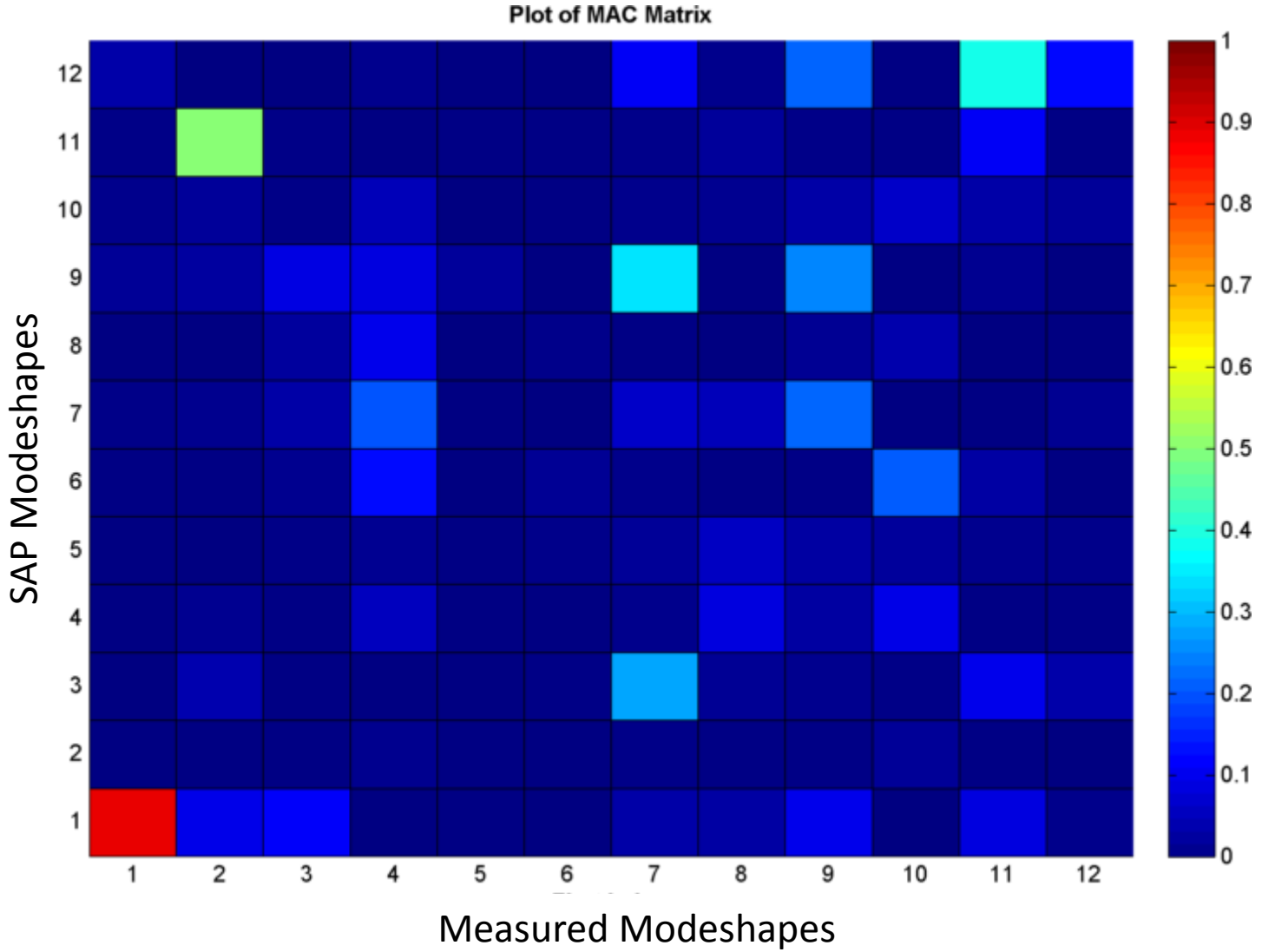
Experimental Results



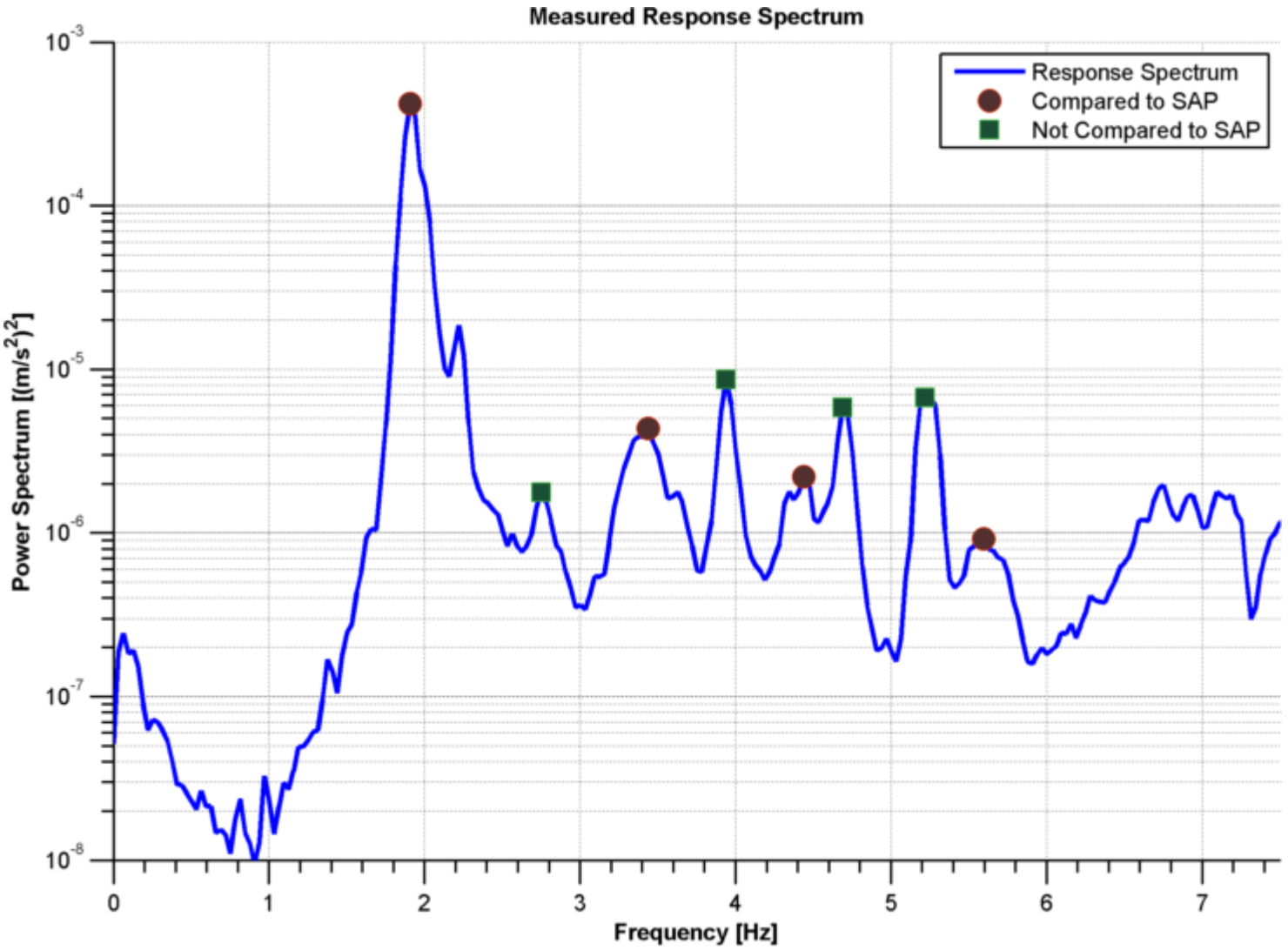
Experimental Results



MAC Values for Modeshapes



Experimental Results



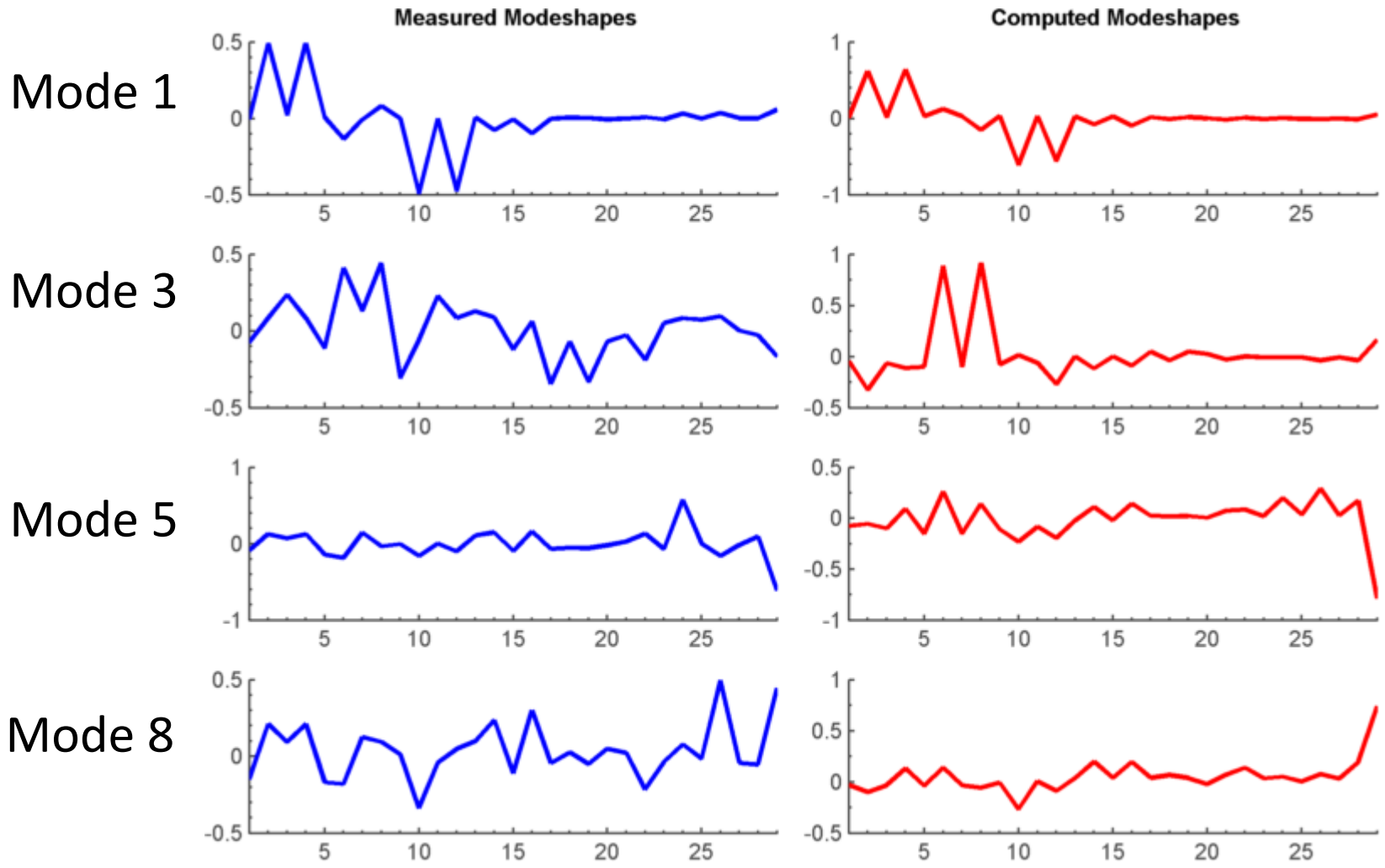
Experimental Results

Mode	Nat. Frequency (Hz)	Damping (%)
1	1.90	2.45
2	2.75	3.40
3	3.44	3.62
4	3.94	1.18
5	4.44	2.46
6	4.69	0.99
7	5.23	1.49
8	5.58	3.07

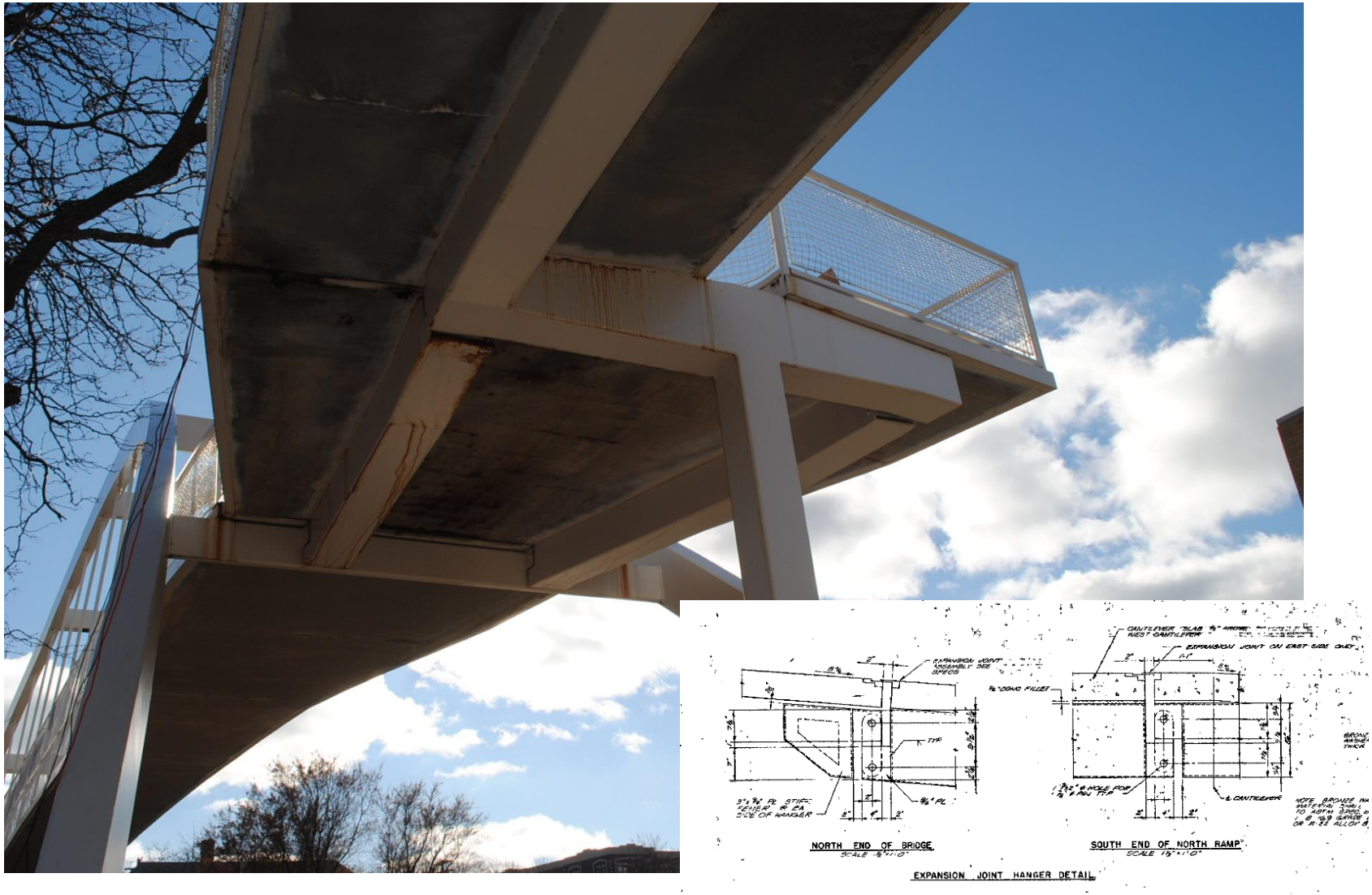
Comparison with Model

Mode	Measured	Computed	
	Frequency [Hz]		Variation %
1	1.91	2.05	7.62
3	3.45	3.87	12.33
5	4.44	4.50	1.30
8	5.58	5.50	1.40

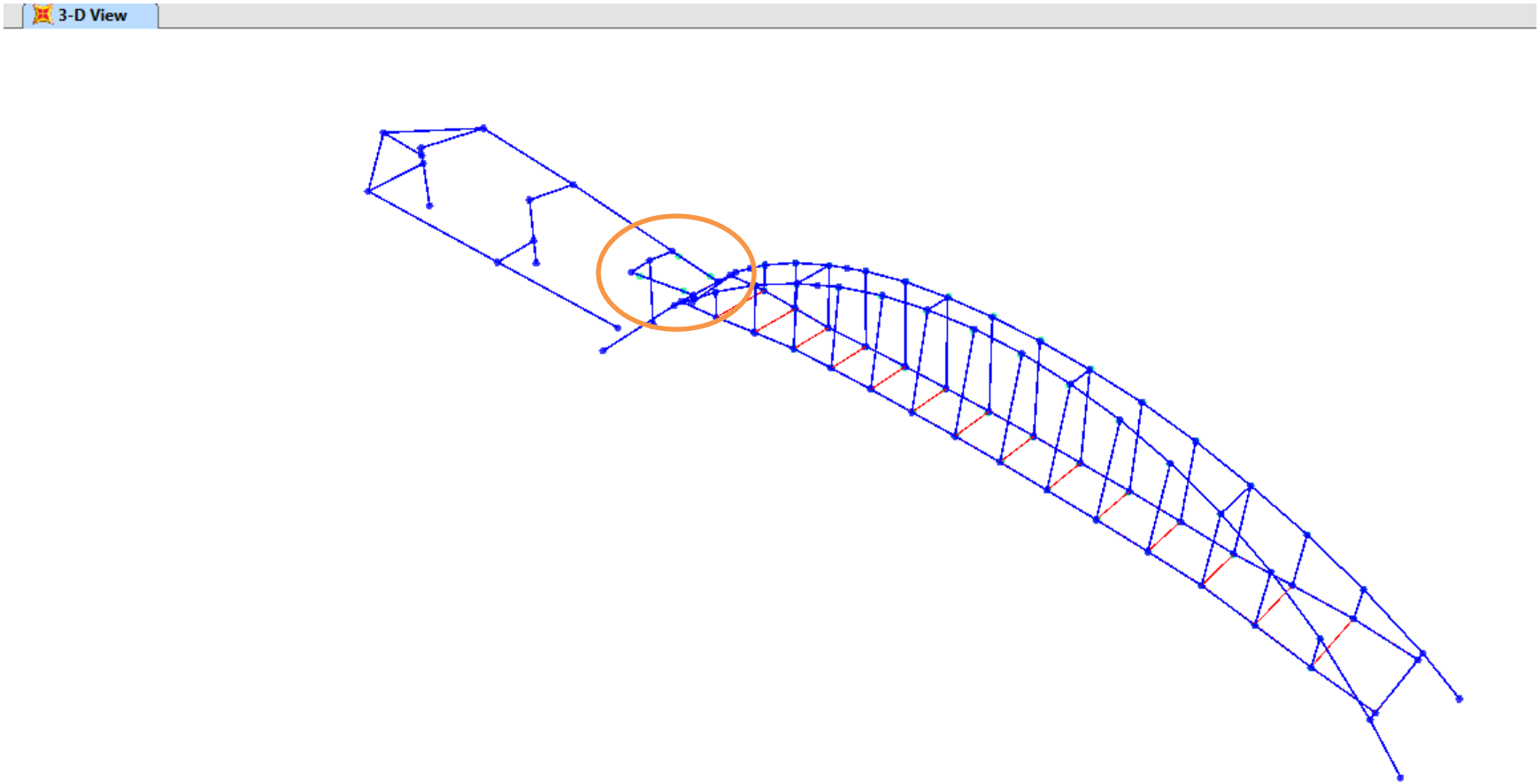
Most Comparable Modeshapes



SAP2000 Modification 1



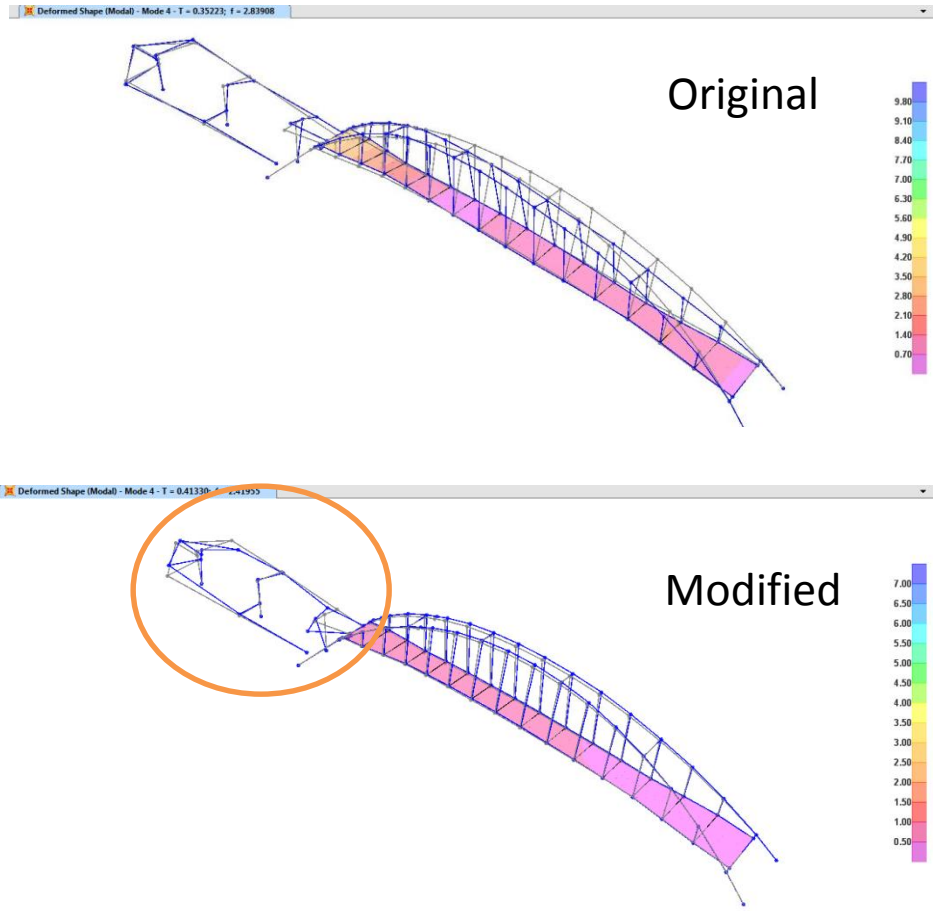
SAP2000 Modification 1



Model Provided and Modification 1 Natural Frequencies

Mode	Original Frequency	Modified Frequency	% Change
	Cyc/sec	Cyc/sec	
1	2.0534	2.035	1%
2	2.2947	2.0725	10%
3	2.3445	2.2054	6%
4	2.8391	2.4196	15%
5	3.1119	2.807	10%
6	3.7281	3.1577	15%
7	3.8696	3.7875	2%
8	4.0099	3.8653	4%

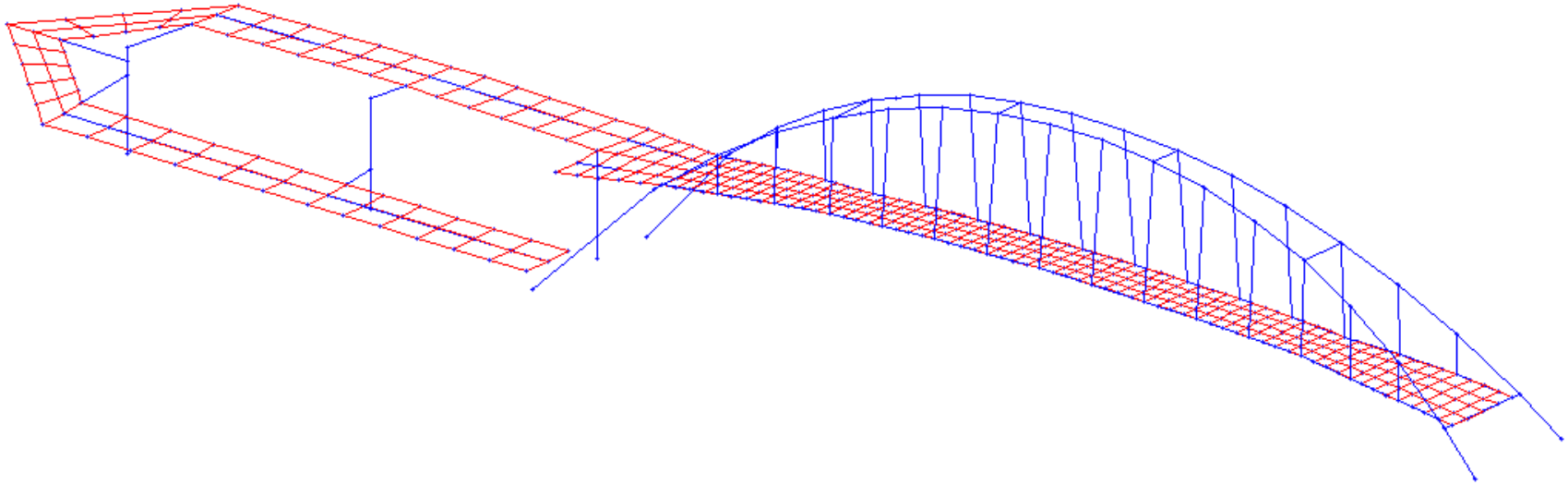
Mode 4



SAP2000 Modification 2

- Section areas were checked
- Slab thickness increased 2 inches
- Material properties changed to standard SAP2000 4000 psi concrete and A36 Steel ($\sigma_{yield} = 36$ ksi)
- Ramp slab added
- Bridge slab refined
- Previous modification kept

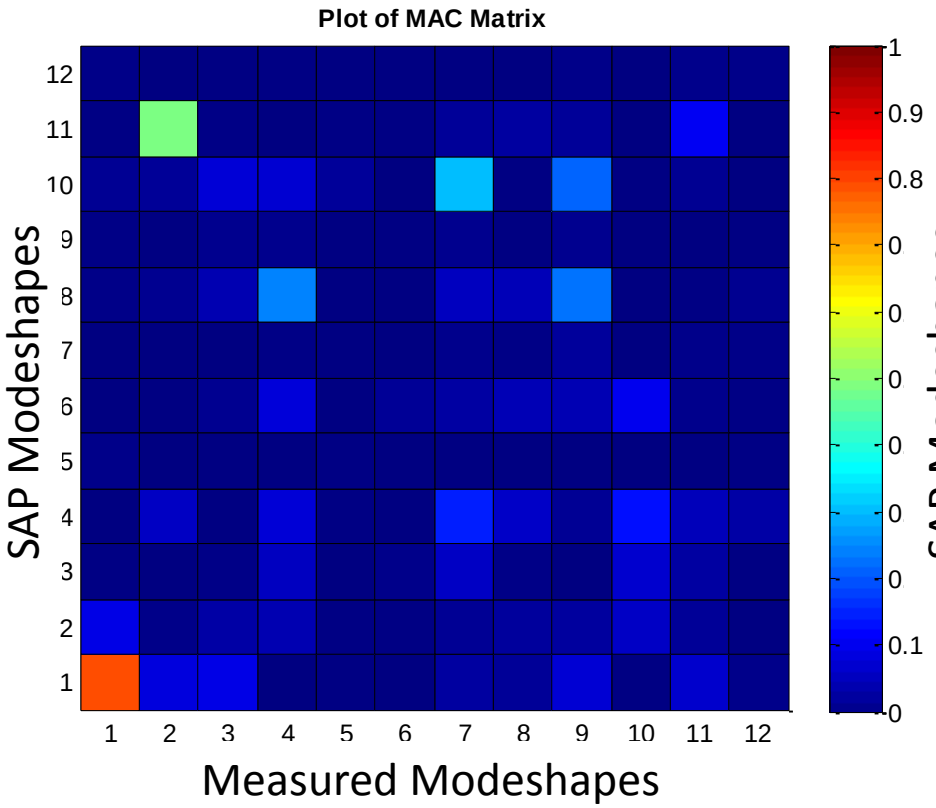
SAP2000 Modification 2



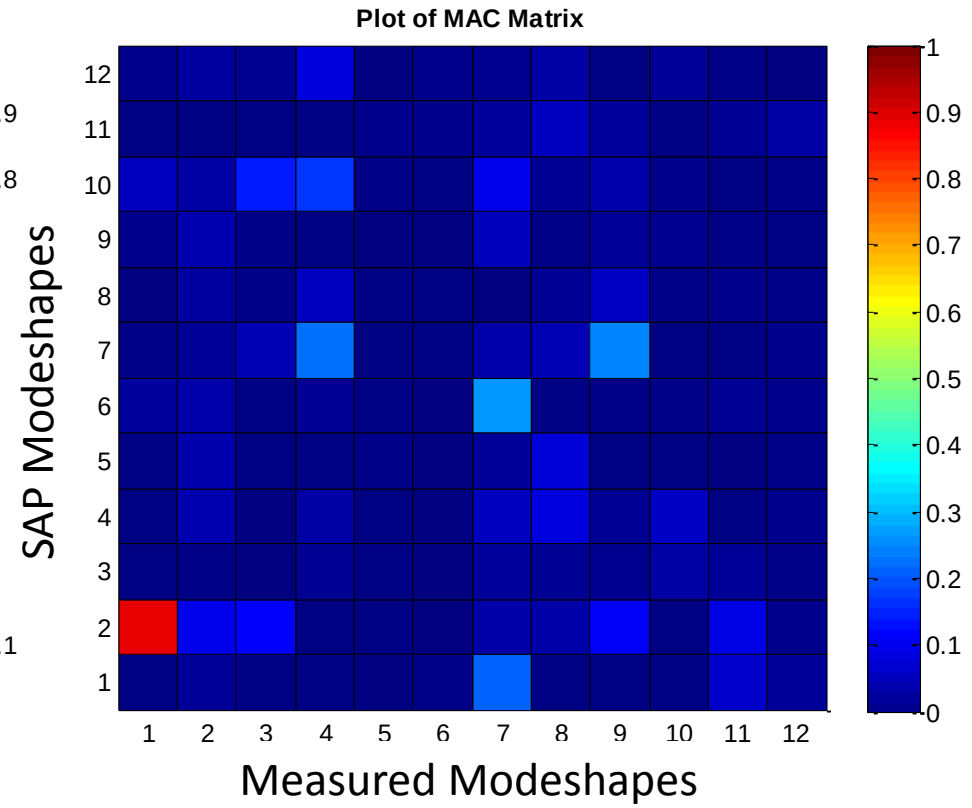
Comparisons of Natural Frequencies

Mode	Frequency Original Model	Frequency Modification 1	% Change compared to original	Frequency Modification 2	% Change compared to original
	Cyc/sec	Cyc/sec		Cyc/sec	
1	2.0534	2.035	1%	1.8221	11.3%
2	2.2947	2.0725	10%	1.8751	18.3%
3	2.3445	2.2054	6%	2.1849	6.8%
4	2.8391	2.4196	15%	2.8286	0.4%

Comparison of Modeshapes



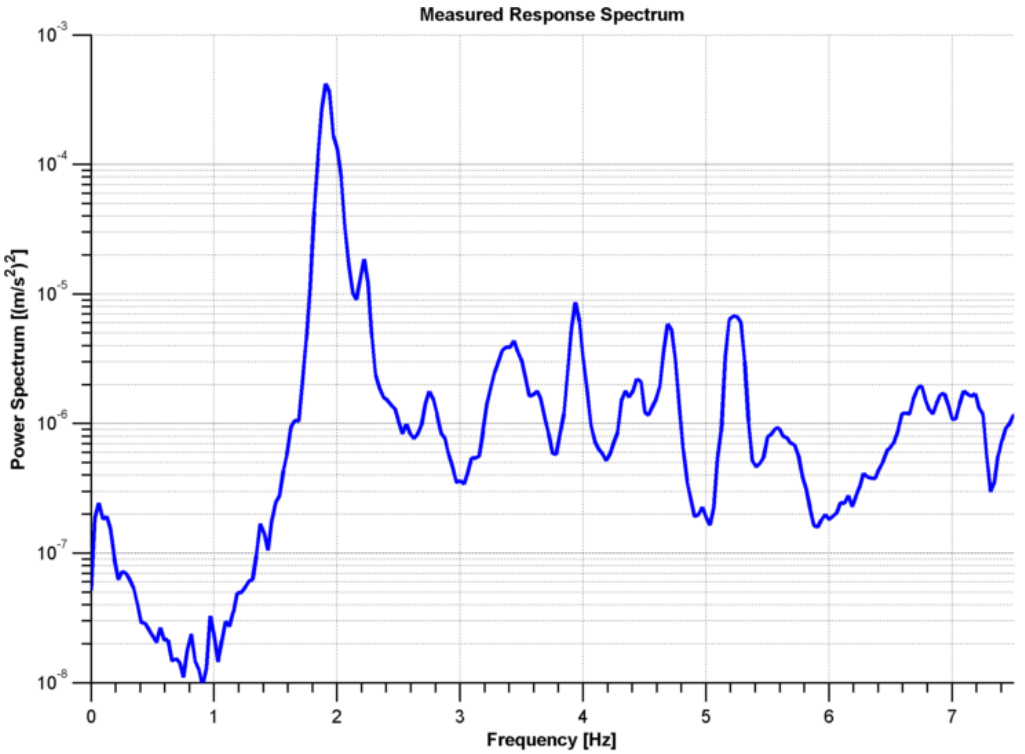
1st Modification



Final Modification

Error Sources – Experimental Procedure

- Poor orientation of accelerometers - unlikely
- **Excitation issues**:
  - Predominantly vertical (only primary bending modes excited)
  - Not random with time or position
  - Not broadband – gait pace located in 1 – 3 Hz range



Error Sources – Instrumentation Placement

- Engineering judgment
  - Avoided nodes
  - Maximum deflections
- Lowest stiffness to mass ratio
  - K_{ii}/M_{ii} for the i^{th} coordinate

Original SAP Model

Picked nodes	K/M	Overall ranking
21	5877	1
22	5898	2
14	8181	3
15	8663	4
23	8896	5
7	26059	6
S13L	36726	8
S11R	36726	9
S07L	48797	19
S17R	48840	21
S18L	58524	24
S06R	58527	25
8	86633	31

Latest SAP Model

Picked nodes	Modified model K/M	Overall ranking
7	608751	130
S11R	632982	136
S13L	632982	137
14	656533	143
15	729975	153
S07L	739998	154
S17R	740417	157
S18L	836420	163
S06R	836444	164
21	1018349	258
8	1090298	273
22	1224061	457
23	1416241	462

Error Sources – Instrumentation Placement

Limitations of Model

- SAP2000 Model Assumptions
  - Constant cross-section beam sections were used
  - Uncertainty in material properties
  - Joint behavior – modeled as either rigid or pinned

Possible Sources of Error

Structural Component	Deck	Superstructure (Arch)	Substructure (Piers, Abutments)
Ratings	**6**	**6**	**5**

- National Bridge Inventory Ratings:
  - 6 Satisfactory Condition: Structural elements show minor deterioration.
  - 5 Fair Condition: Old primary structure elements are sound but might have minor damage.
- Corrosion may have **stiffen** bridge connections

Conclusion

- Experimental improvements:
  - More varied methods of excitement – higher winds, more pedestrian loading, sledgehammer at “random” locations
  - Re-examine accelerometer locations
  - Perform test in warmer weather to enable use of wax for assisting with accelerometer placement

Conclusion

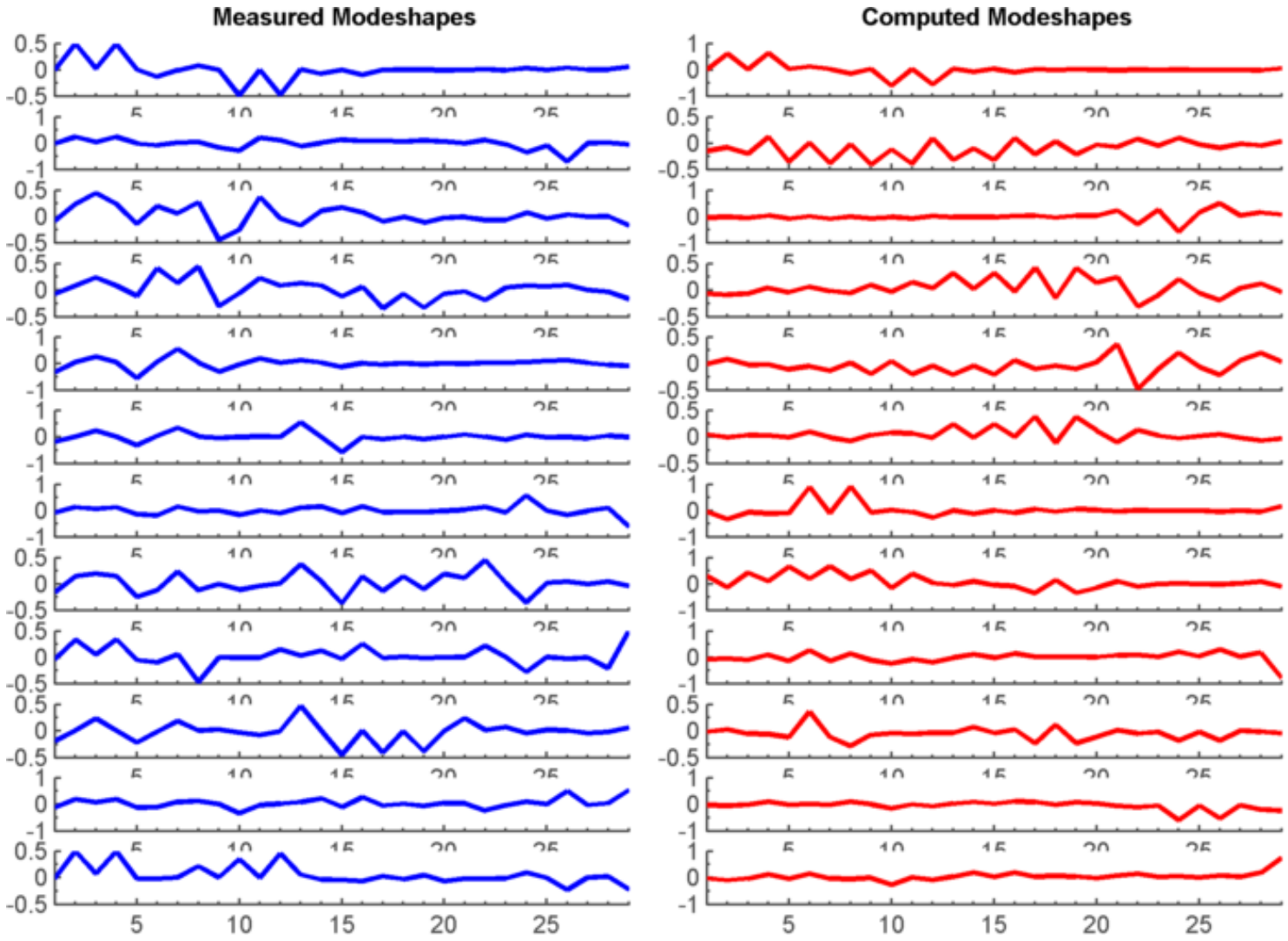
- Model improvements:
  - Re-examine geometry of beam cross-sections
  - Parametric study of joint stiffness: implement torsional springs at joints and test results for various stiffening levels
  - Simulate response under random dynamic load to generate FRF and compare to experimental result

Conclusion

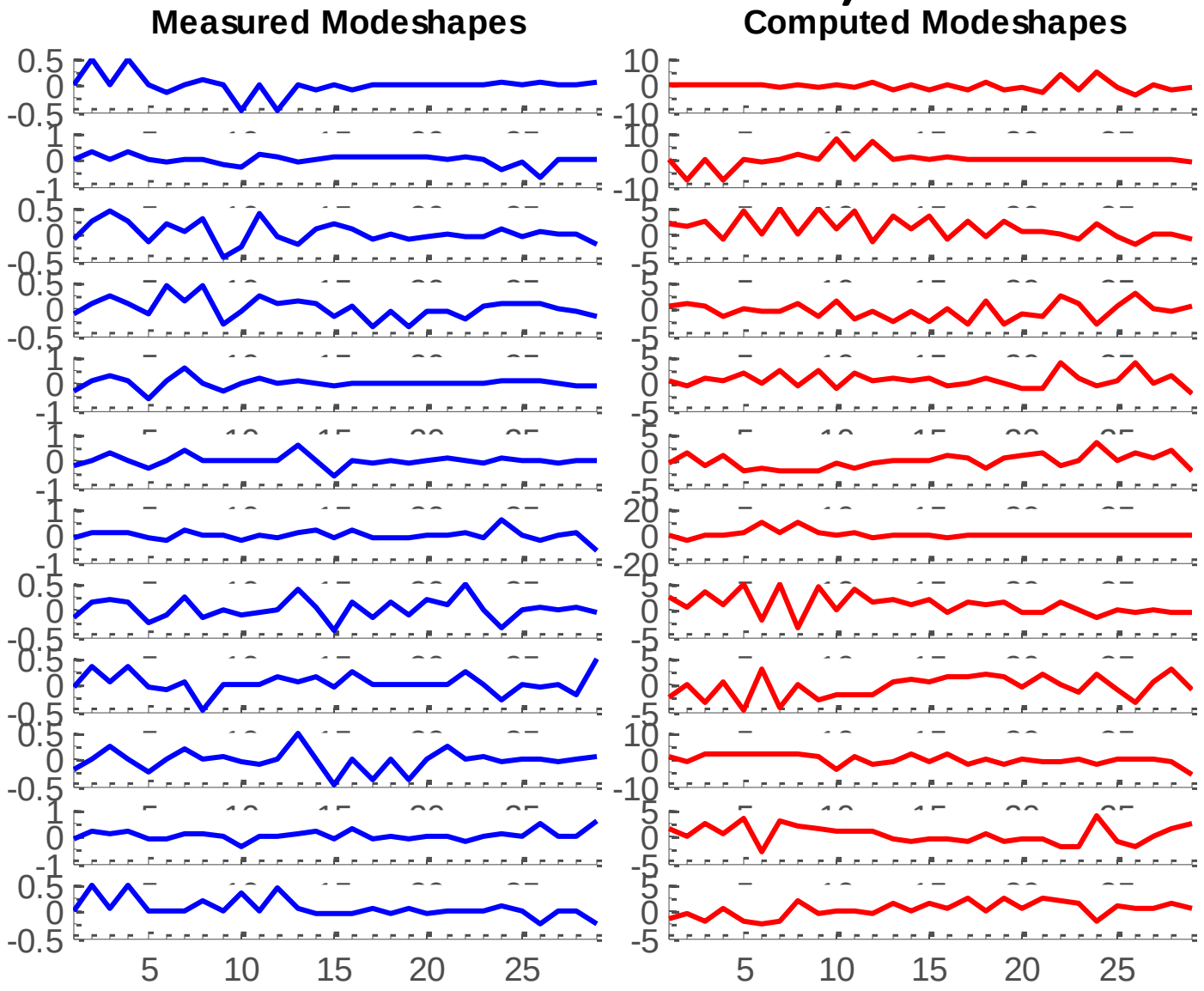
- According to AASHTO LRFD, the fundamental frequency in a vertical mode of pedestrian bridges shall be greater than 3 Hz to avoid the first harmonic
- Bridge does not comply with most recent dynamic design standard

Questions?

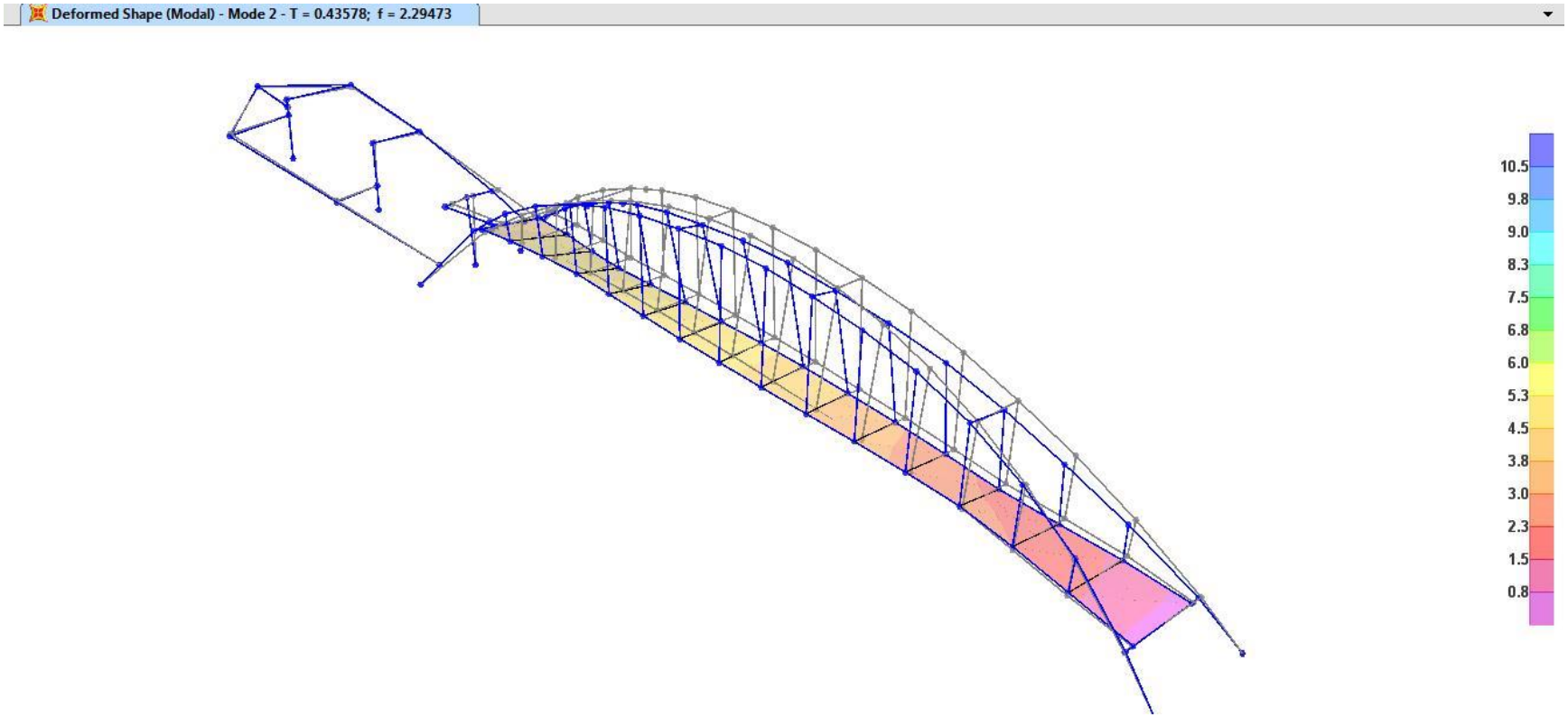
Full Modeshape Comparison (Original Model)



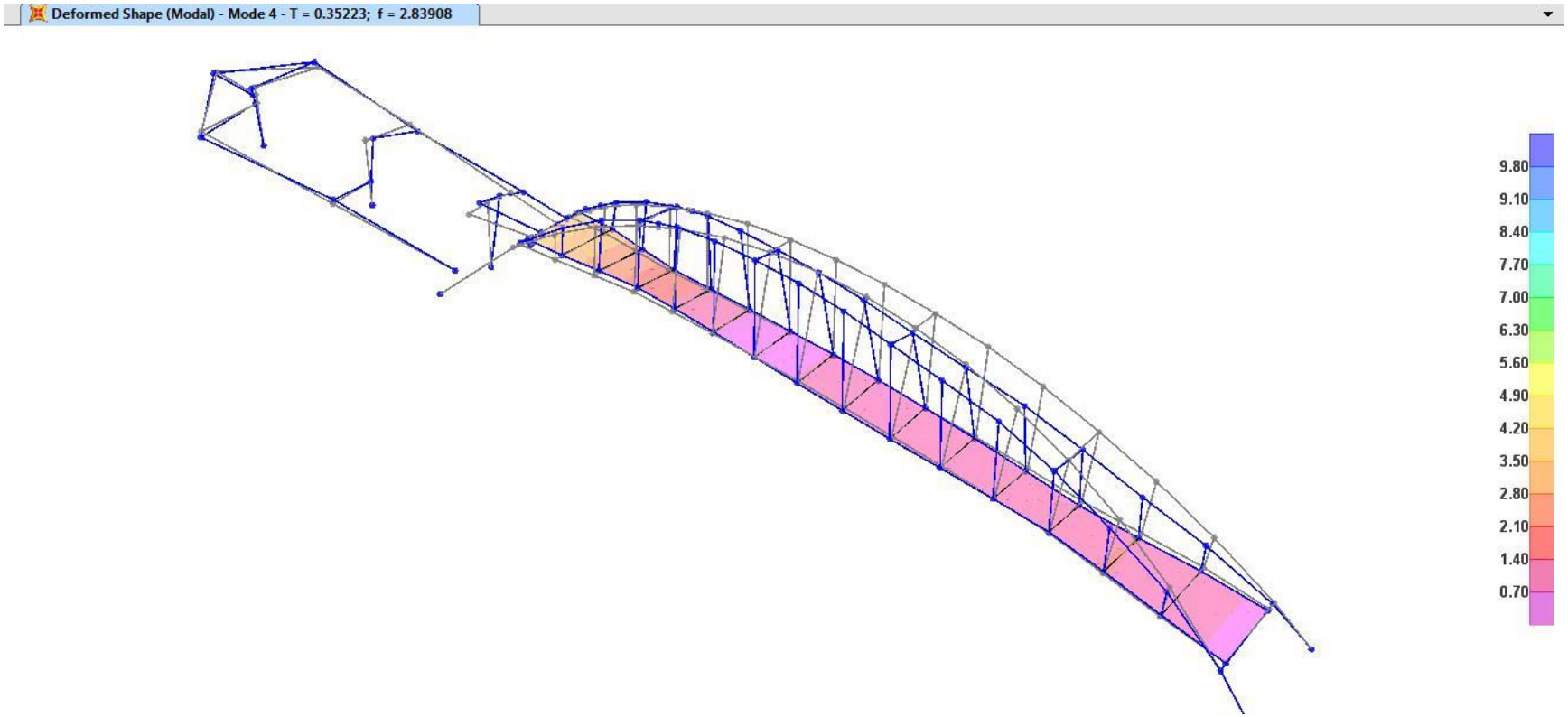
Full Modeshape Comparison (Final Modification)



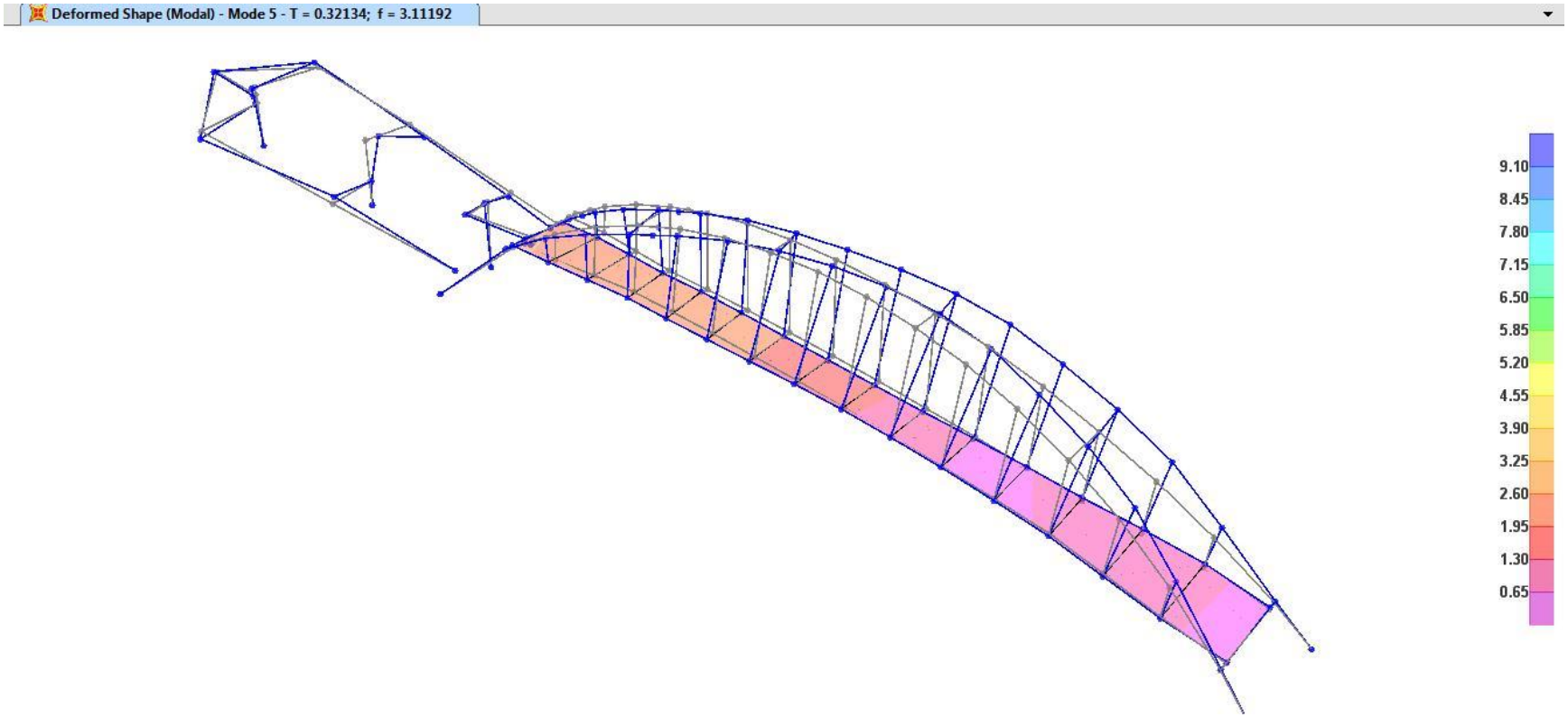
Dynamic Behavior of Model Provided Mode 2



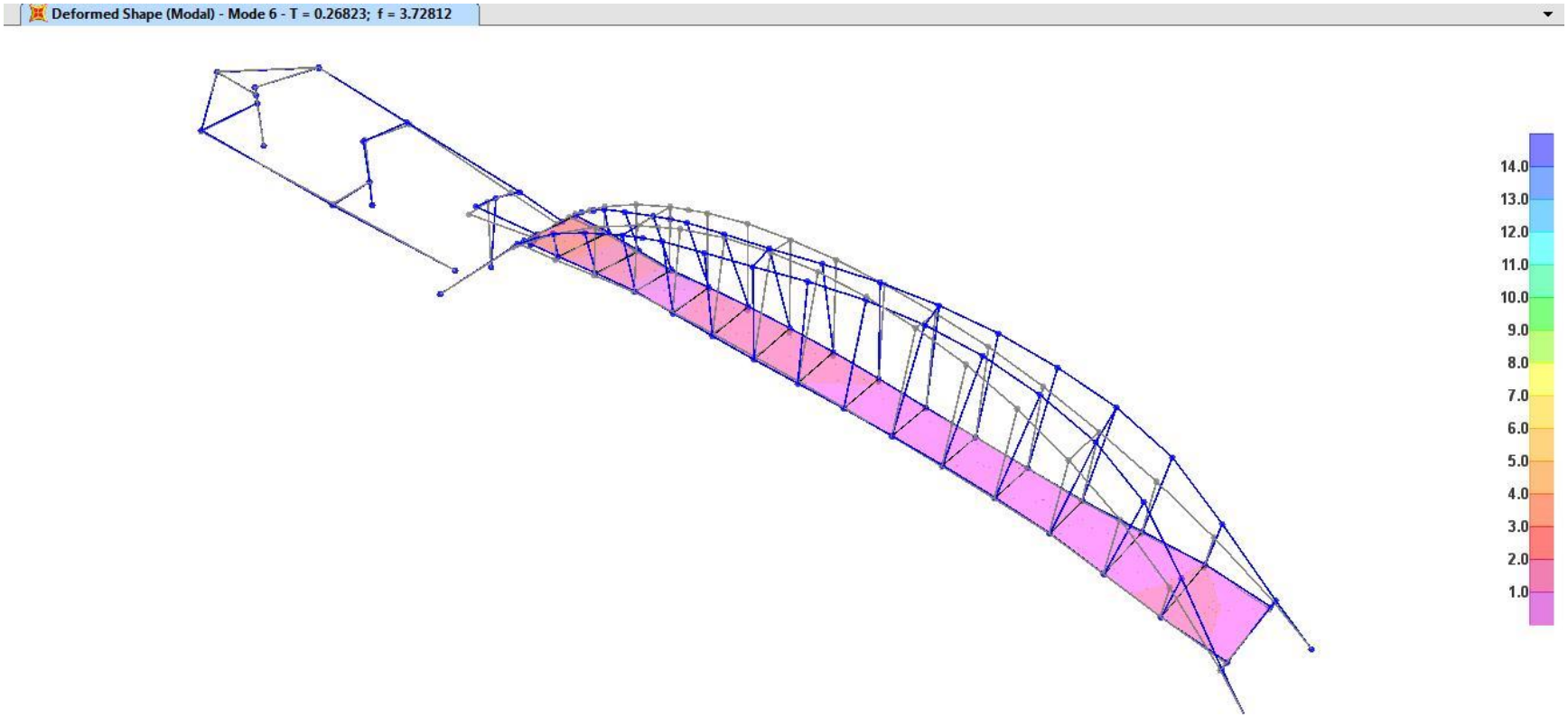
Dynamic Behavior of Model Provided Mode 4



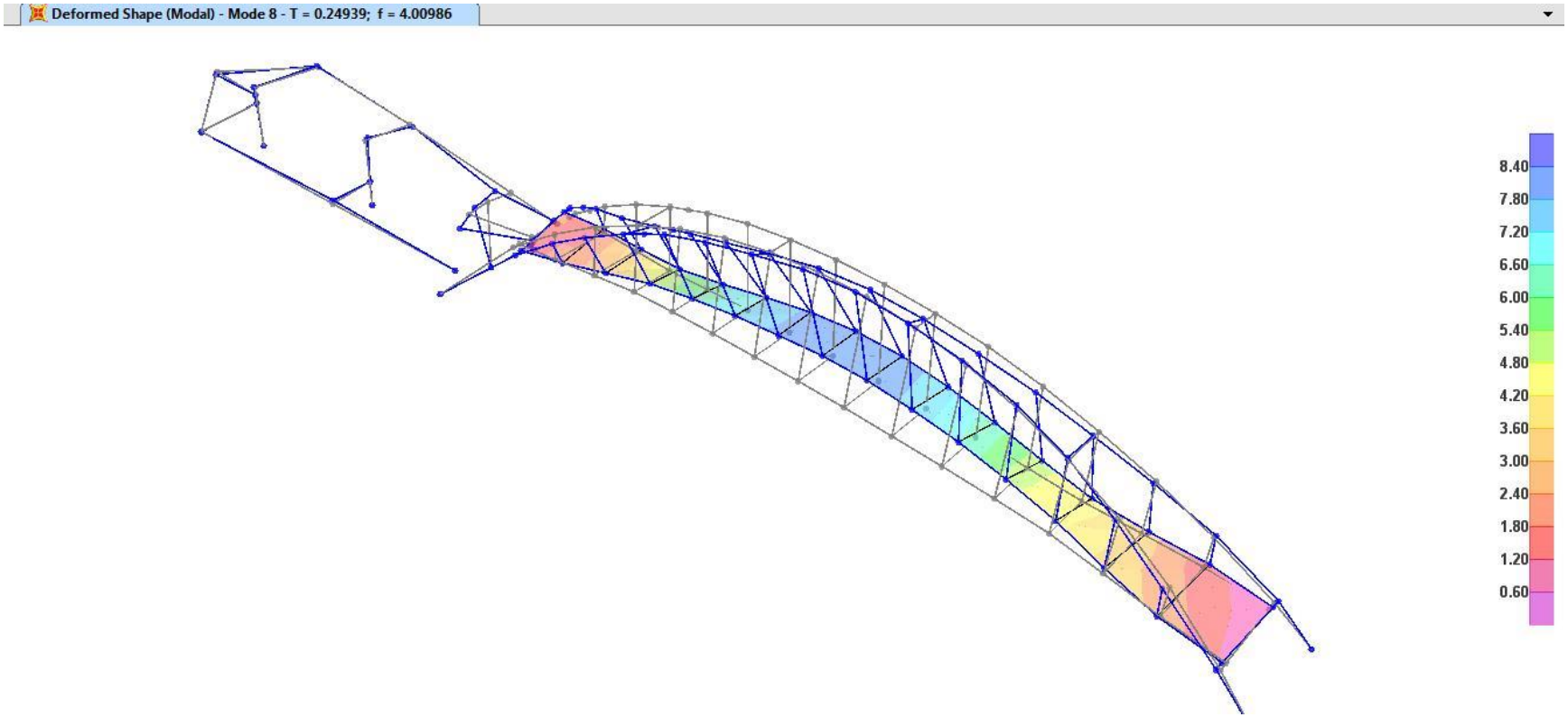
Dynamic Behavior of Model Provided Mode 5



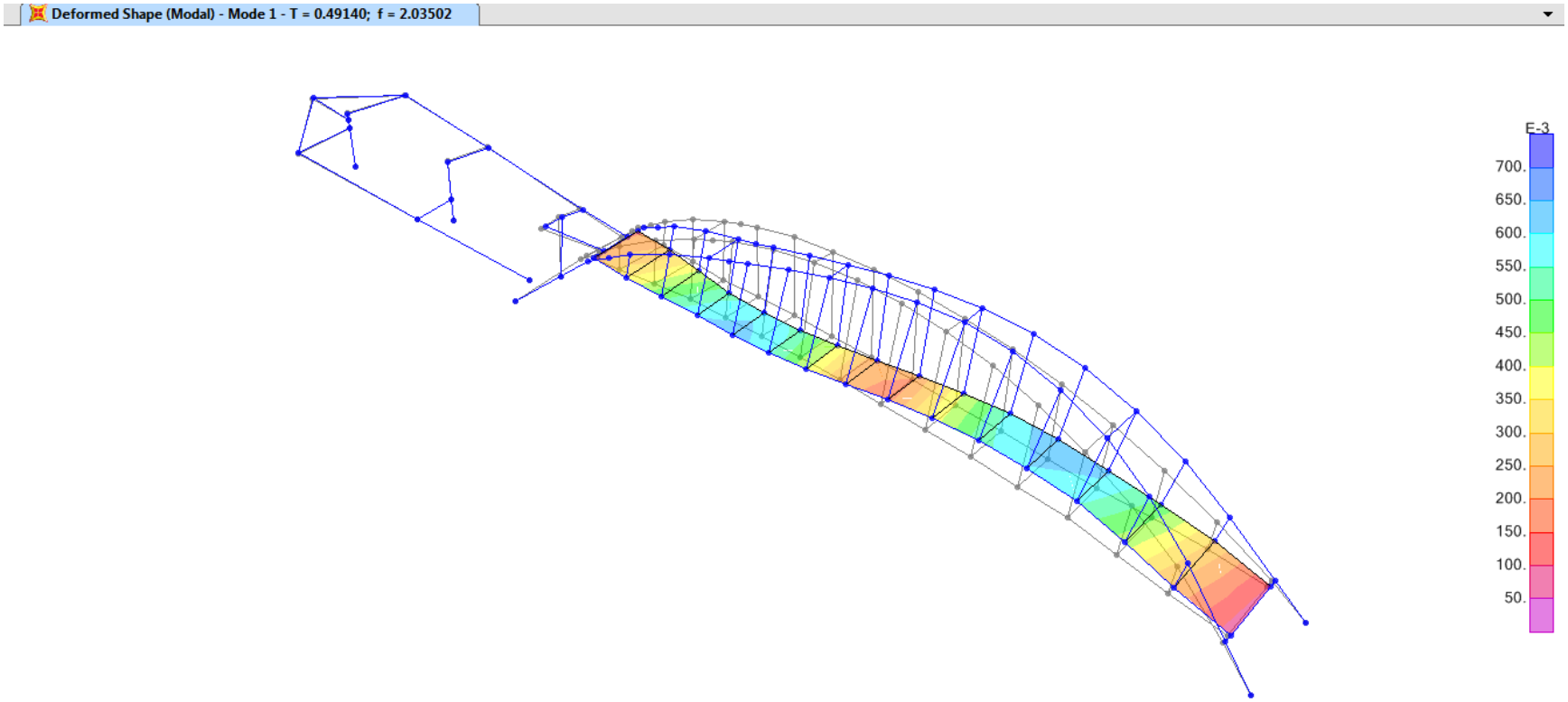
Dynamic Behavior of Model Provided Mode 6



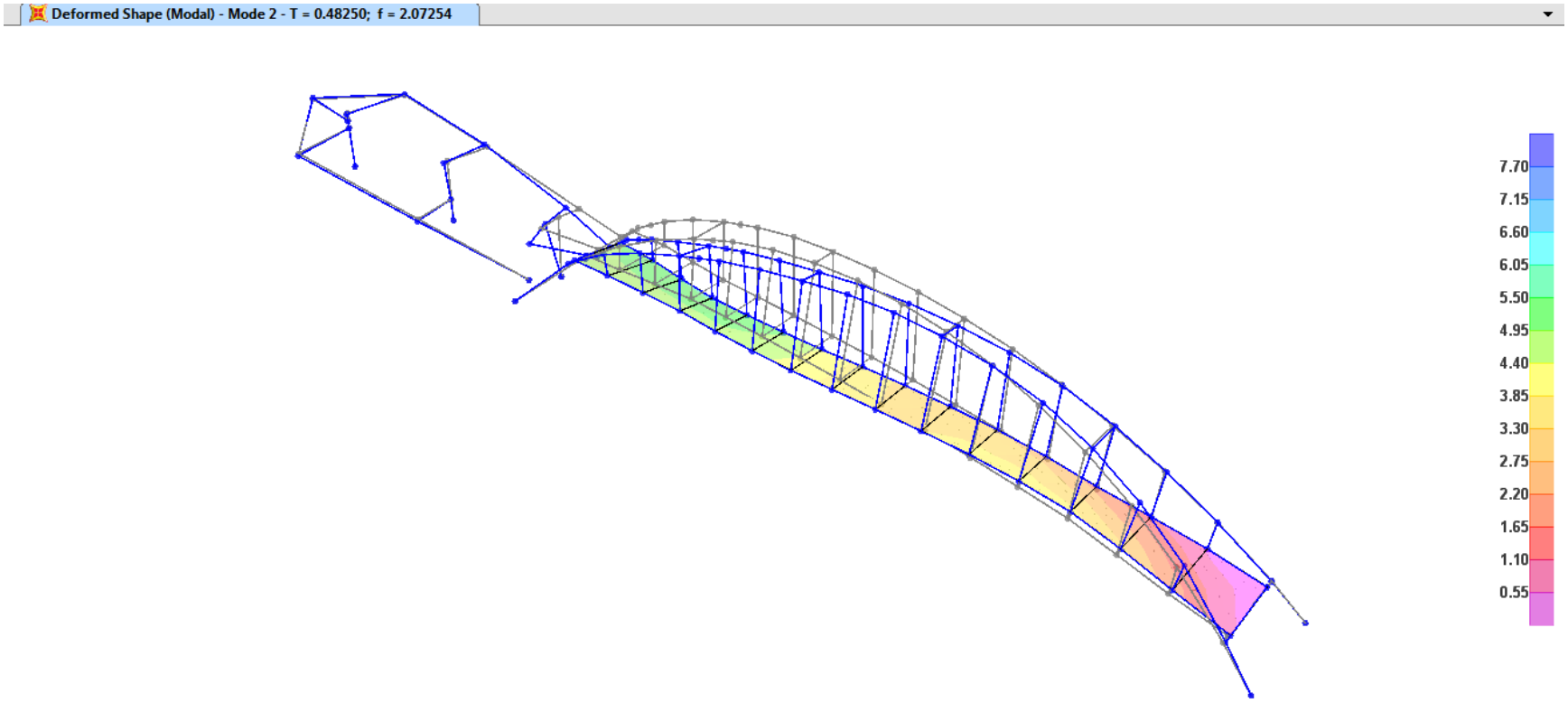
Dynamic Behavior of Model Provided Mode 8



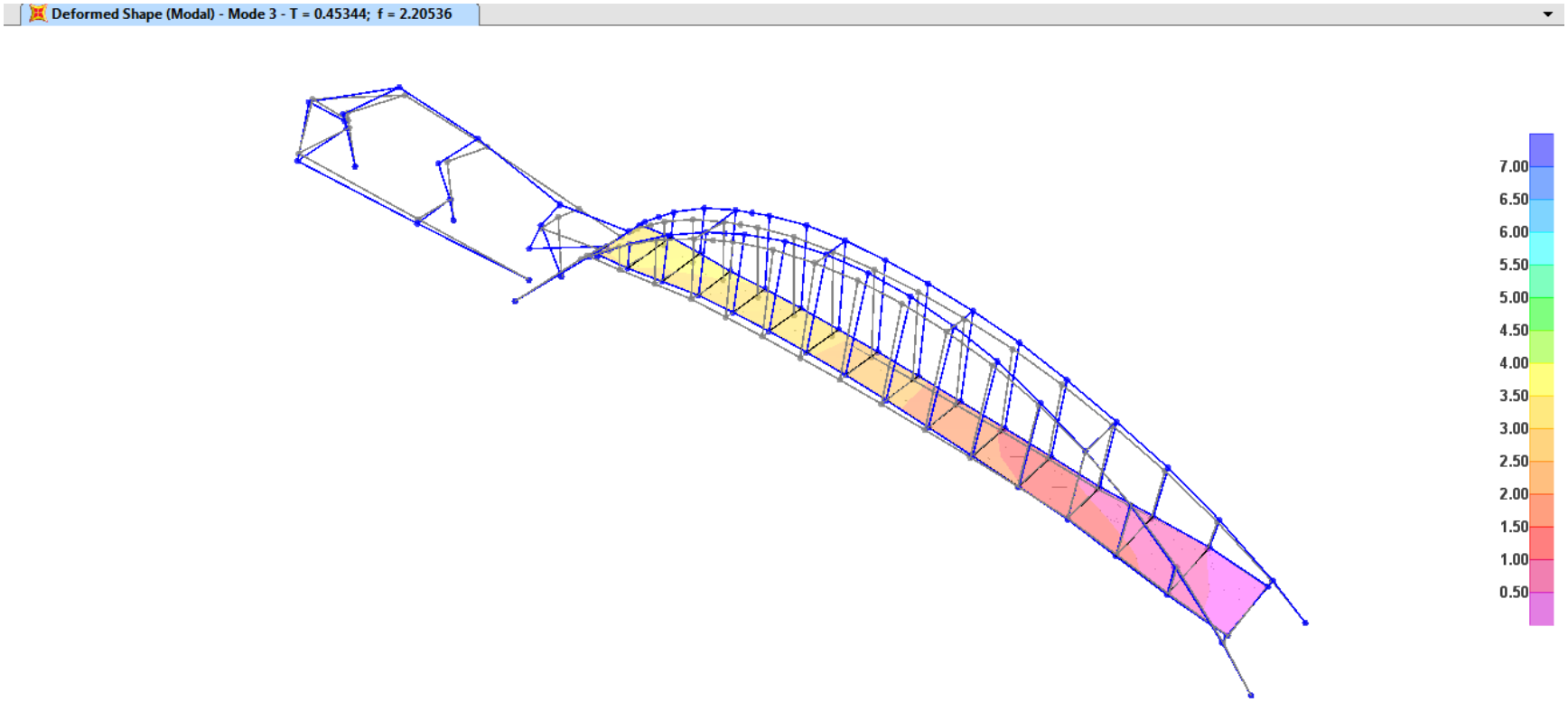
Dynamic Behavior of SAP2000 Modification 1 Mode 1



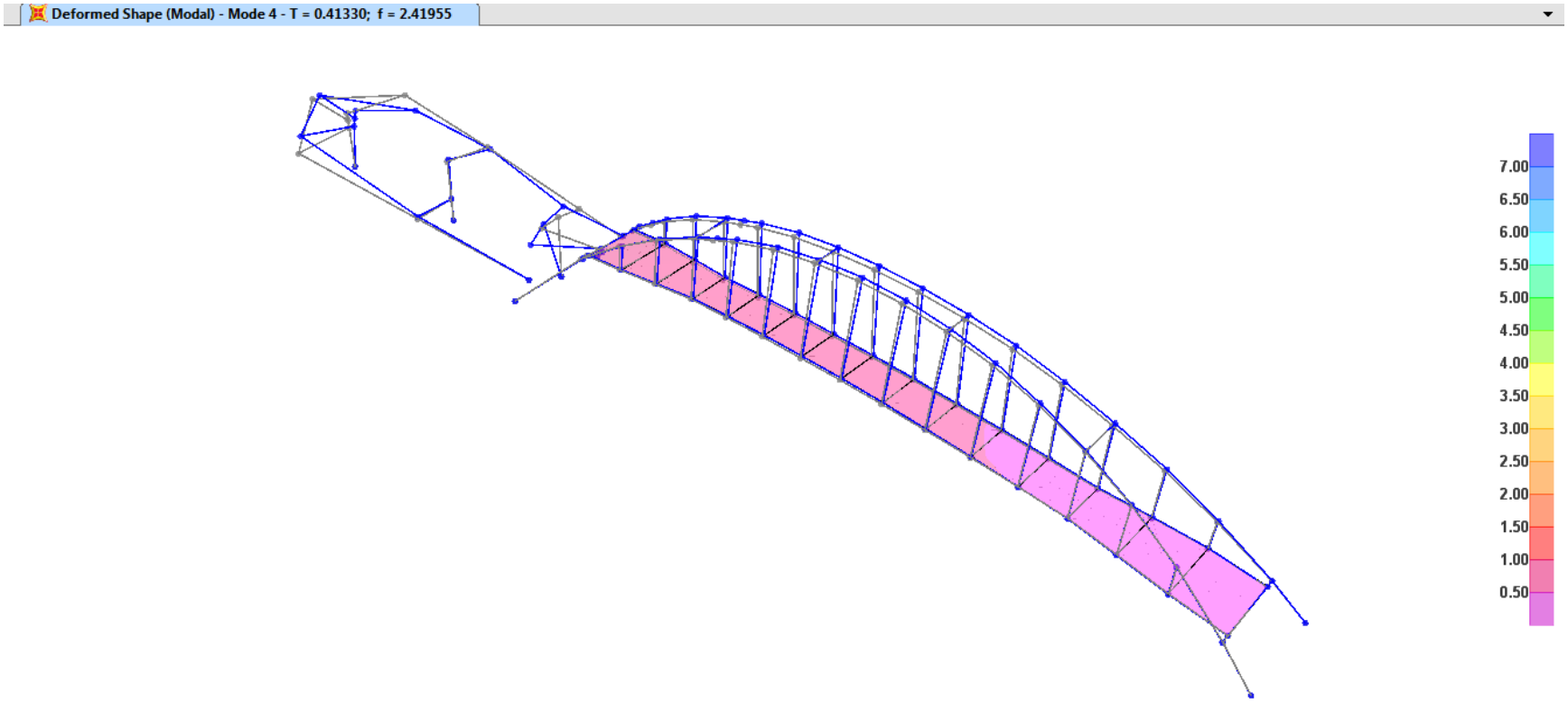
Dynamic Behavior of SAP2000 Modification 1 Mode 2



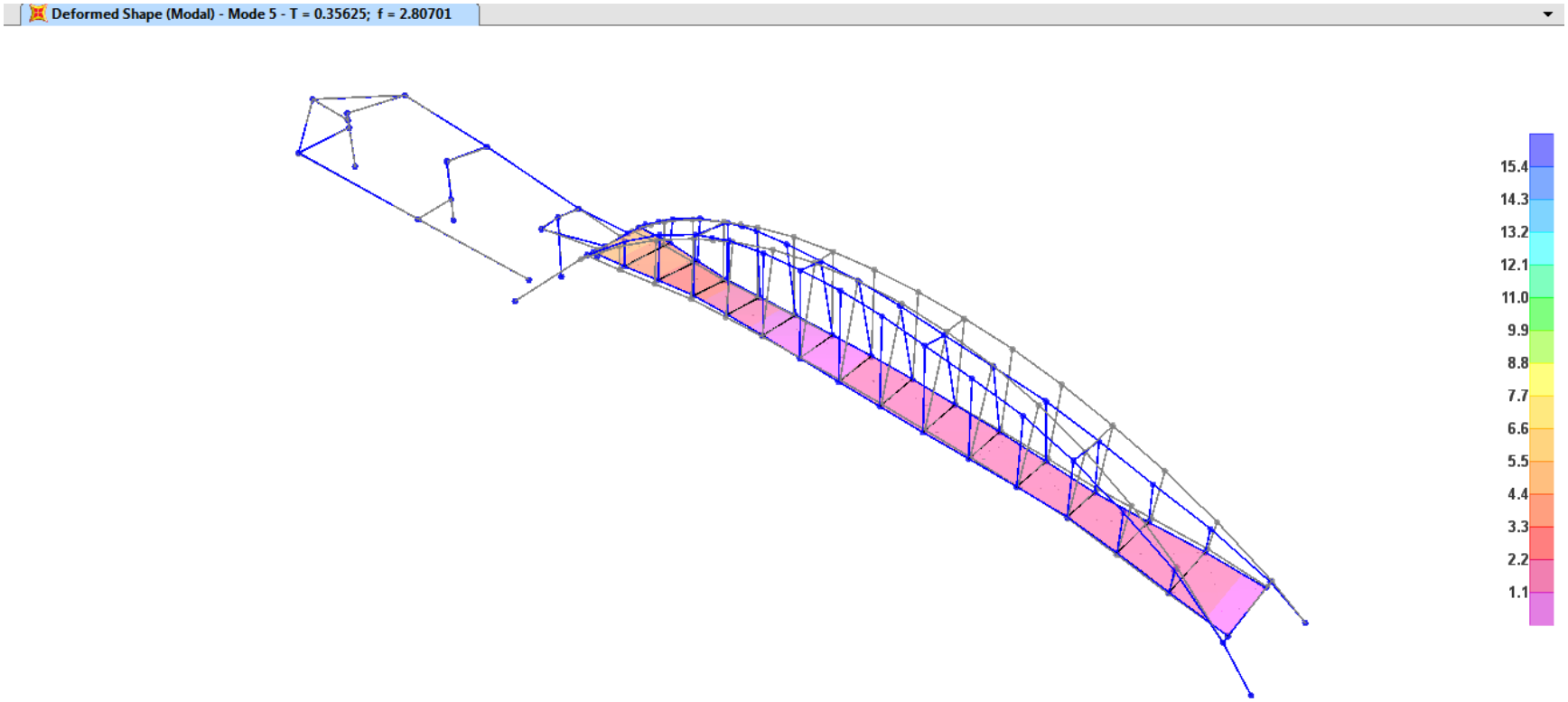
Dynamic Behavior of SAP2000 Modification 1 Mode 3



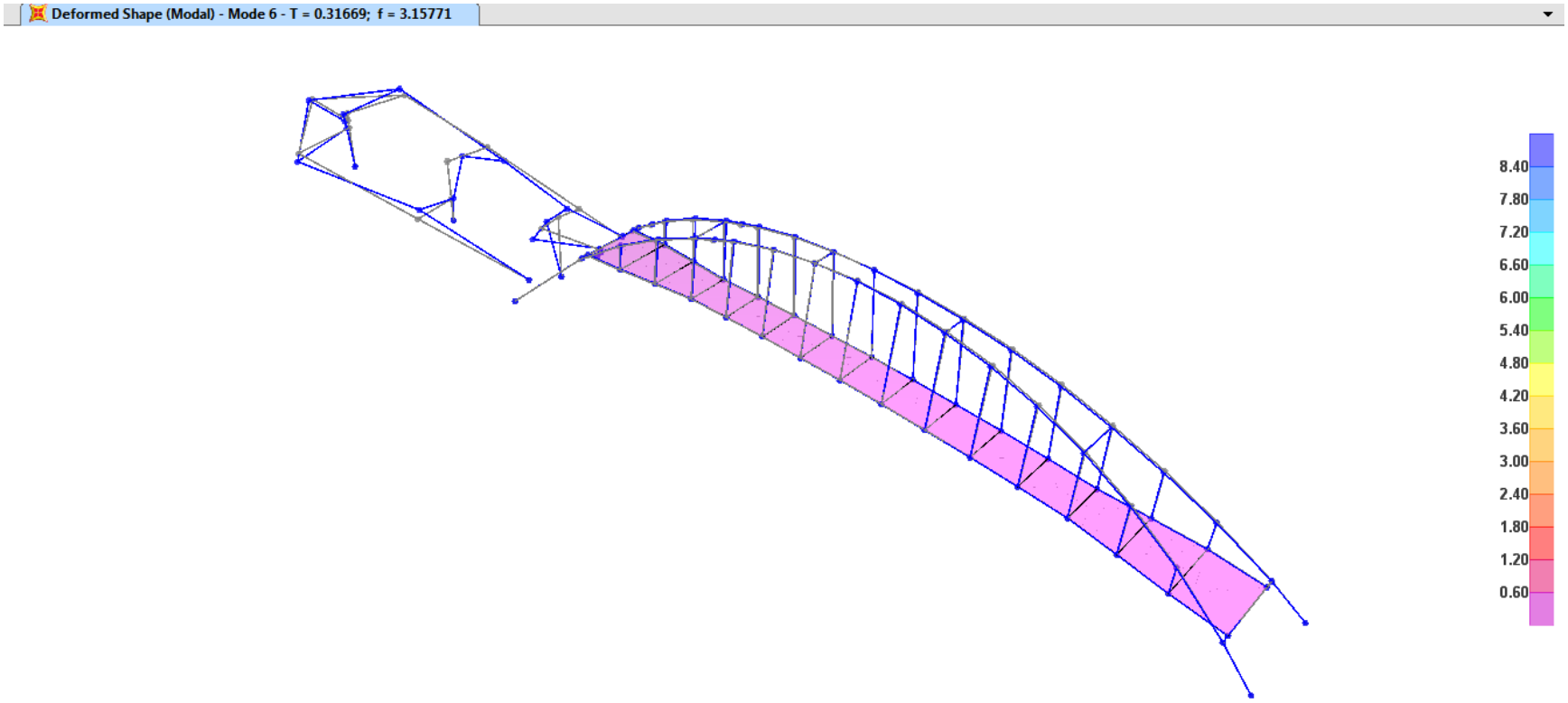
Dynamic Behavior of SAP2000 Modification 1 Mode 4



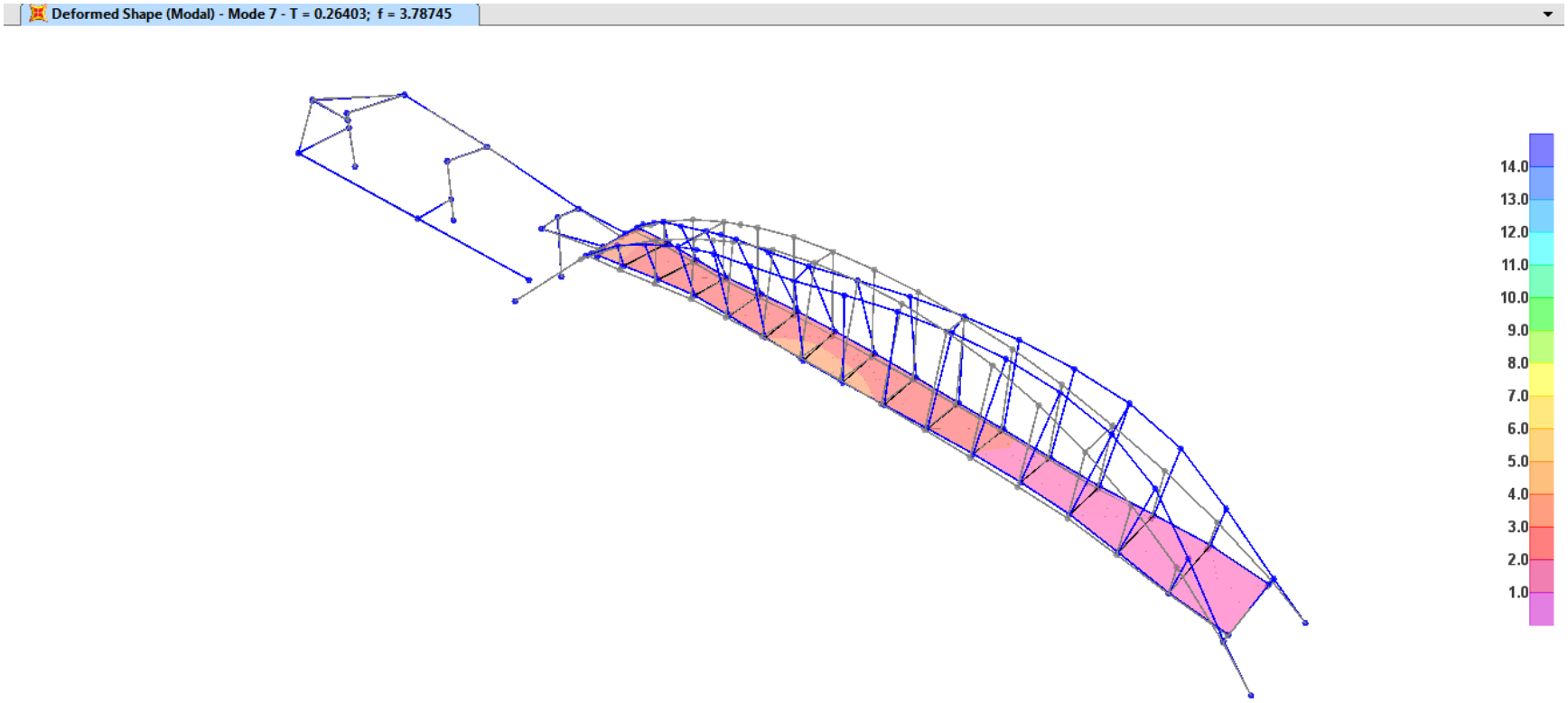
Dynamic Behavior of SAP2000 Modification 1 Mode 5



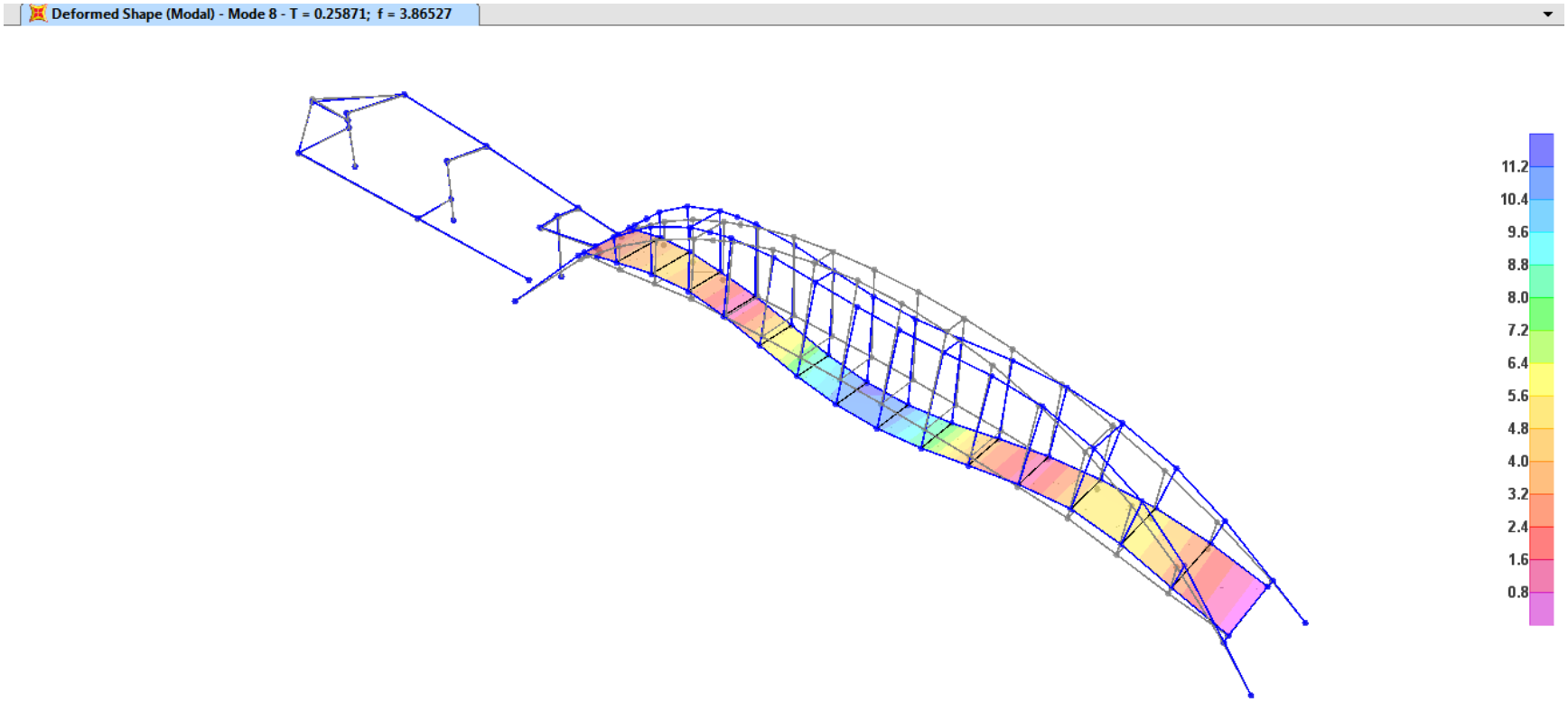
Dynamic Behavior of SAP2000 Modification 1 Mode 6



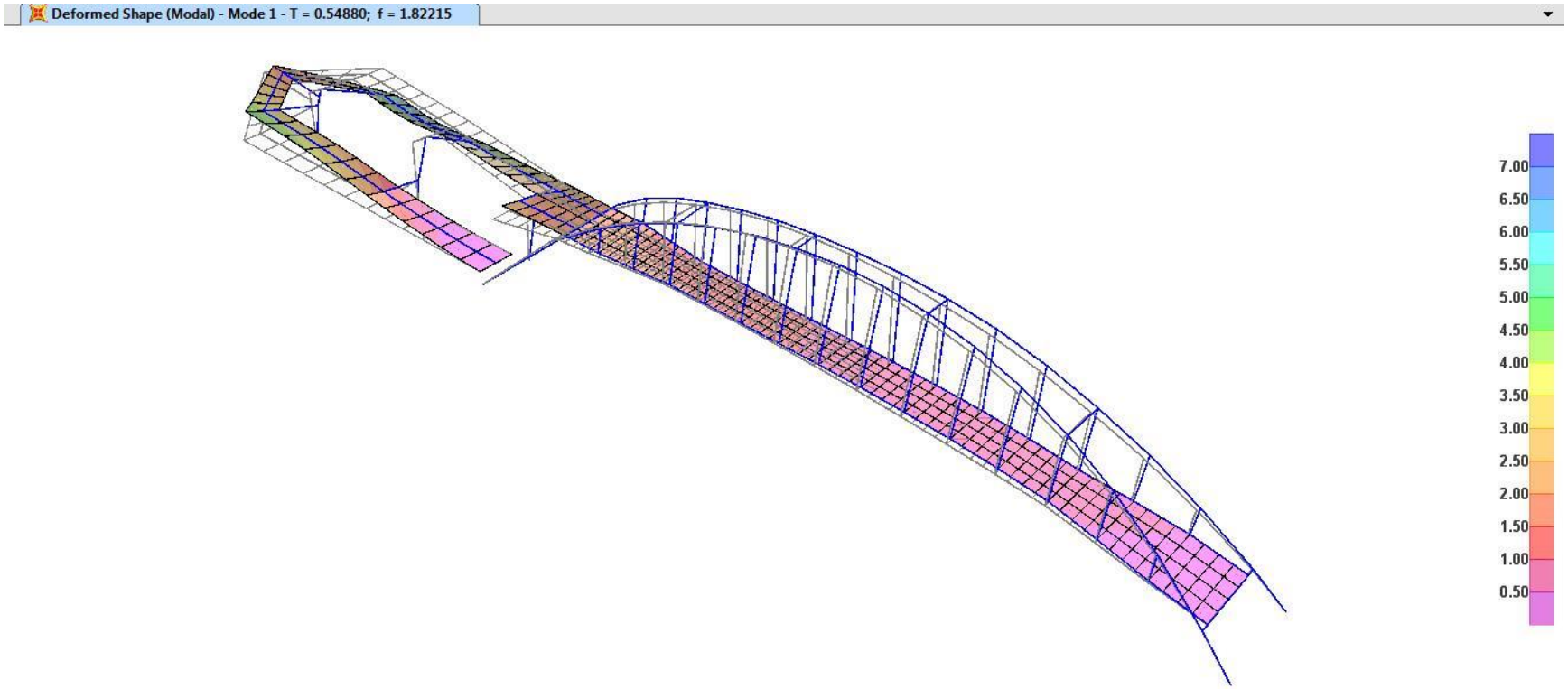
Dynamic Behavior of SAP2000 Modification 1 Mode 7



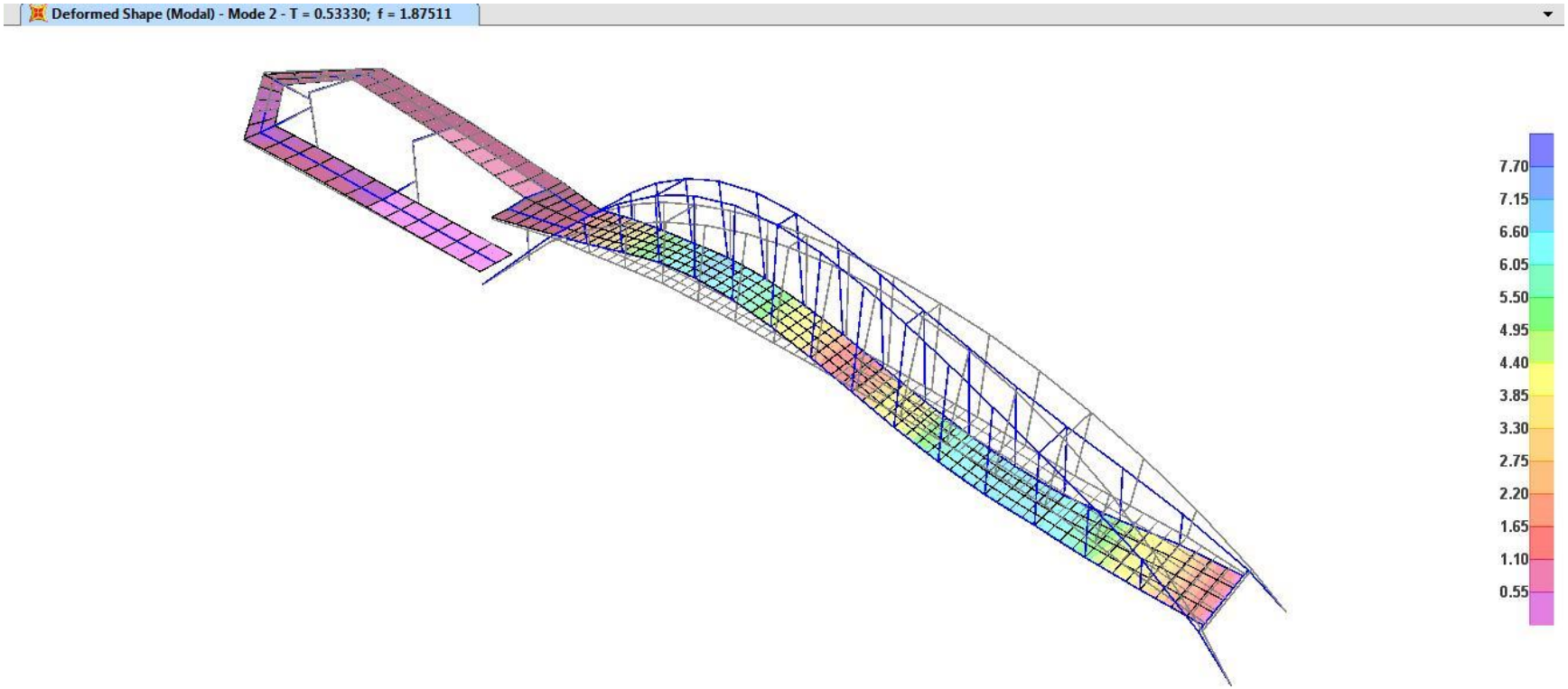
Dynamic Behavior of SAP2000 Modification 1 Mode 8



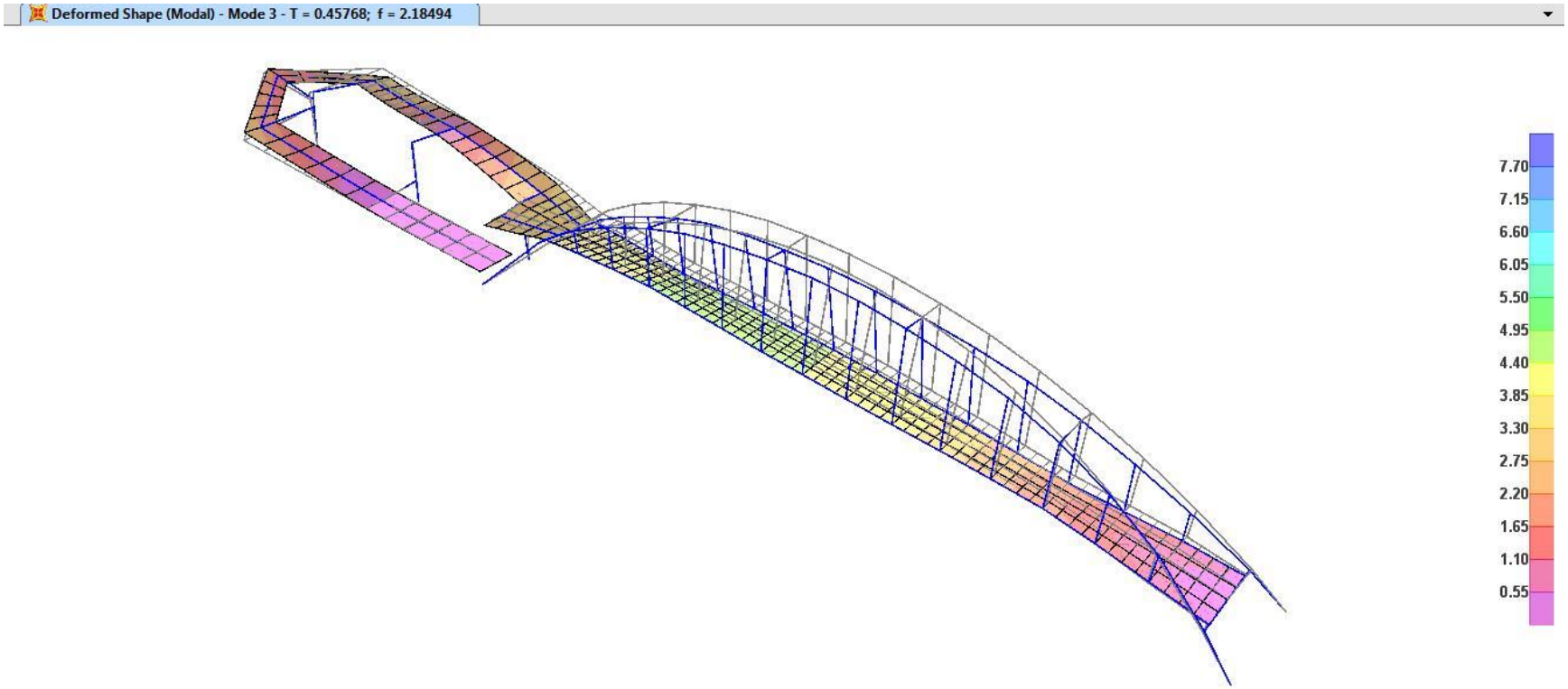
Dynamic Behavior of SAP2000 Modification 2 Mode 1



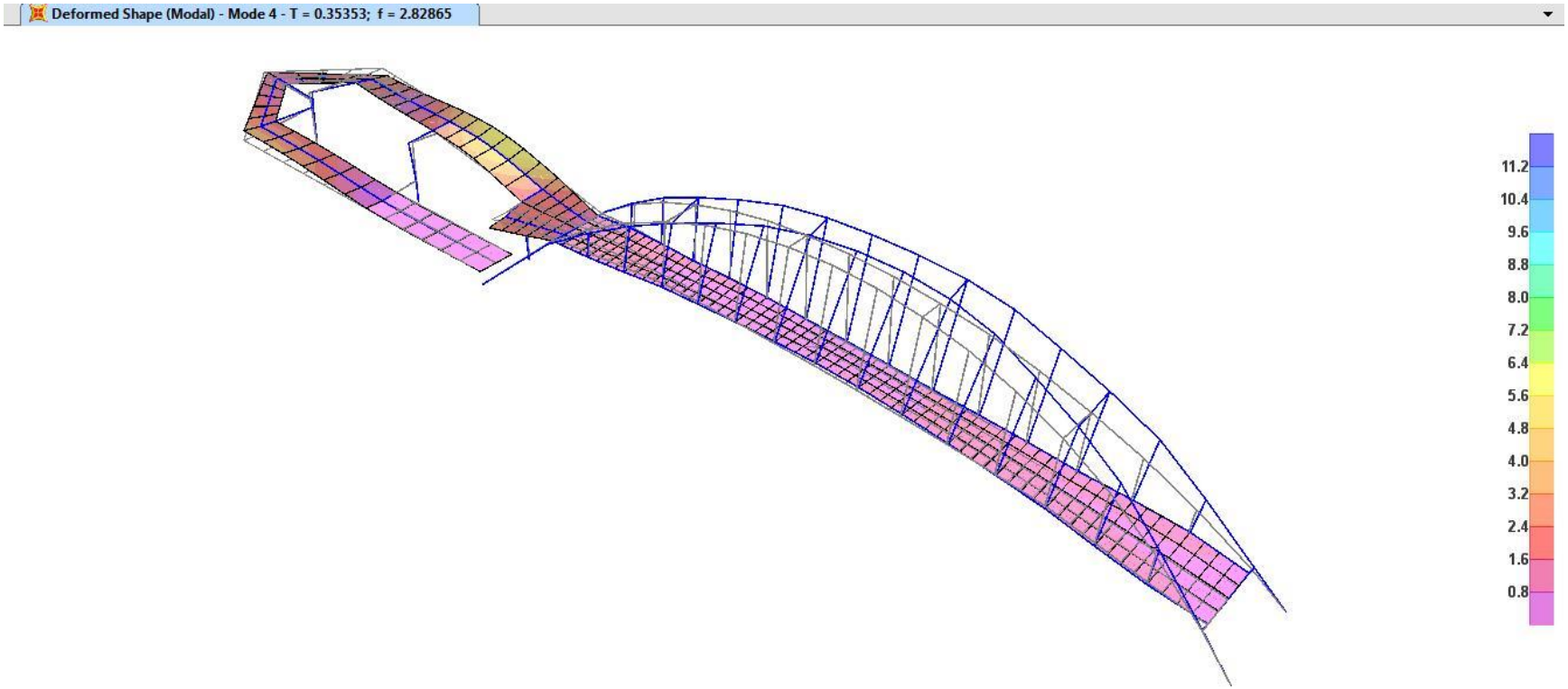
Dynamic Behavior of SAP2000 Modification 2 Mode 2



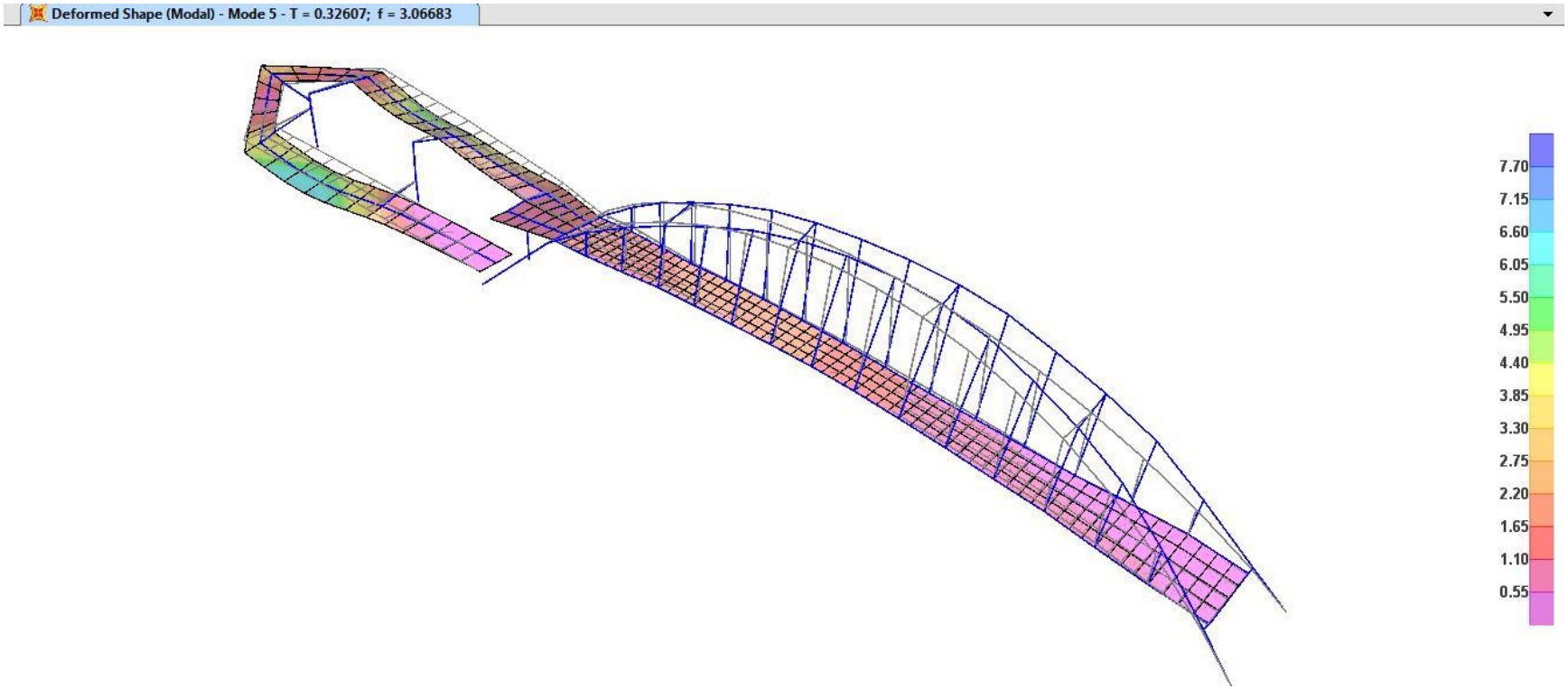
Dynamic Behavior of SAP2000 Modification 2 Mode 3



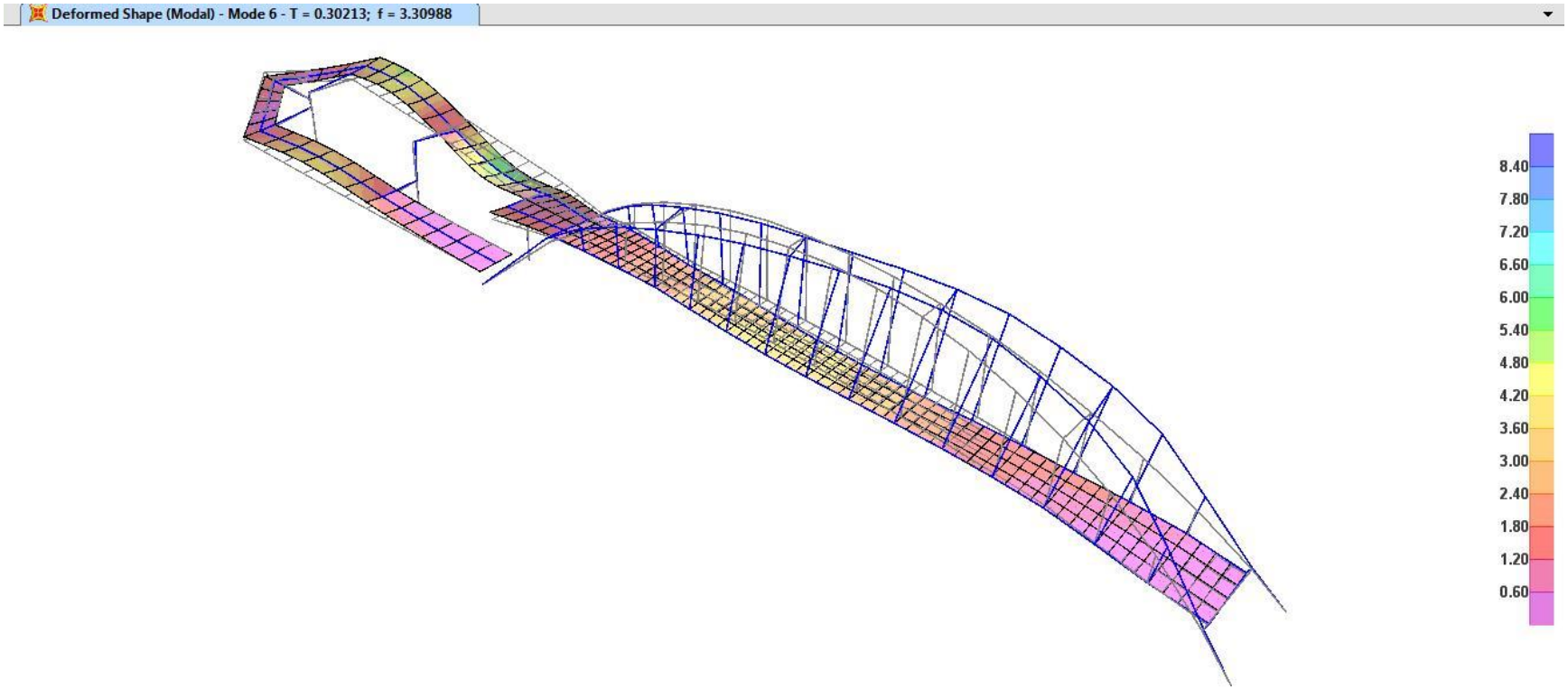
Dynamic Behavior of SAP2000 Modification 2 Mode 4



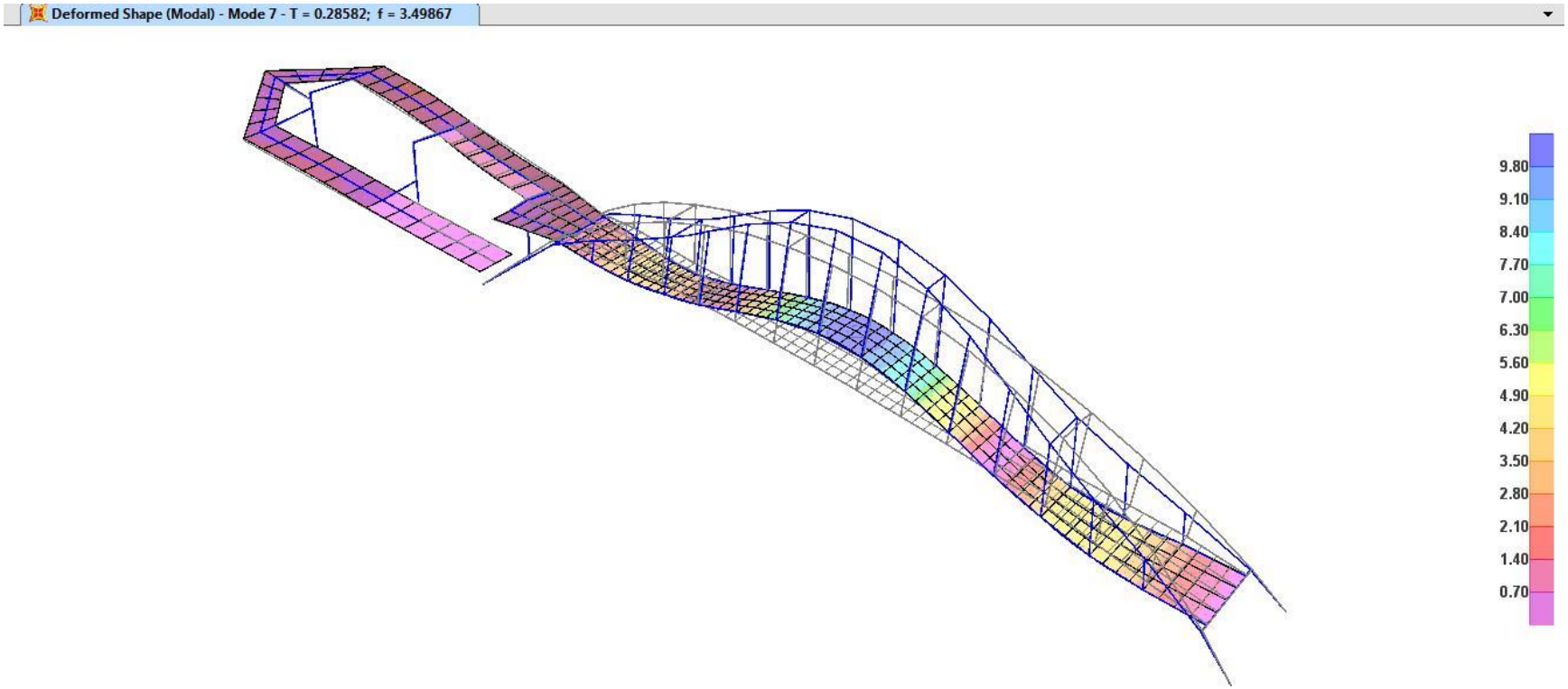
Dynamic Behavior of SAP2000 Modification 2 Mode 5



Dynamic Behavior of SAP2000 Modification 2 Mode 6



Dynamic Behavior of SAP2000 Modification 2 Mode 7



Dynamic Behavior of SAP2000 Modification 2 Mode 8