Ansys Mechanical Linear and Nonlinear Dynamics

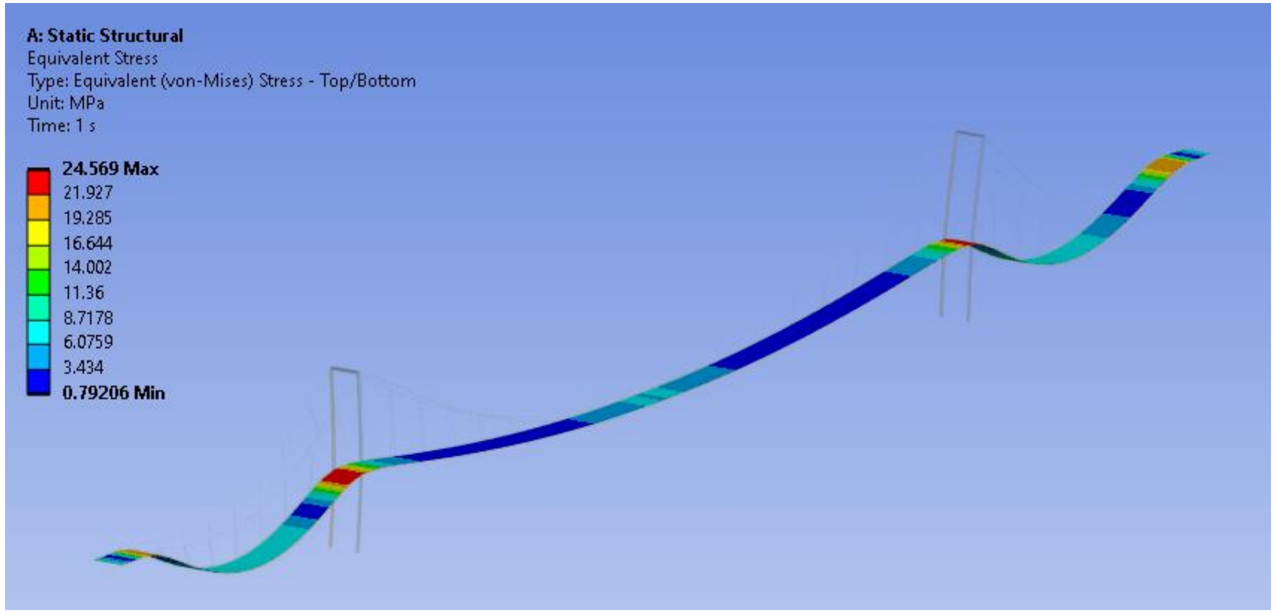
WS 07.1: Suspension Bridge

Release 2022 R2

Please note:
- These training materials were developed and tested in Ansys Release 2022 R2. Although they are expected to behave similarly in later releases, this has not been tested and is not guaranteed.
- The screen images included with these training materials may vary from the visual appearance of a local software session.
- Although some workshop files may open successfully in previous releases, backward compatibility is somewhat unlikely and is not guaranteed.

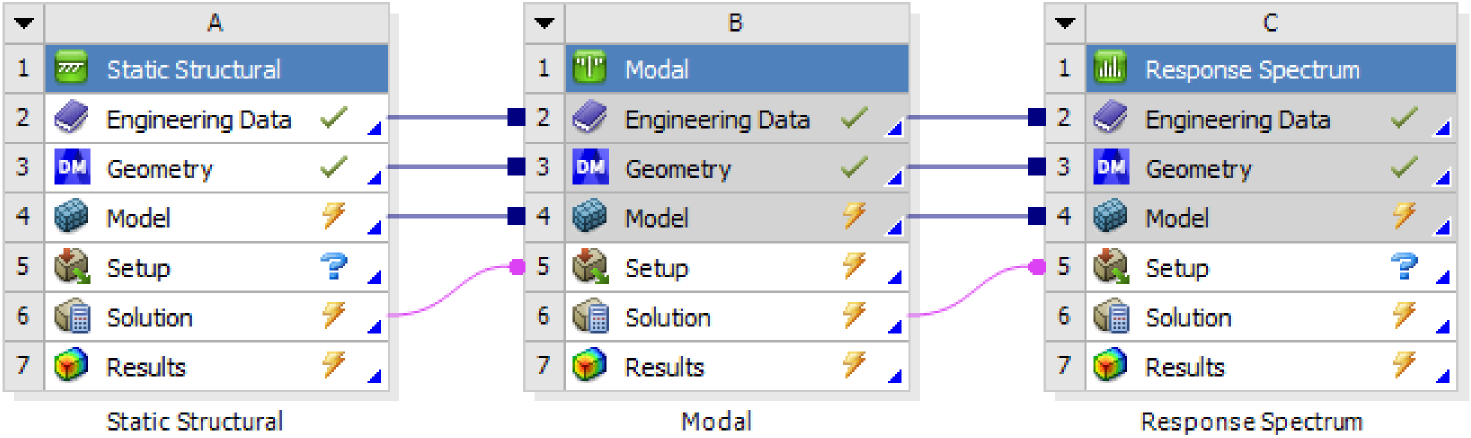
Workshop 07.1 - Goal

- Determine the response of a pre-stressed suspension bridge subjected to a seismic load.
  - The seismic load is applied as an acceleration in the lateral direction (Y axis) over a frequency range of 0 – 50 Hz.
- Gain practical experience in working with closely spaced modes and whether missing mass and rigid response effects are necessary.



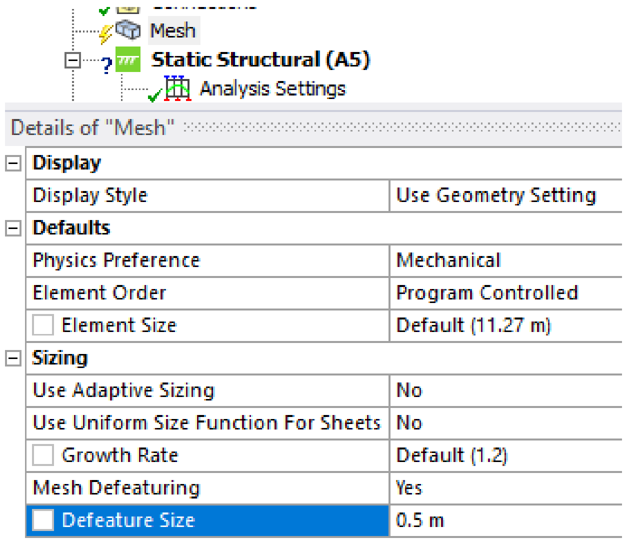
Workshop 07.1 - Project Schematic

- Start a new Workbench session and open the archive file “WS07.1-Suspension_Bridge.wbpz”.
- The project contains a pre-stressed response spectrum analysis schematic already defined.



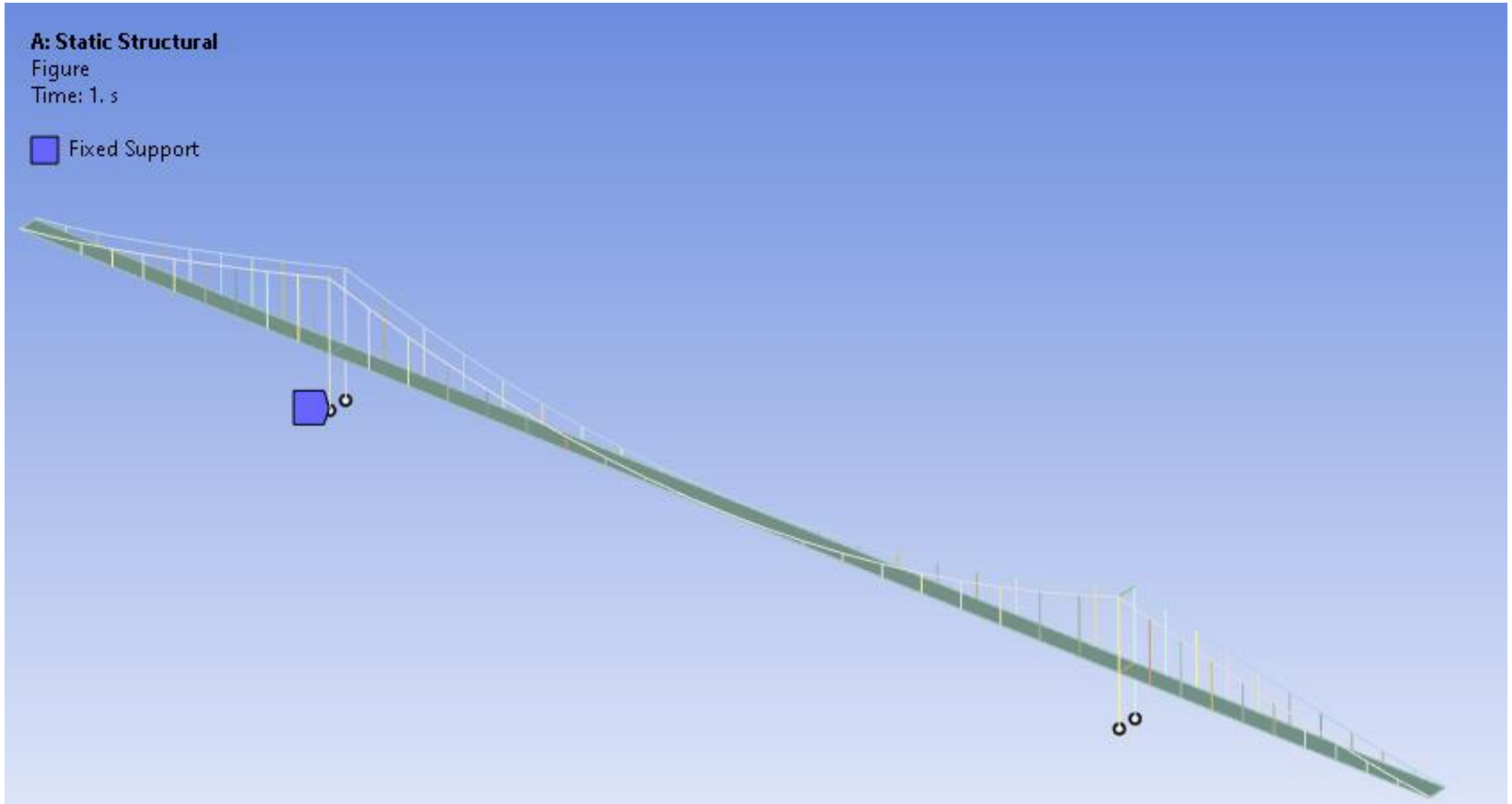
Workshop 07.1 - Preprocessing

- Edit the Static Structural Model cell to open the Mechanical application.
- In Mechanical, set the units system as follows:
  - Metric (m, kg, N, s, V, A)
  - Degrees
  - RPM
  - Celsius



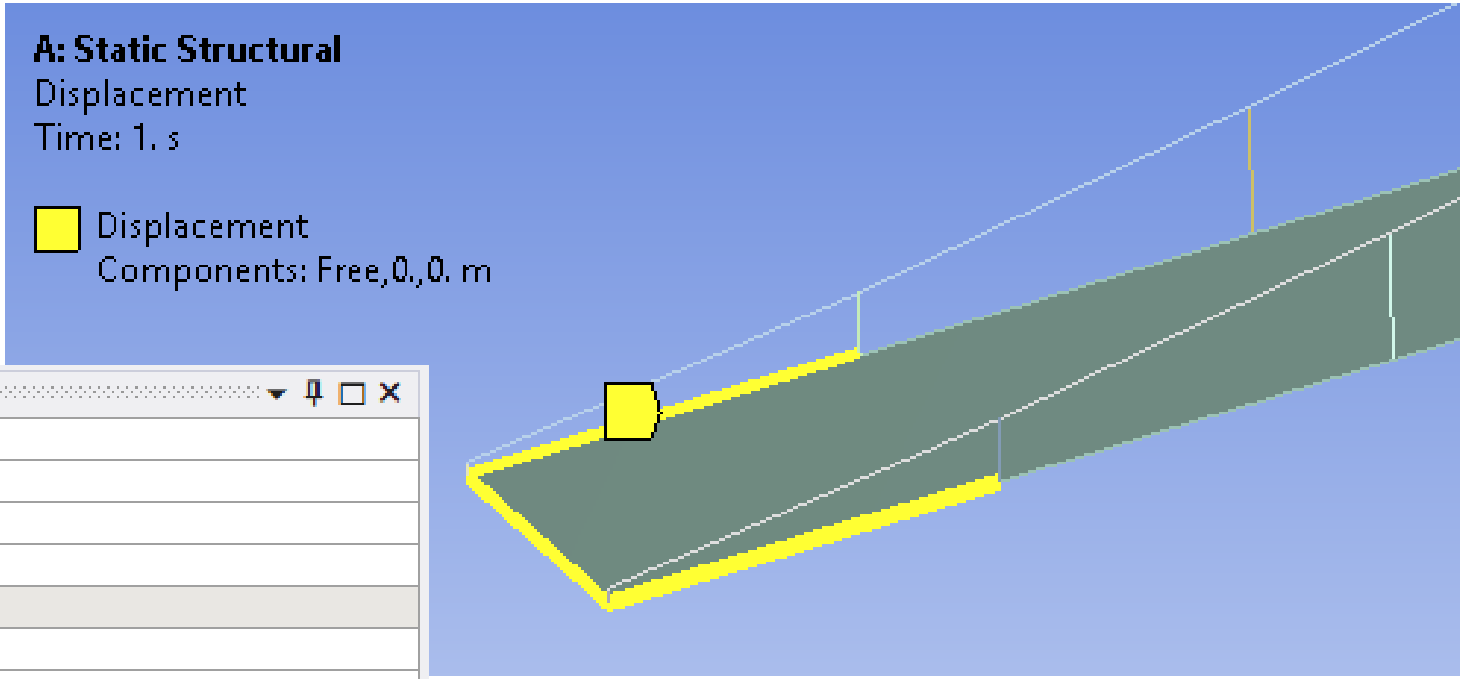
- Set the mesh defeaturing size to 0.5 m.
- Insert a fixed support at the vertices of all four tower foundations as shown on next slide.
  - The Modal and Response Spectrum systems will inherit this support

Workshop 07.1 - Preprocessing



Workshop 07.1 - Preprocessing

- Insert a zero-displacement constraint in the Y and Z directions on the three outer edges at *both* ends of the bridge deck.

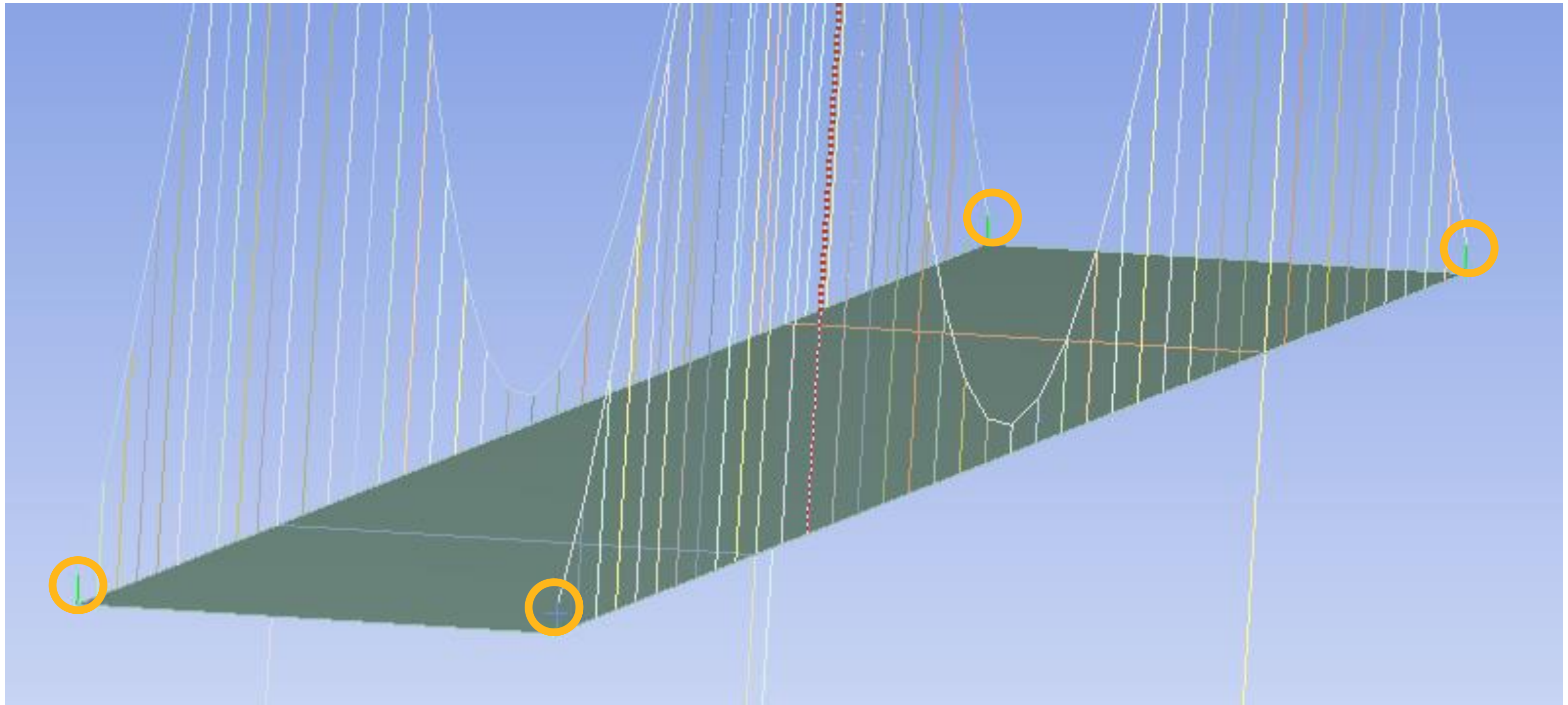


Details of "Displacement"

Scope	
Scoping Method	Geometry Selection
Geometry	3 Edges
Definition	
Type	Displacement
Define By	Components
Coordinate System	Global Coordinate System
X Component	Free
Y Component	0. m (ramped)
Z Component	0. m (ramped)
Suppressed	No

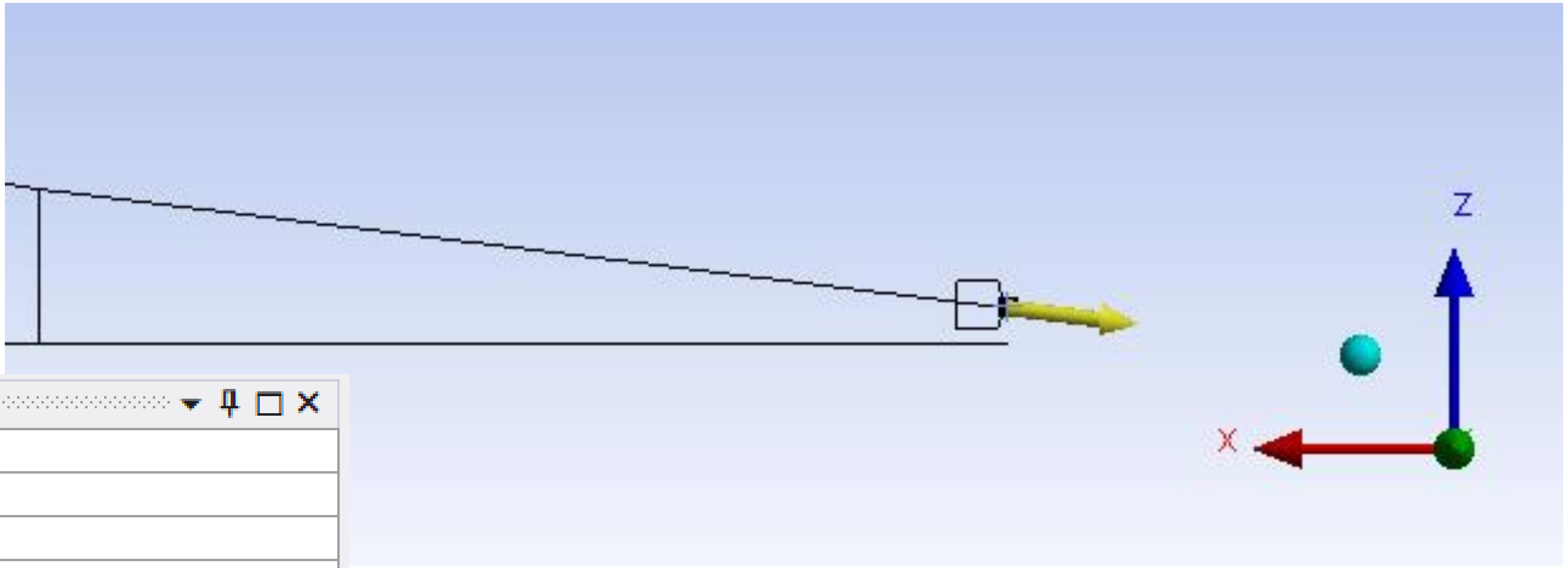
Workshop 07.1 - Preprocessing

- Suppress the last vertical line body on each corner of the bridge deck to allow for <u>cable pre-tension.</u>



Workshop 07.1 - Preprocessing

- Apply a displacement to the free ends of the 2 wires at the –X end of the bridge as shown.

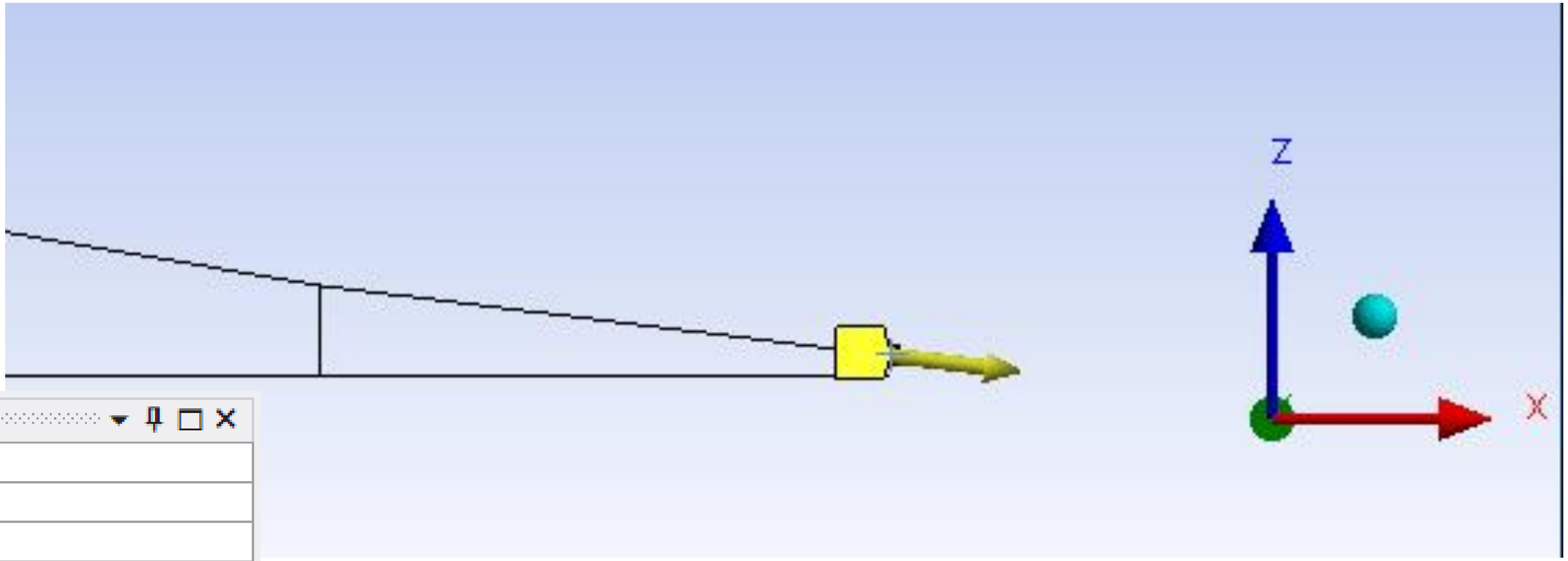


Details of "Displacement 3"

Scope	
Scoping Method	Geometry Selection
Geometry	2 Vertices
Definition	
Type	Displacement
Define By	Components
Coordinate System	Global Coordinate System
X Component	-0.993 m (ramped)
Y Component	Free
Z Component	-0.122 m (ramped)
Suppressed	No

Workshop 07.1 - Preprocessing

- Similarly, apply an equal but opposite displacement to the free ends of the 2 wires at the +X end of the bridge.



Details of "Displacement 4"

Scope	
Scoping Method	Geometry Selection
Geometry	2 Vertices
Definition	
Type	Displacement
Define By	Components
Coordinate System	Global Coordinate System
X Component	0.993 m (ramped)
Y Component	Free
Z Component	-0.122 m (ramped)
Suppressed	No

Workshop 07.1 - Preprocessing

- Finally, insert Standard Earth Gravity (-Z direction) from the Inertial loads toolbar button.
- Remember to set the Analysis Settings to use Large Deflection.
- Solve the Static Structural system.

Details of "Analysis Settings"

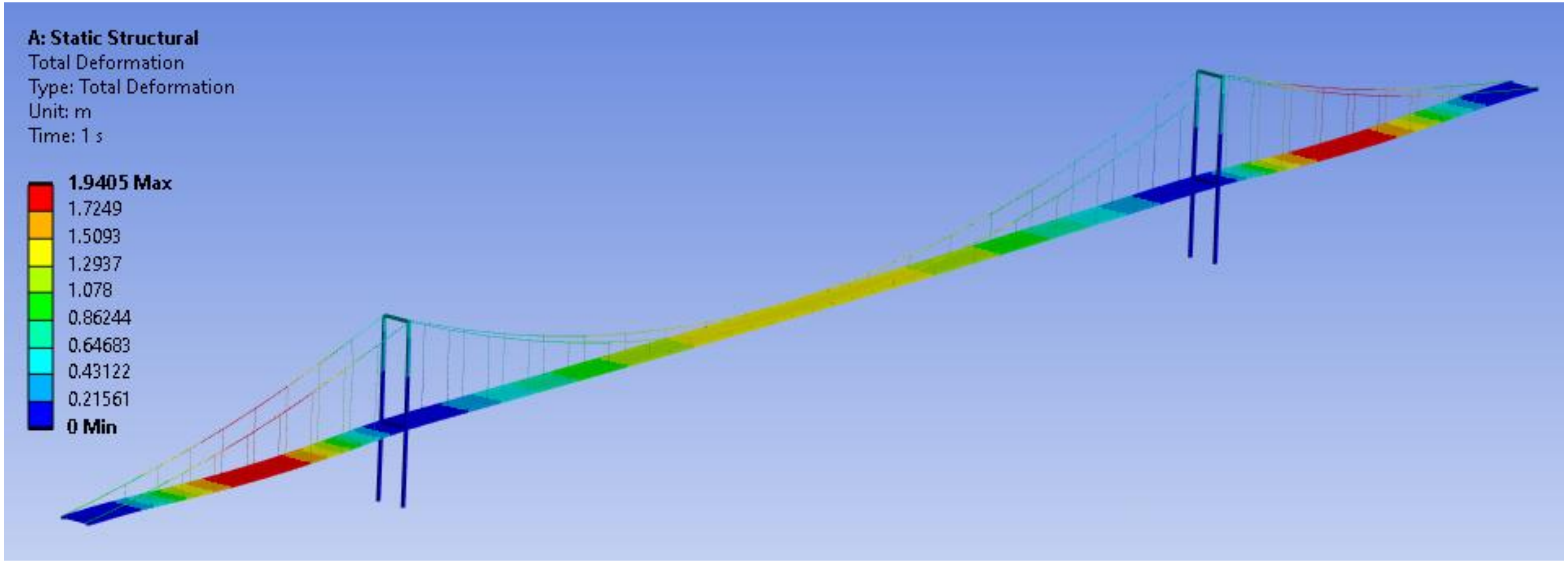
Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Off
Solver Pivot Checking	Program Controlled
Large Deflection	On
Inertia Relief	Off
Rotordynamics Controls	

Ansys

Workshop 07.1 - Static Solution

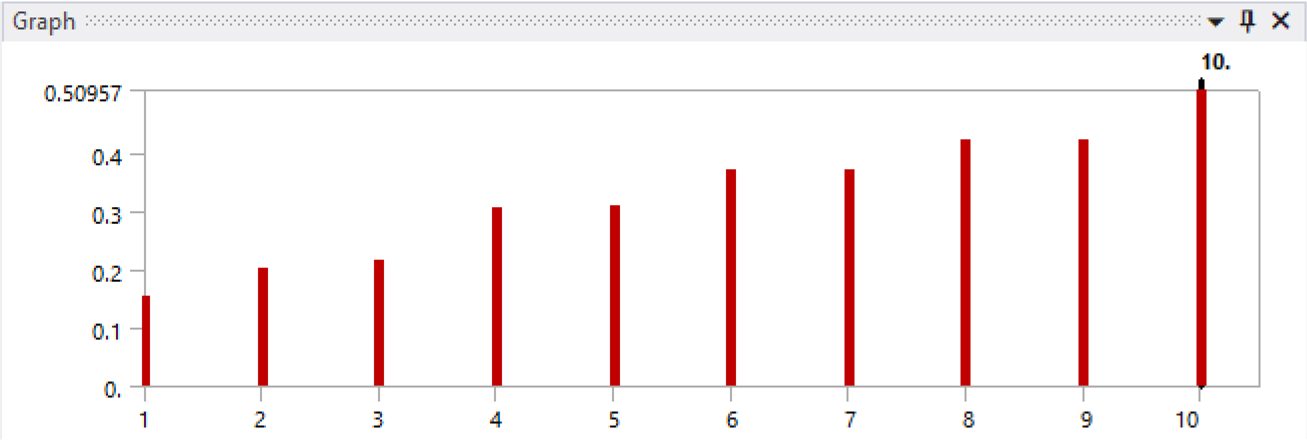
Note: your result magnitudes may vary slightly throughout this workshop due to mesh and software release differences

- Add a Total Deformation result and review the static structural solution.



Workshop 07.1 - Modal Solution

- With an excitation frequency range from 0 – 50 Hz, ideally we would extract enough modes to encompass 1.5x that range, or up to 75 Hz.
- Since we don't know how many modes are needed to reach 75 Hz, start by setting Max Modes to Find to 10, then run the Modal solution.
- Review the frequency table for the extracted modes.
  - From these results, it may be impractical to extract enough modes to encompass the full 75 Hz range.



Tabular Data

	Mode	Frequency [Hz]
1	1.	0.15502
2	2.	0.20201
3	3.	0.21705
4	4.	0.30802
5	5.	0.30971
6	6.	0.37027
7	7.	0.37235
8	8.	0.42229
9	9.	0.42386
10	10.	0.50957

Workshop 07.1 - Modal Solution

- Use the Participation Factor Summary report in Solution Information to examine the Ratio of Effective Mass to Total Mass in the seismic excitation (Y) direction.
  - Ideally, we'd like to have at least 90% of the effective mass represented by the modes in the Y direction; this may be a case for applying Missing Mass effects…

Details of "Solution Information"

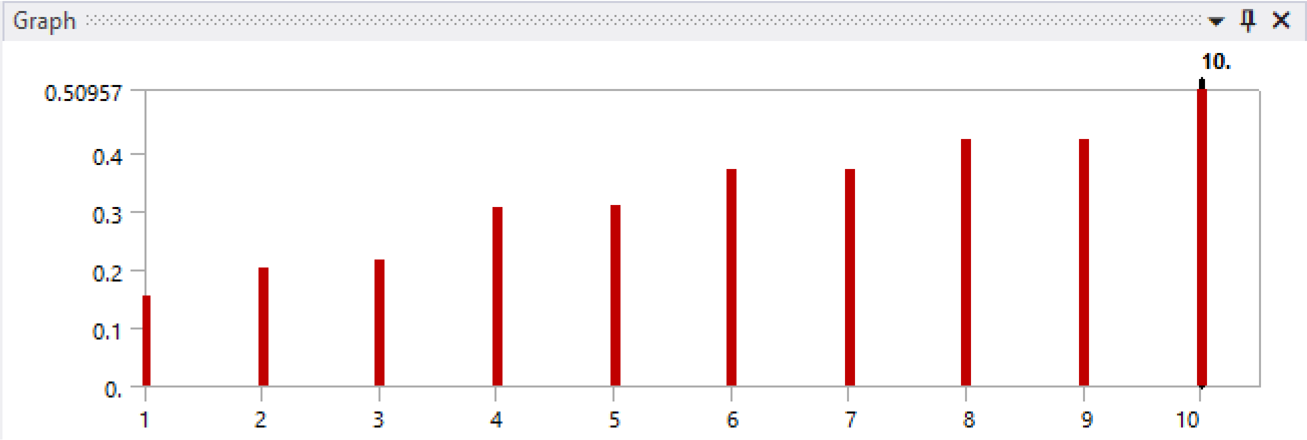
Solution Information	
Solution Output	Participation Factor Summary
Summary Type	All
Newton-Raphson Residuals	0
Identify Element Violations	0
Update Interval	2.5 s
Display Points	All

Ratio of Effective Mass to Total Mass

Mode	Frequency [Hz]	X Direction	Y Direction	Z Direction	Rotation X	Rotation Y	Rotation Z
1	0.15502	1.3262e-021	0.65057	1.6927e-022	2.7456e-003	9.8829e-022	5.18e-018
2	0.20201	6.1956e-017	1.0252e-021	0.13908	4.2534e-002	9.485e-018	3.6491e-020
3	0.21705	7.7483e-002	1.2224e-020	1.3163e-016	4.0131e-017	5.0387e-002	4.5625e-005
4	0.30802	2.7512e-014	3.0511e-022	9.1197e-004	2.7891e-004	1.8337e-013	1.5992e-017
5	0.30971	6.7668e-002	2.5855e-023	1.0131e-015	3.0982e-016	0.41771	3.9845e-005
6	0.37027	4.1531e-024	8.1176e-016	5.3721e-019	1.4884e-014	2.6677e-022	0.42956
7	0.37235	2.1486e-015	4.7329e-023	0.56133	0.17167	9.7418e-016	3.1284e-018
8	0.42229	5.6447e-021	8.7764e-003	2.8744e-021	0.13137	2.4103e-019	2.9842e-015
9	0.42386	8.9813e-004	6.9929e-020	6.2972e-016	2.2008e-016	3.579e-002	5.2885e-007
10	0.50957	6.4379e-023	2.3344e-002	2.3174e-022	0.3168	6.2185e-023	4.753e-013
Sum		0.14605	0.68269	0.70132	0.6654	0.50389	0.42964

Workshop 07.1 - Modal Solution

- Review the frequency table once again for the extracted modes.



Tabular Data

	Mode	Frequency [Hz]
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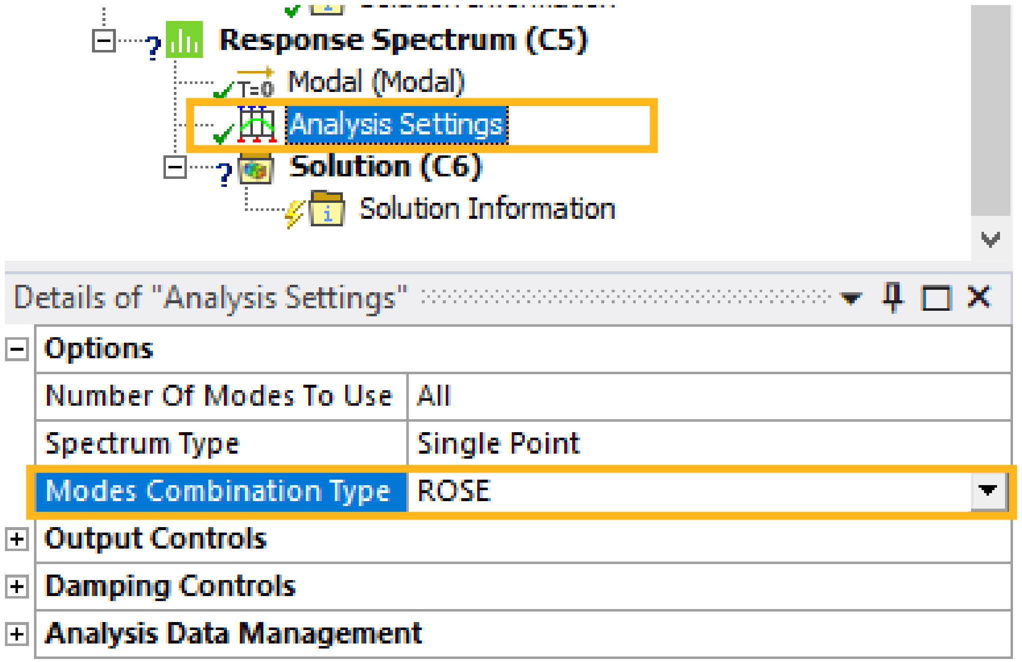
5	5.	0.30971
6	6.	0.37027
7	7.	0.37235
8	8.	0.42229
9	9.	0.42386
10	10.	0.50957

- Are the frequencies closely spaced?
  - Yes
- Make note of the highest extracted frequency.
  - $f = 0.51$ Hz

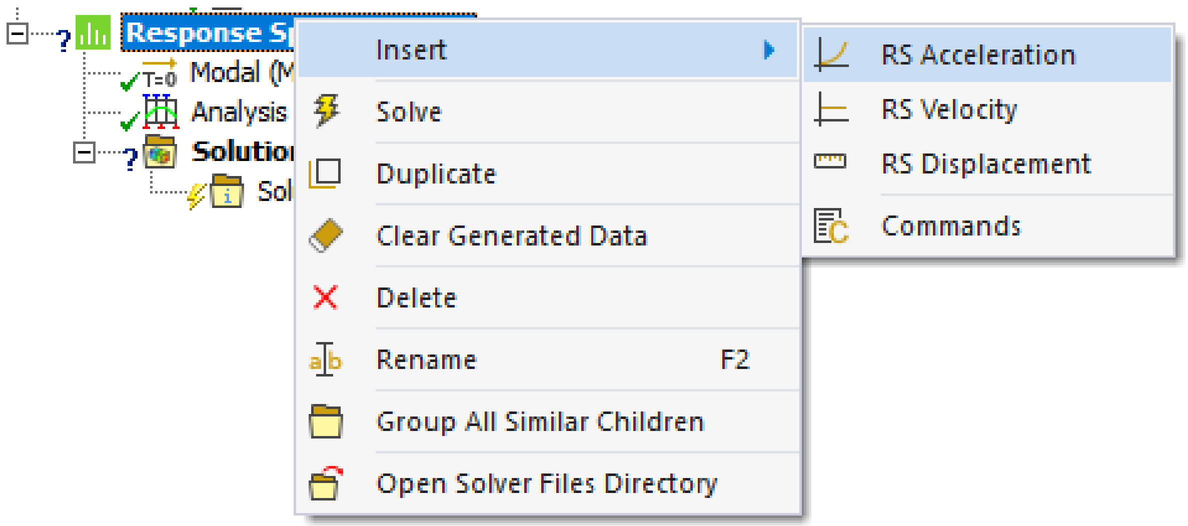
Workshop 07.1 – Response Spectrum Solution

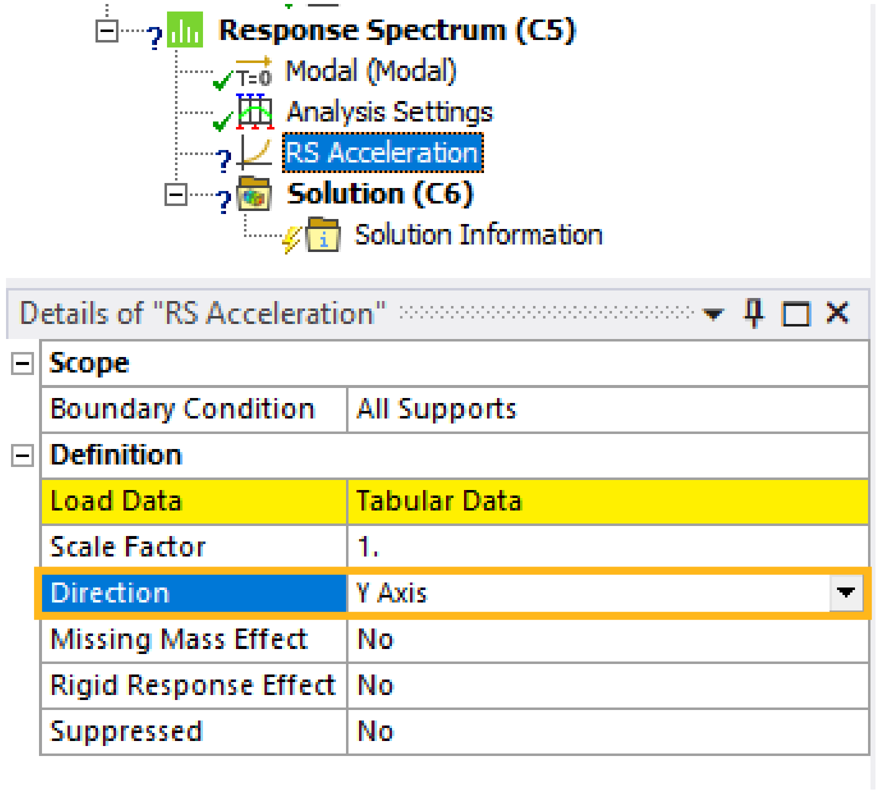
- Since we have closely-spaced modes, change the mode combination method in the Response Spectrum solution to something other than SRSS (e.g., ROSE):



Workshop 07.1 – Response Spectrum Solution

- Insert an RS Acceleration load in the Response Spectrum branch.
- Change Boundary Condition to All Supports and Direction to Y Axis



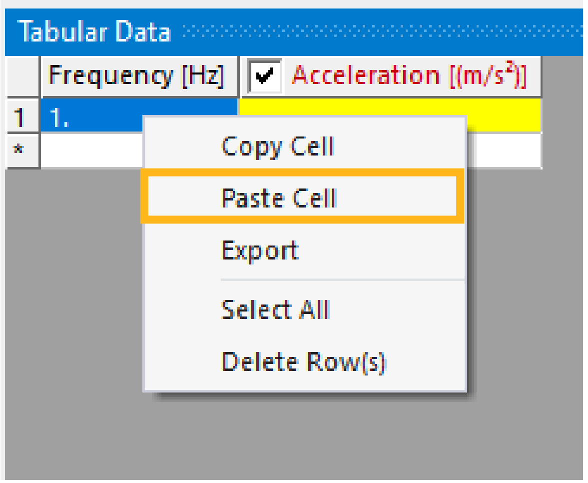


Workshop 07.1 - Response Spectrum Solution

- Open the seismic data file supplied with this workshop, “Savannah River Earthquake.xls”, copy the spectrum data, and paste it into the Tabular Data.

	A	B	C	D	E
1	Savannah River Site Disaggregated Seismic Spectra				
2					
3	Freq	Accel (g)			
4	0.10	0.002			
5	0.11	0.			
6	0.13	0.003			
7	0.14	0.005			
8	0.17	0.006			
9	0.20	0.006			
10	0.25	0.010			
11	0.33	0.021			
12	0.50	0.032			
13	0.67	0.047			
14	1.00	0.070			
15	1.11	0.088			
16	1.25	0.105			
17	1.43	0.110			
18	1.67	0.130			
19	2.00	0.150			
20	2.50	0.200			
21	3.33	0.255			
22	4.00	0.265			
23	5.00	0.255			
24	6.67	0.200			
25	10.00	0.165			
26	11.11	0.153			
27	12.50	0.140			
28	14.29	0.131			
29	16.67	0.121			
30	20.00	0.111			
31	25.00	0.100			
32	50.00	0.100			

Copy

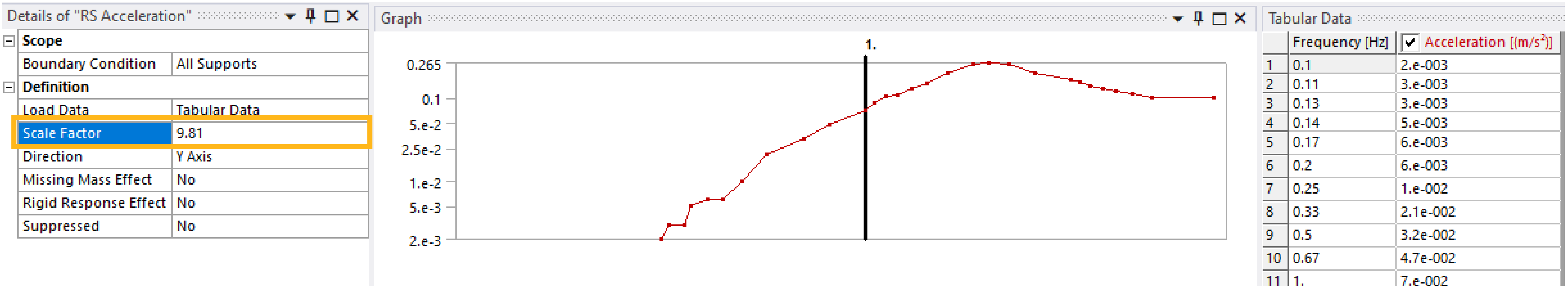


Tabular Data

	Frequency [Hz]	Acceleration [(m/s²)]
1	0.1	2.e-003
2	0.11	3.e-003
3	0.13	3.e-003
4	0.14	5.e-003
5	0.17	6.e-003
6	0.2	6.e-003
7	0.25	1.e-002
8	0.33	2.1e-002
9	0.5	3.2e-002
10	0.67	4.7e-002
11	1.	7.e-002
12	1.11	8.8e-002
13	1.25	0.105
14	1.43	0.11
15	1.67	0.13
16	2.	0.15
17	2.5	0.2
18	3.33	0.255
19	4.	0.265
20	5.	0.255
21	6.67	0.2
22	10.	0.165
23	11.11	0.153
24	12.5	0.14
25	14.29	0.131
26	16.67	0.121
27	20.	0.111

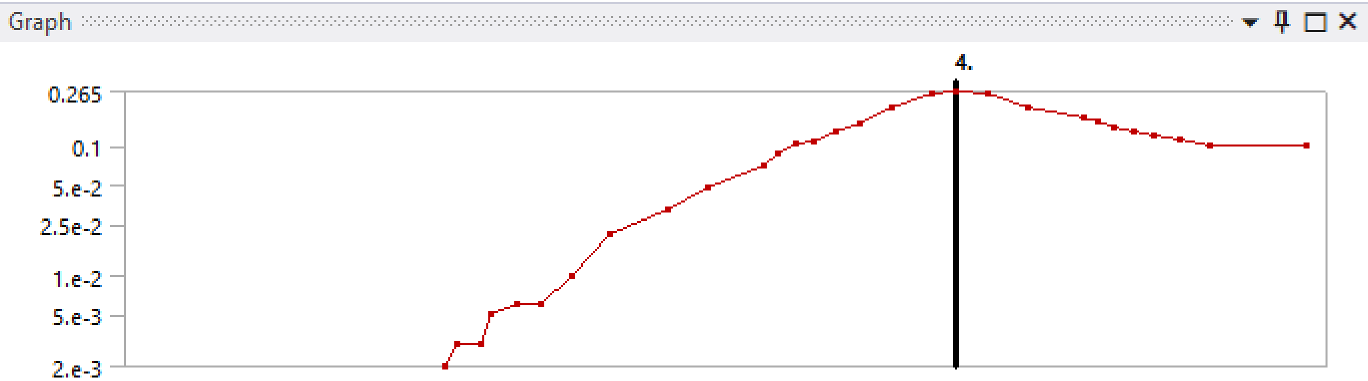
Workshop 07.1 - Response Spectrum Solution

- Since the seismic data were supplied in units of g (acceleration), insert a Scale Factor equal to the acceleration due to gravity in the working units:
  - 9.81 for MKS unit system.



Workshop 07.1 - Response Spectrum Solution

- Note the frequency at the spectral peak for this spectrum.
  - f_{SP} = 4 Hz



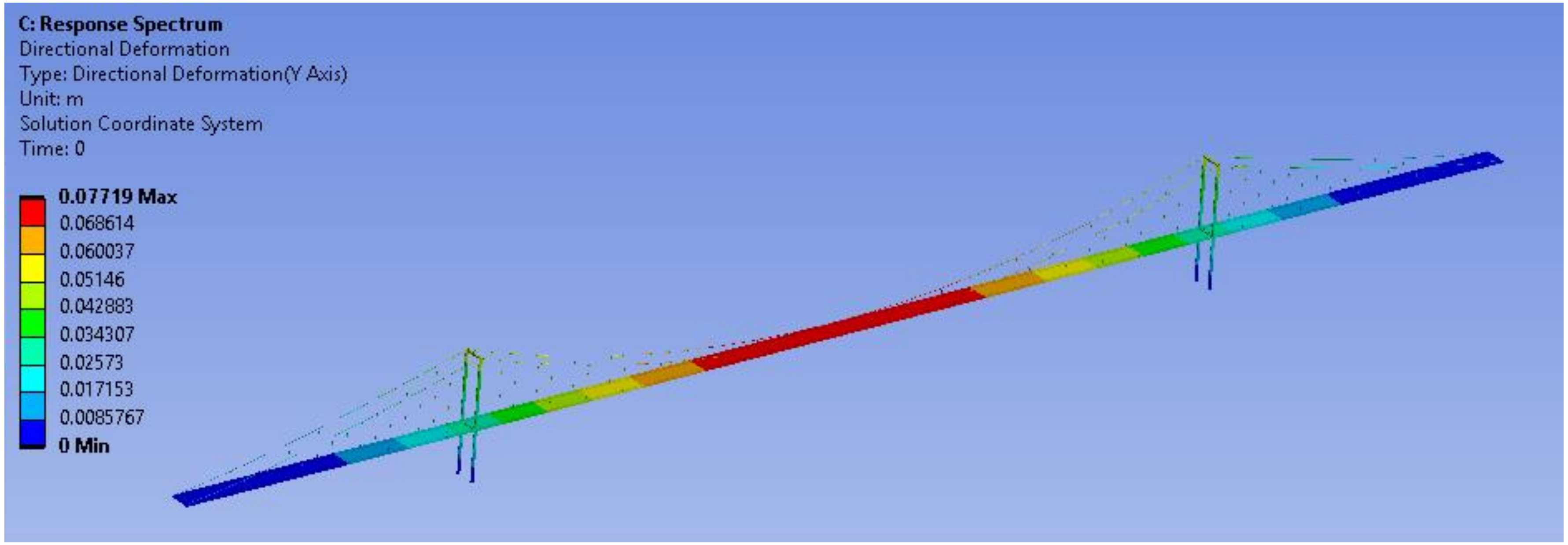
Tabular Data

	Frequency [Hz]	Acceleration [(m/s²)]
14	1.43	0.11
15	1.67	0.13
16	2.	0.15
17	2.5	0.2
18	3.33	0.255
19	4.	0.265
20	5.	0.255
21	6.67	0.2
22	10.	0.165
23	11.11	0.153

- How does this compare to our extracted modes?
  - all modes have $f < f_{SP}$
  - this means all modes are in the low-frequency region
  - therefore, no rigid response or missing mass is needed, and our spectrum results should not be affected appreciably by having captured only 68% of the effective mass in the Y direction from the modal analysis

Workshop 07.1 – Response Spectrum Results

- Finally, run the solution and insert result items of your choice.



- If time permits,
  - Return to the modal analysis, extract more modes (100 total?) and rerun the modal and spectrum analyses. Note the ratio of effective mass to total; do the results change?
  - the bridge deck may need some mesh refinement. Try changing the mesh settings and re-solving.

End of presentation