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Sandia National Laboratories

Dead Ends and Challenges in Simplified Finite Element Modeling of a Resonant Plate

Angela Patterson – Intern, Dept. 1557

Vit Babuska – Distinguished Member of the Technical Staff, Dept. 1557

David Soine – Principal Member of the Technical Staff, Dept. 1527

Daniel Lee – Member of the Technical Staff, Dept. 1557

U.S. DEPARTMENT OF ENERGY NNSA

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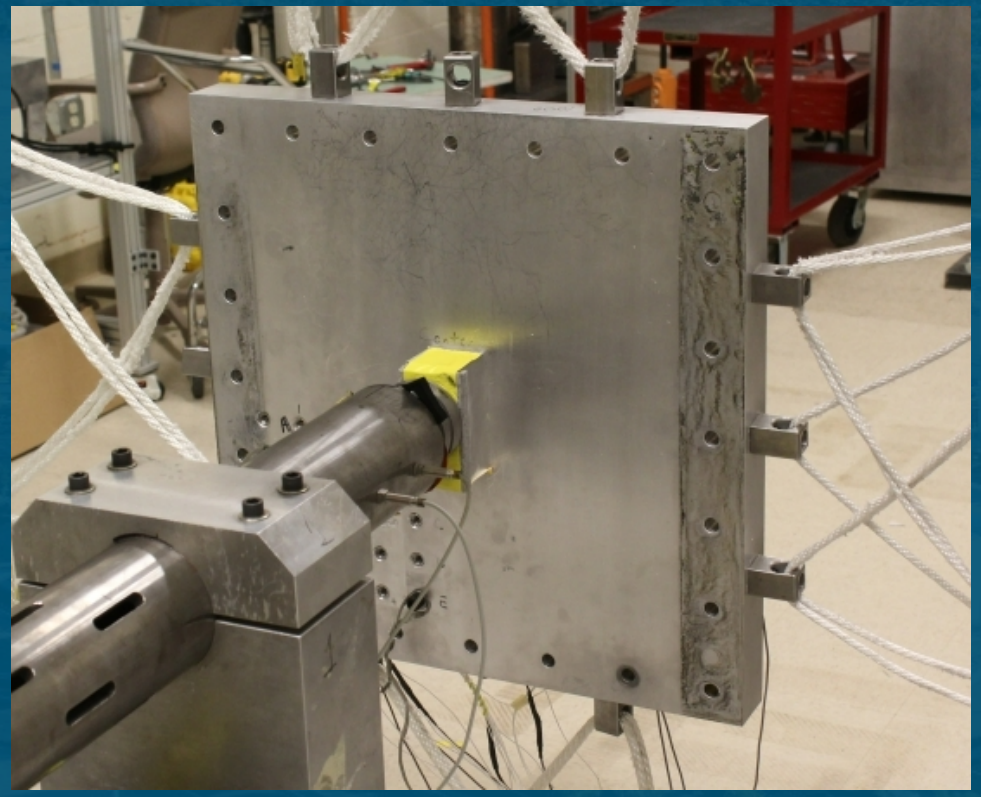
Goal

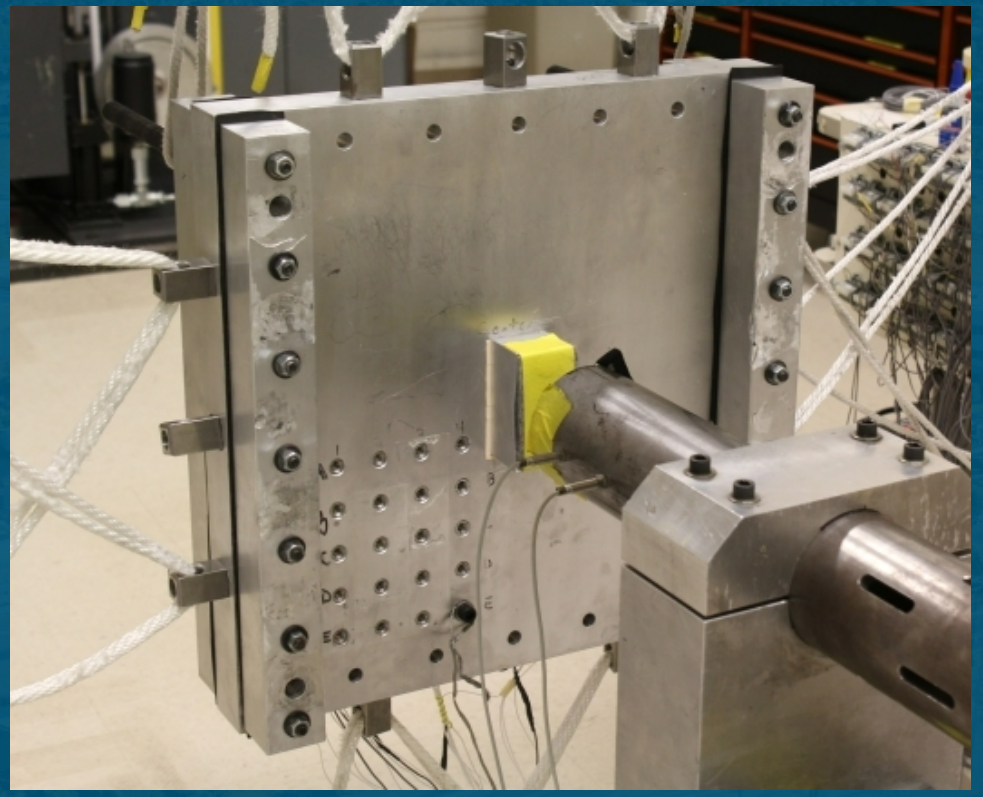
Create a **model for design** that is as **simple** as it can be and no more complicated than it must be to provide **reasonably accurate results**.

1kHz Resonant Plate

Model the Bare Plate



Then Add Damping Bars



How These Presentations are Laid Out

Talk 1:

- Model Overviews & Modal Verification

Talk 2:

- Lessons Learned during Model Development
  - Modeling the Bare Plate
  - Attaching the Damping Bars

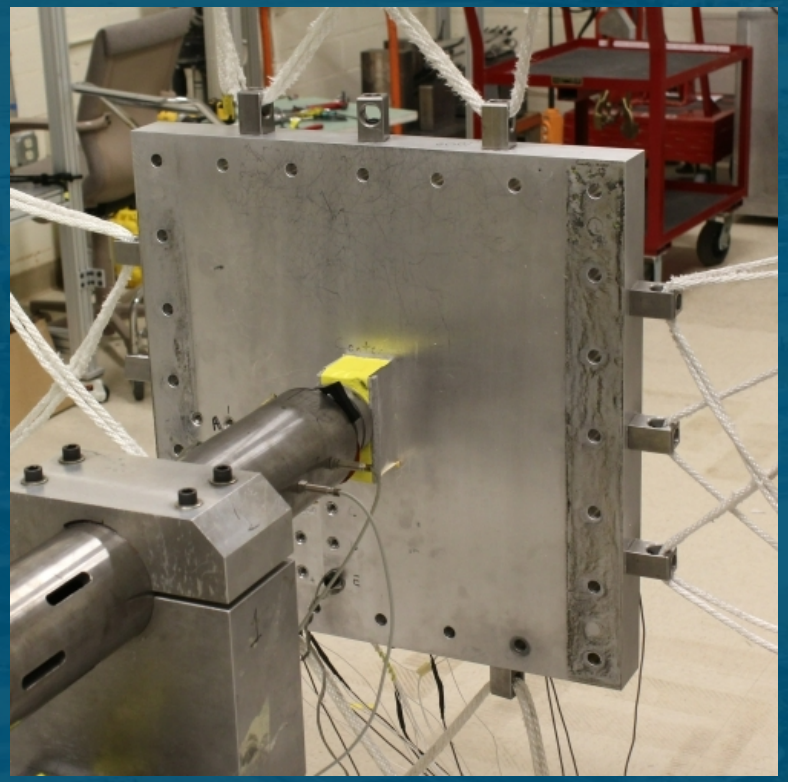
Talk 3:

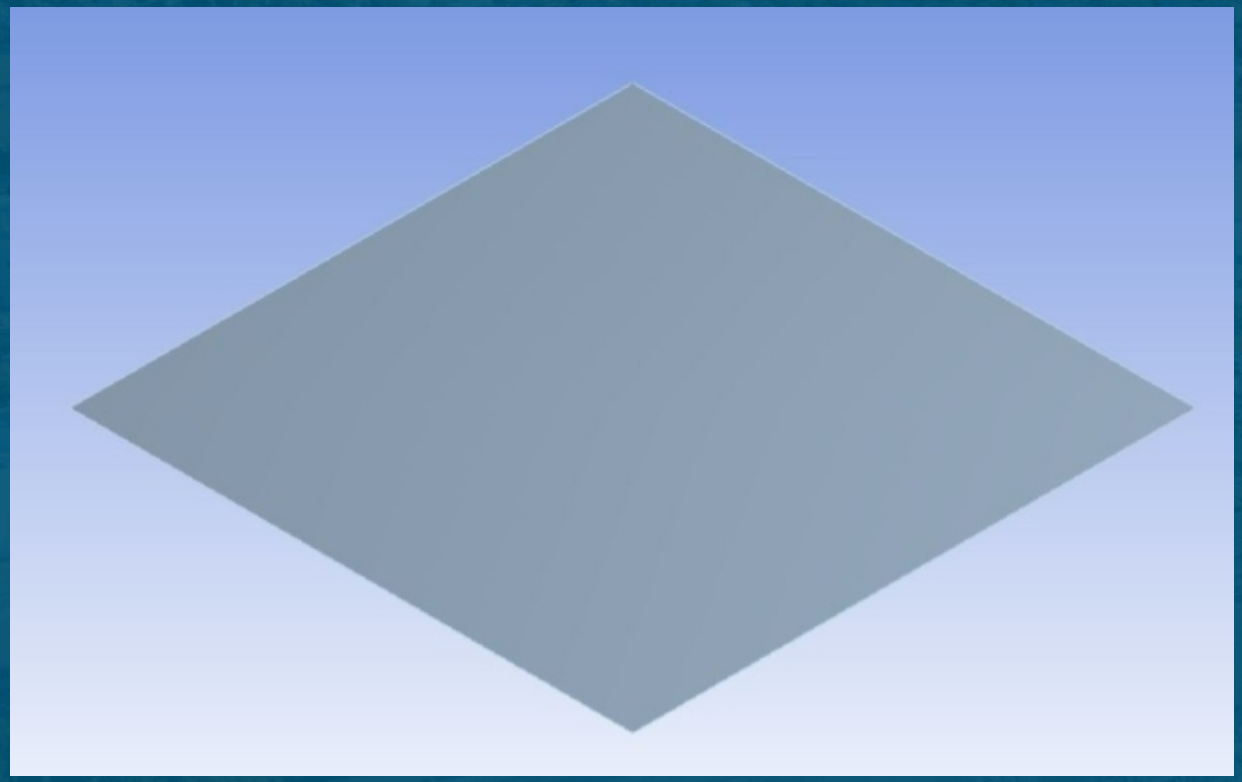
- Shock Verification & Application to Other Plates

Modeling the Bare Plate

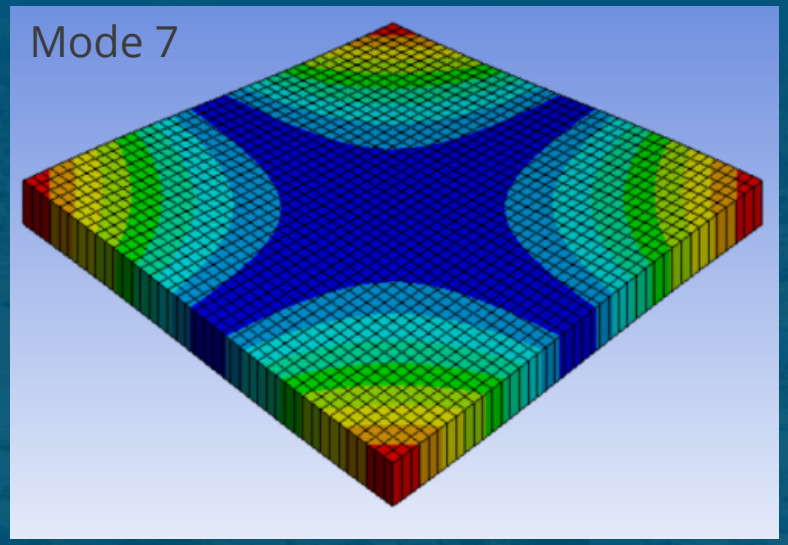
Model for the Bare Plate

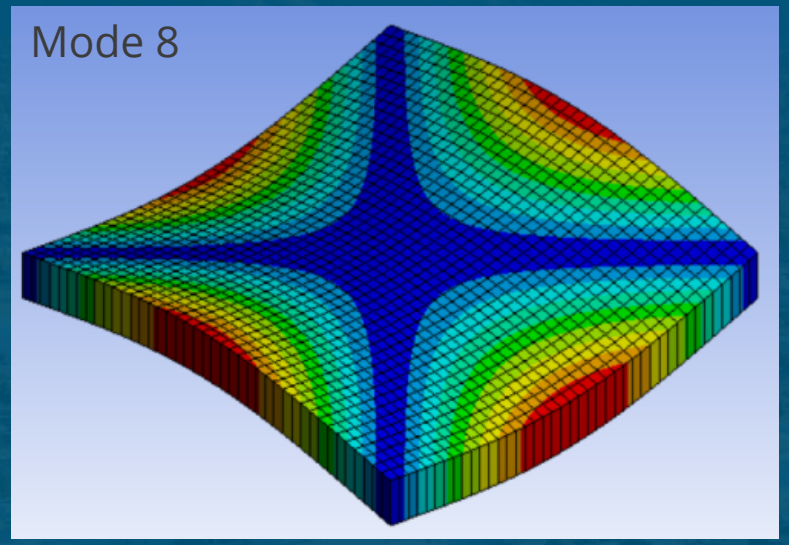
- Starting Point: Shell Element Model

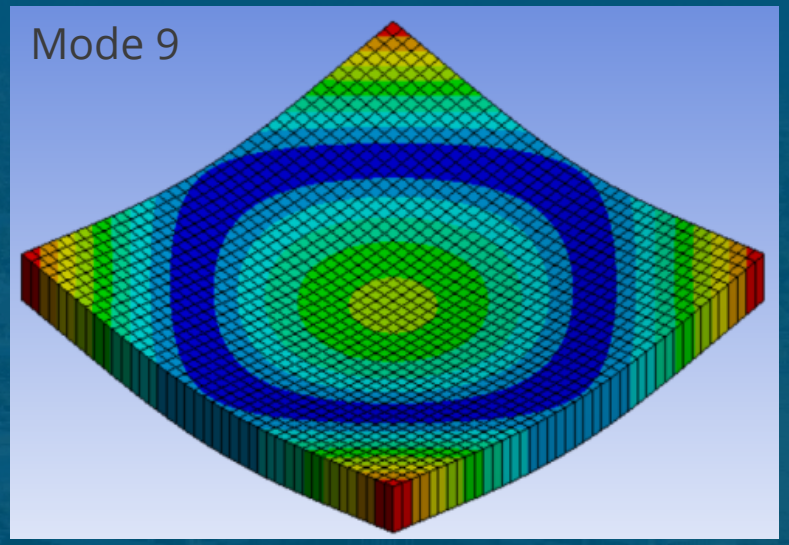


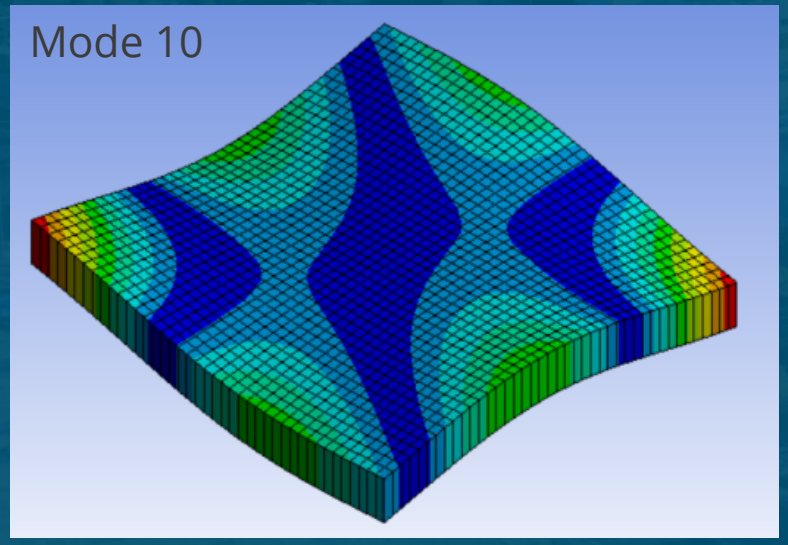


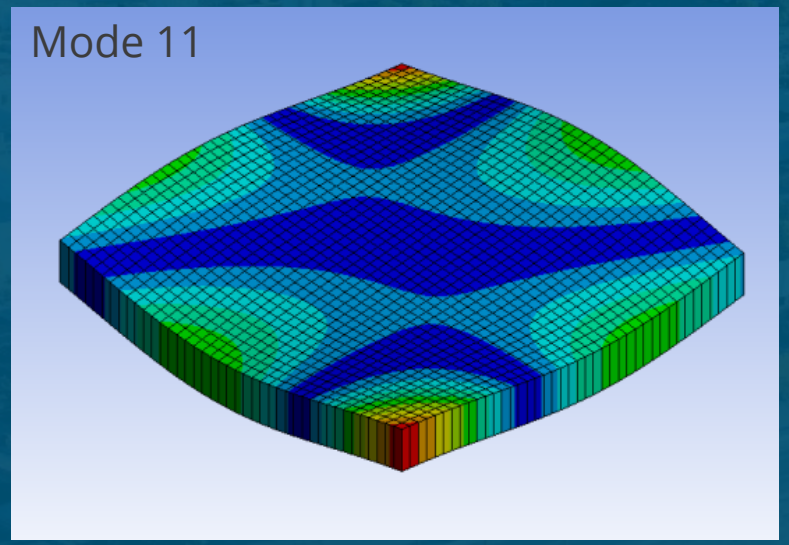
Starting Point: 2 in. Thick Plate

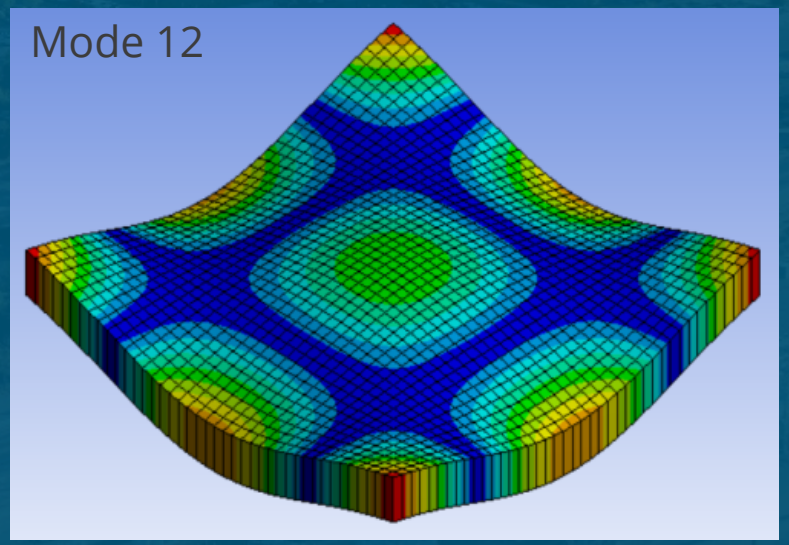












Comparison to Test

Model Frequency (Hz)	Test Frequency (Hz)	% Difference
580.6	545.0	6.53%
867.0	789.6	9.80%
1092.0	1020.0	7.06%
1466.2	1350.0	8.61%
1466.2	1350.0	8.61%
2564.8	2313.8	10.85%

Comparison to Test

- Model frequencies too high
- $\omega_n = \sqrt{k/m}$
- Either:
  - k is too high
  - m is too low

Model Frequency (Hz)	Test Frequency (Hz)	% Difference
580.6	545.0	6.53%
867.0	789.6	9.80%
1092.0	1020.0	7.06%
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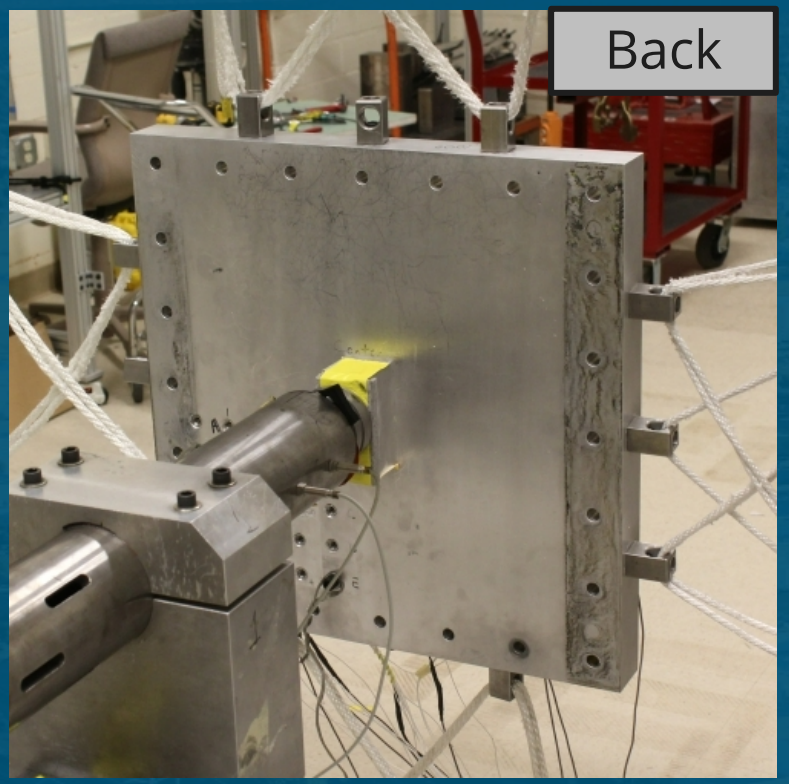
2564.8	2313.8	10.85%

Re-Examine Plate



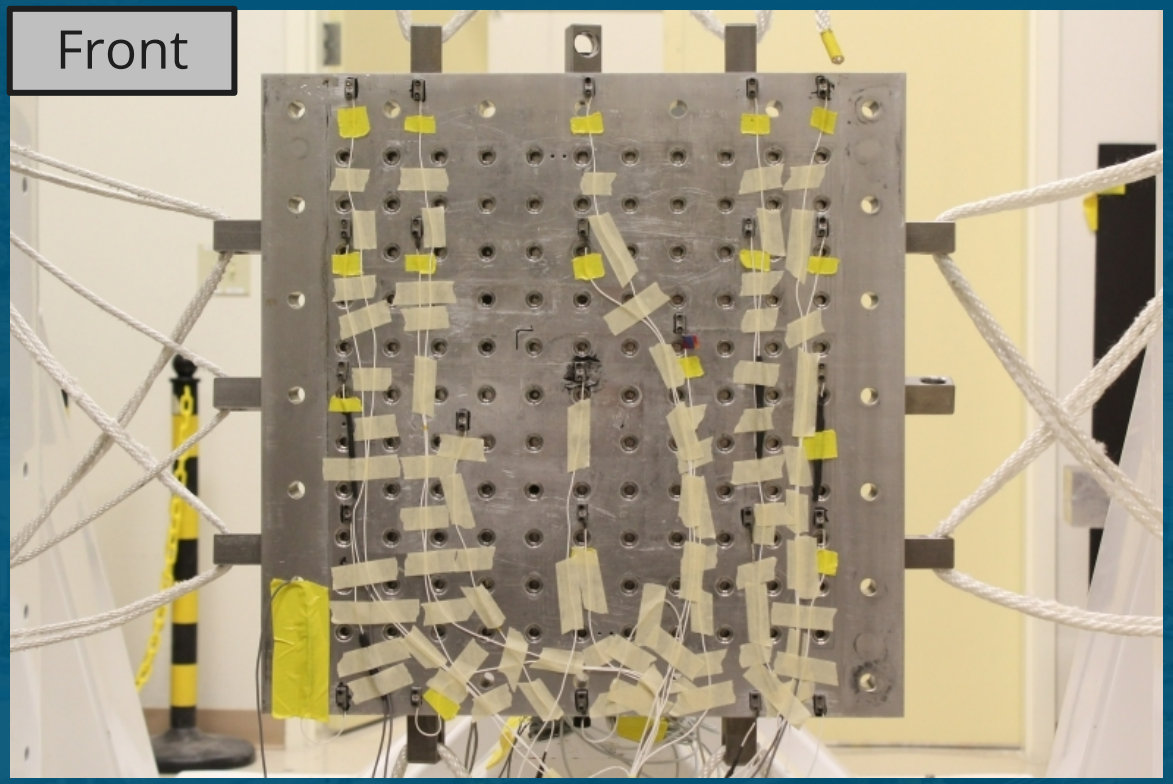


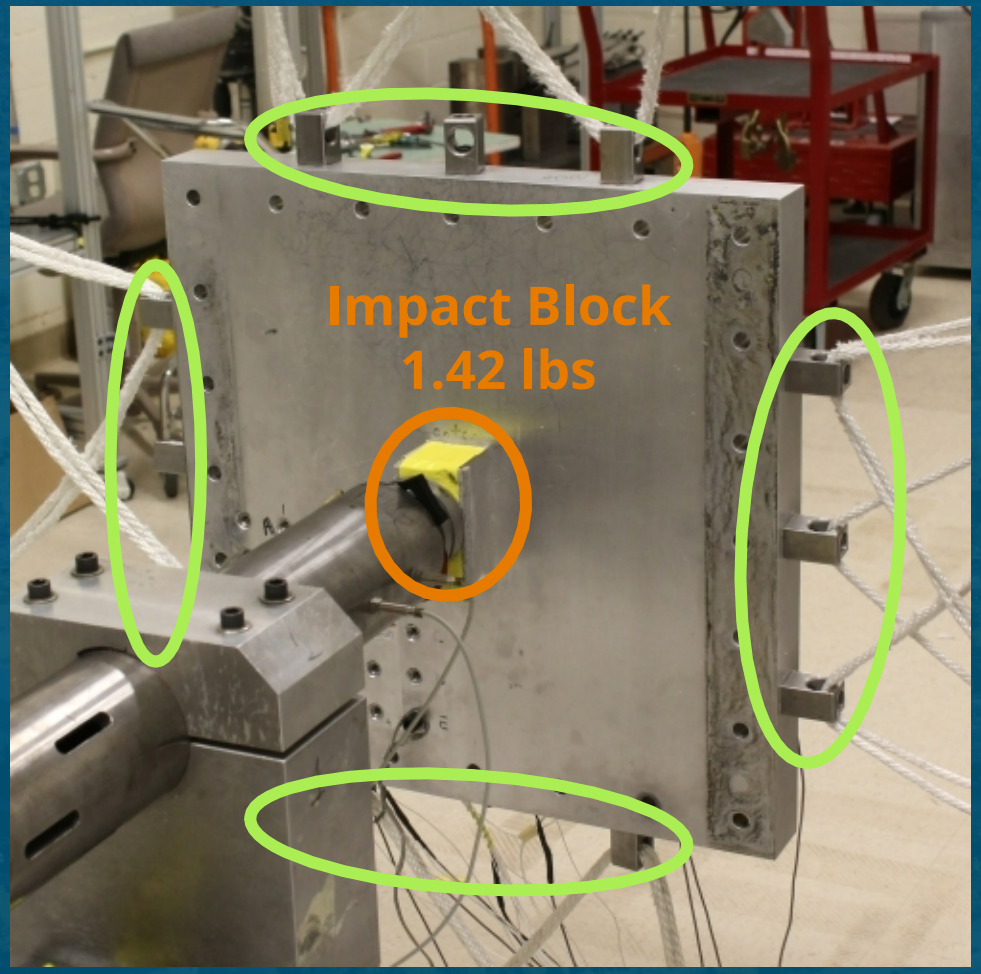
Plate has many holes for bolting test articles

Holes reduce the stiffness of the plate

Stiffness Adjustment

- Adjusted material stiffness (E)
  - Extreme changes not enough
  - 9.7e6 psi instead of 10e6 psi
- Model must be missing mass

Unmodeled Mass on the Bare Plate

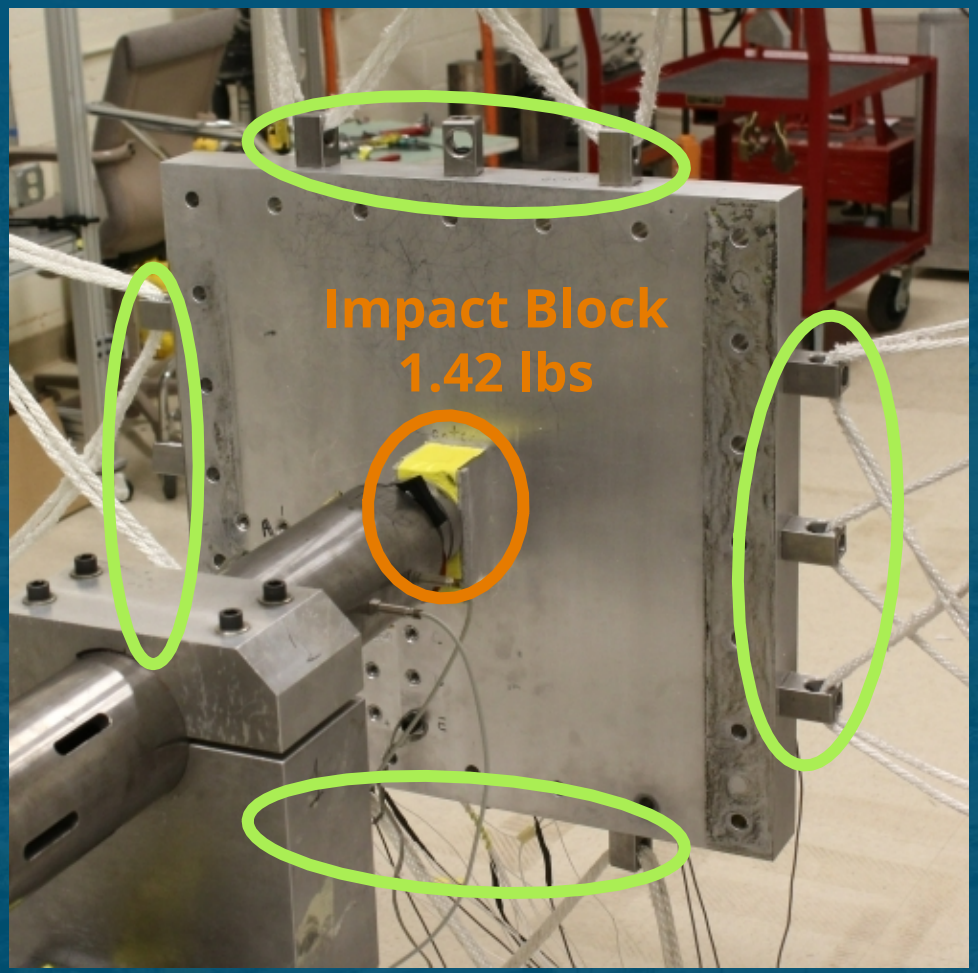


Mounting Blocks
0.31 lbs each

Unmodeled Mass on the Bare Plate

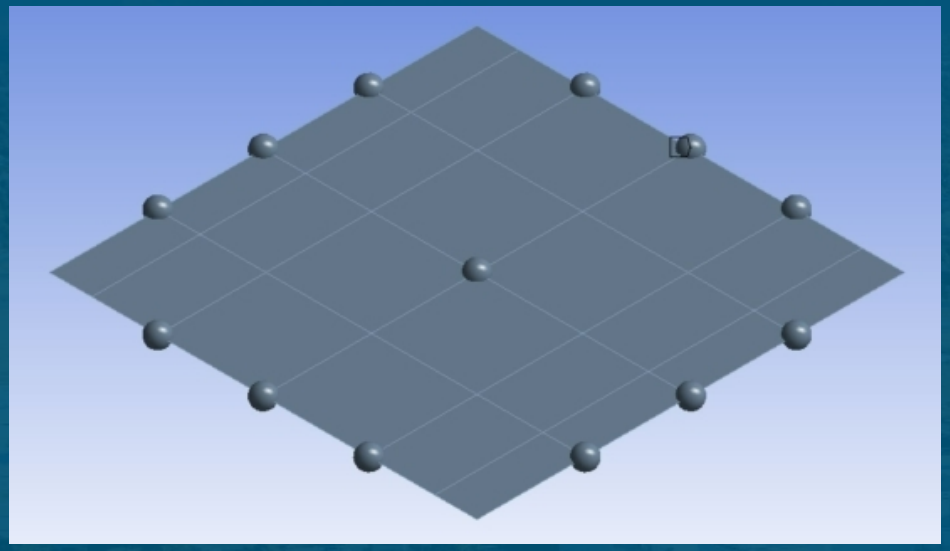
- Plate: 80 lbs
- Masses are tiny (< 2%)
- Large moment arm & motion

- Model as point masses



Mounting Blocks
0.31 lbs each

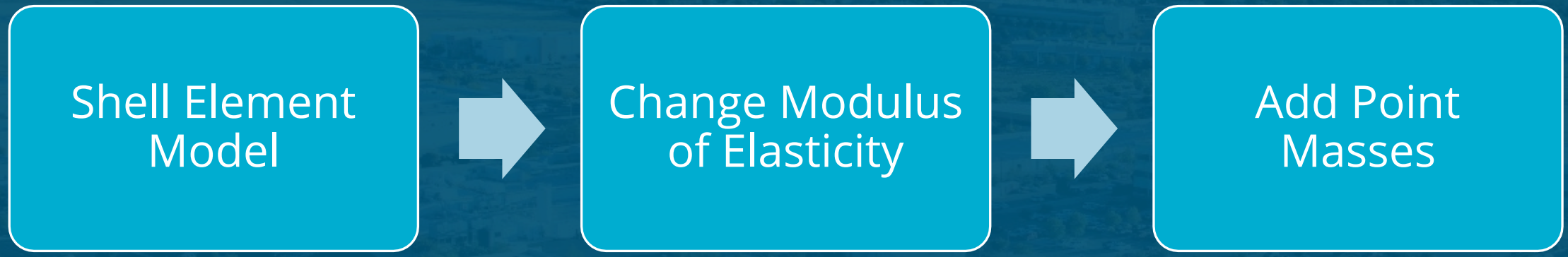
Final Model of the Bare Plate



Model Frequencies (Hz)	Test Frequencies (Hz)	% Difference	MAC Value
559.0	545.0	2.57%	1.000
798.6	789.6	1.15%	1.000
1039.2	1020.0	1.88%	0.999
1388.0	1350.0	2.82%	0.999
2381.3	2347.3	1.45%	0.688
2453.9	2313.0	6.09%	0.644
2488.5	2365.0	5.22%	0.665
3150.0	3081.5	2.22%	0.991

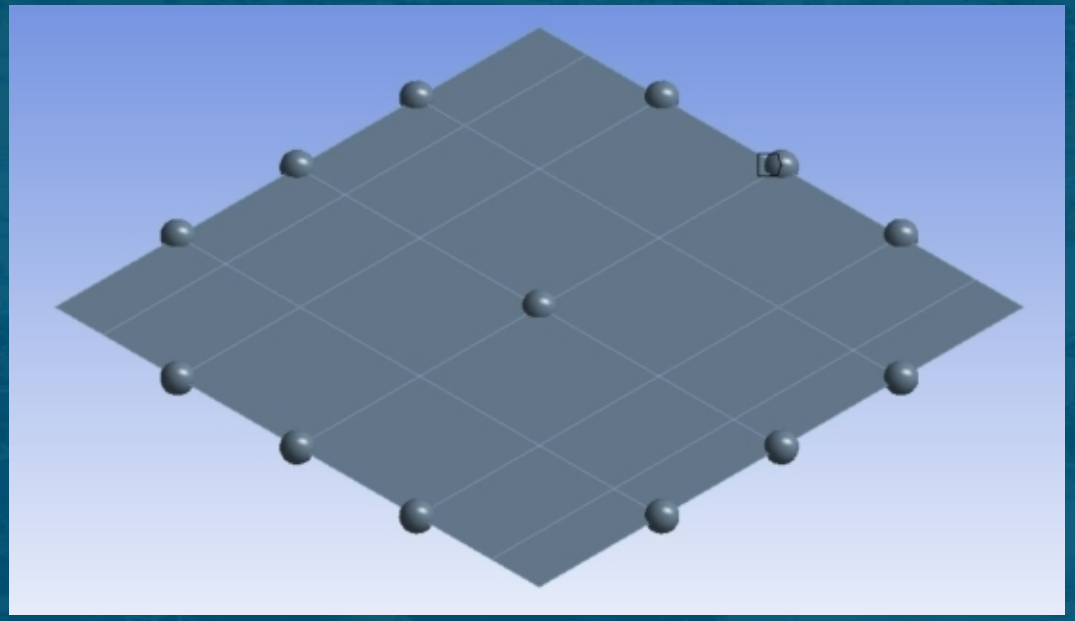
Even small masses must be accounted for

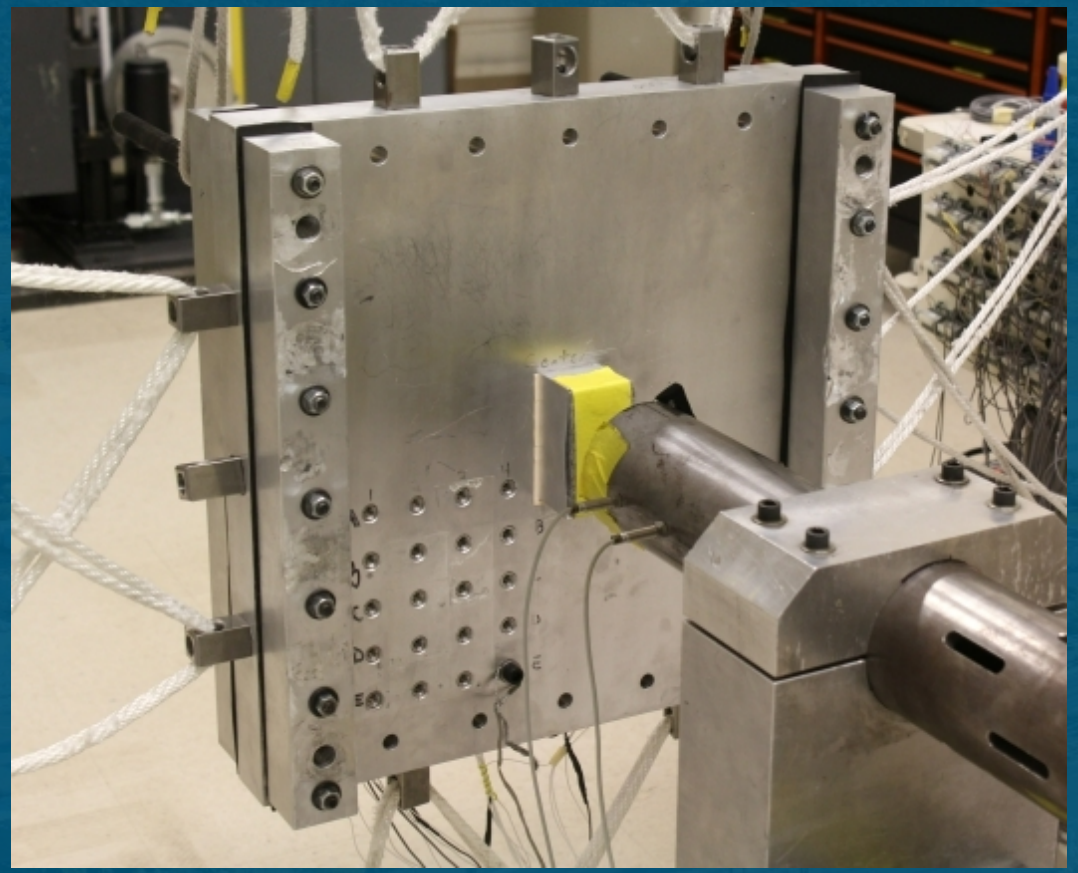
Bare Plate Model Evolution



Attaching Damping Bars

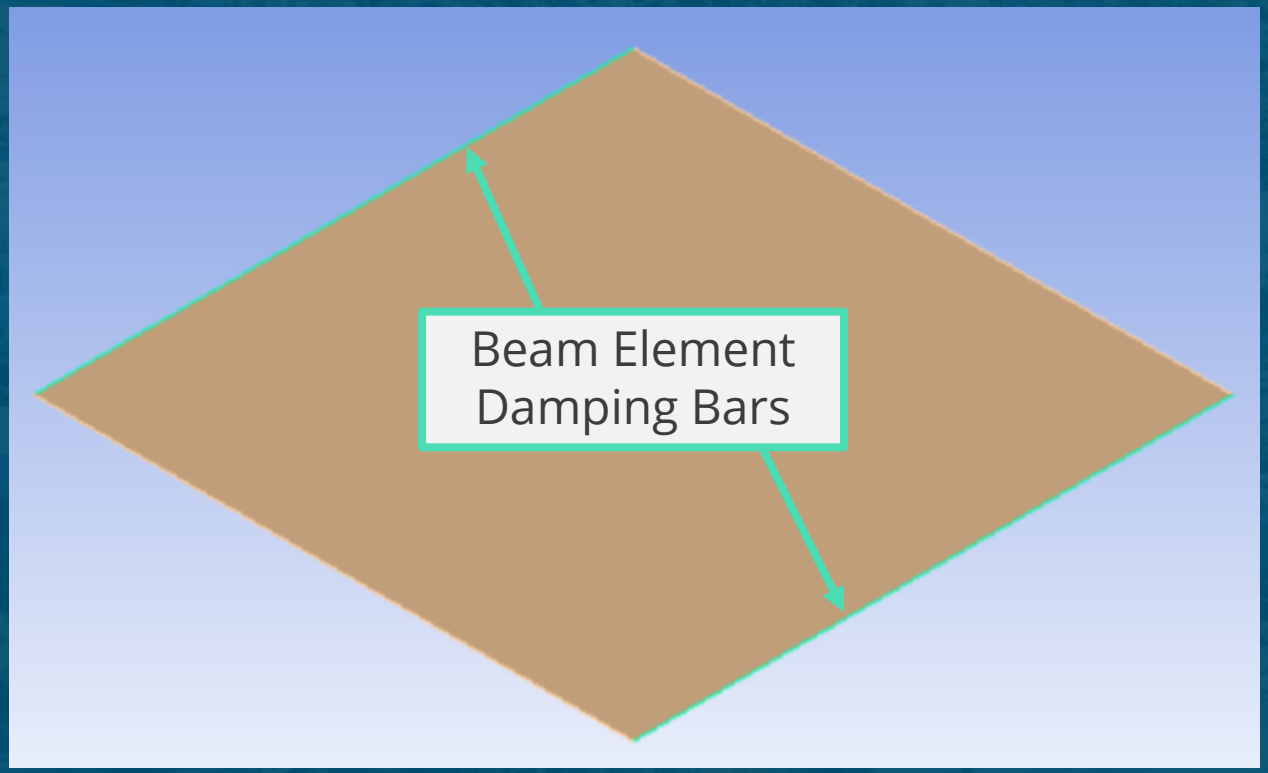
Adding Damping Bars to the Model





Adding Damping Bars to the Model

Approach #1: Model bars as beams, bonded to edges of the plate



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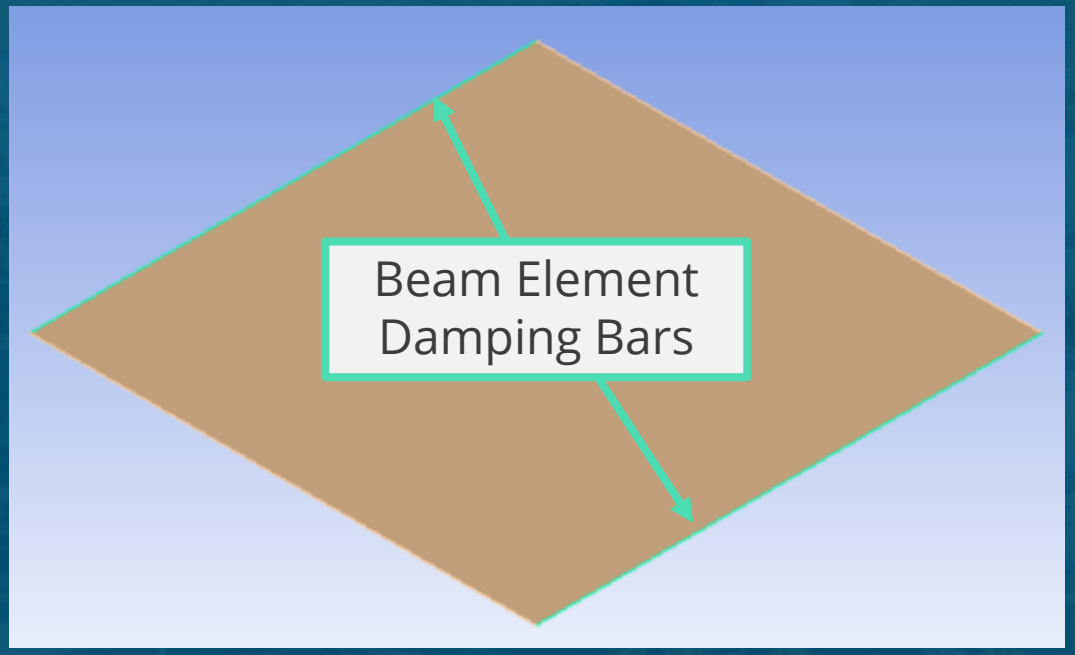
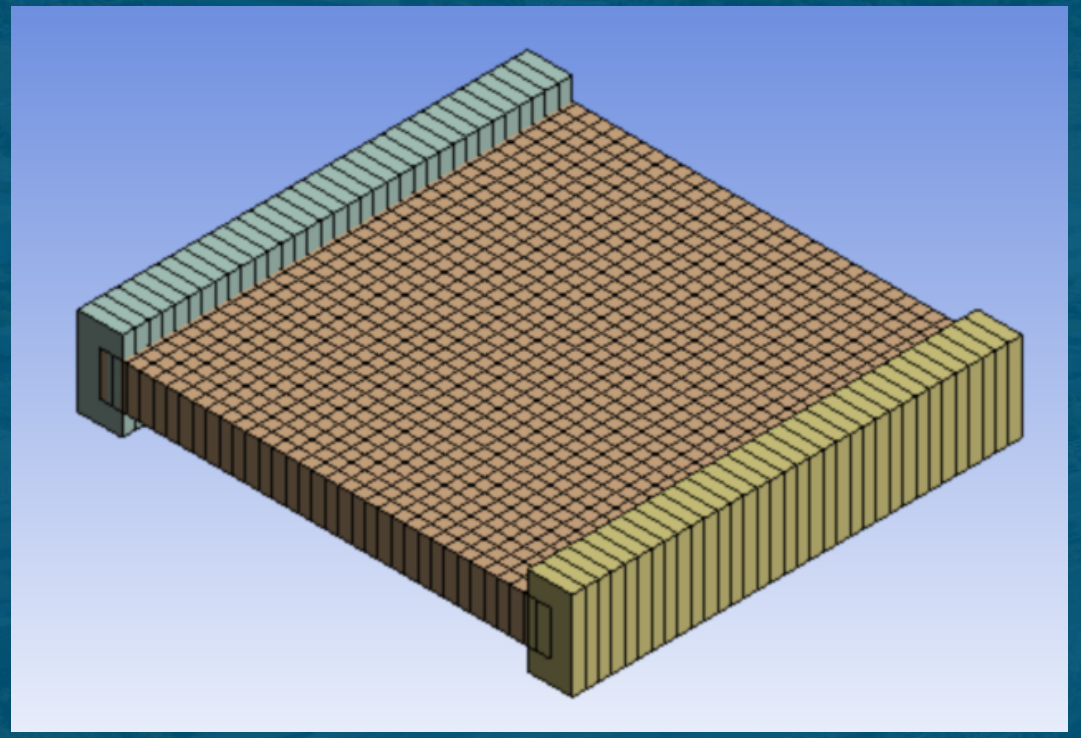
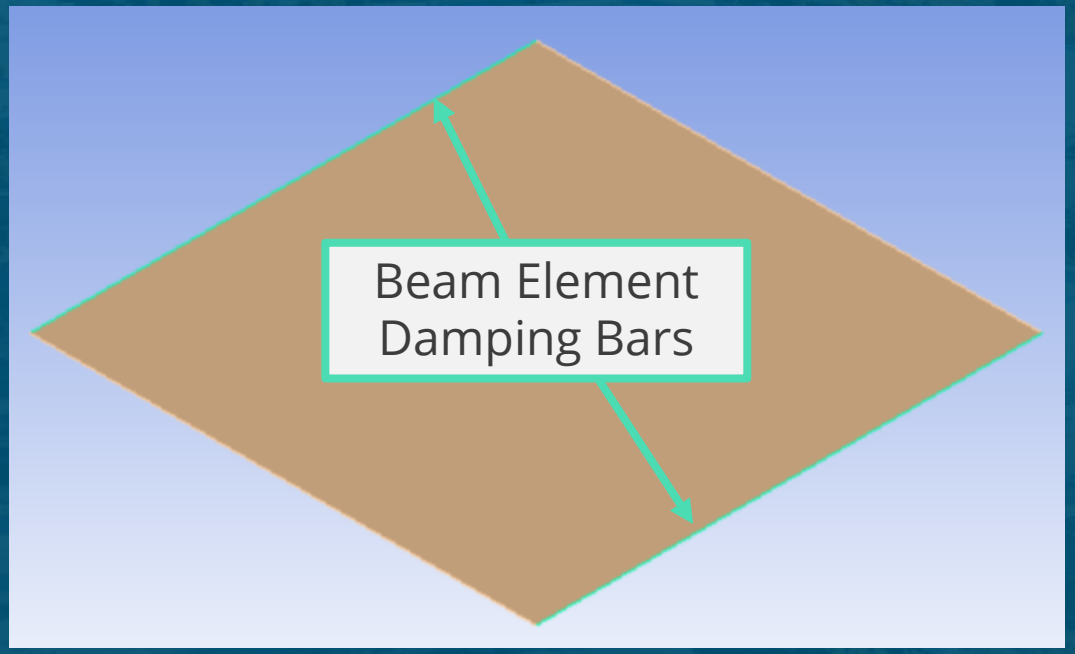


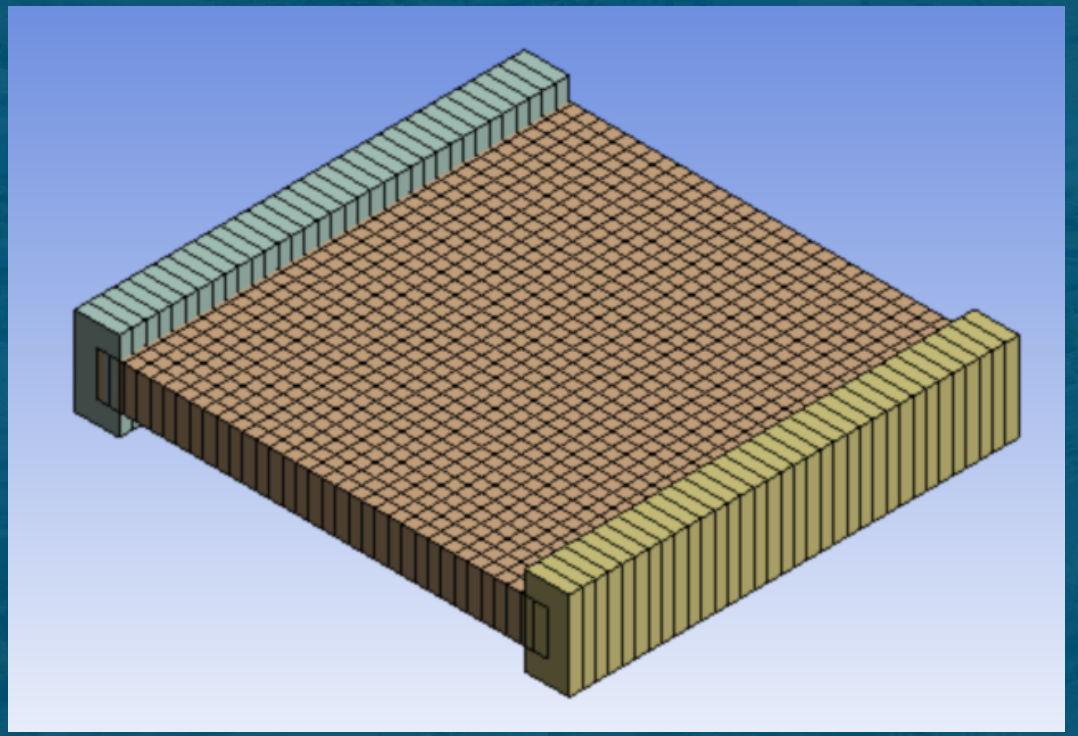


Adding Damping Bars to the Model

Approach #1: Model bars as beams, bonded to edges of the plate

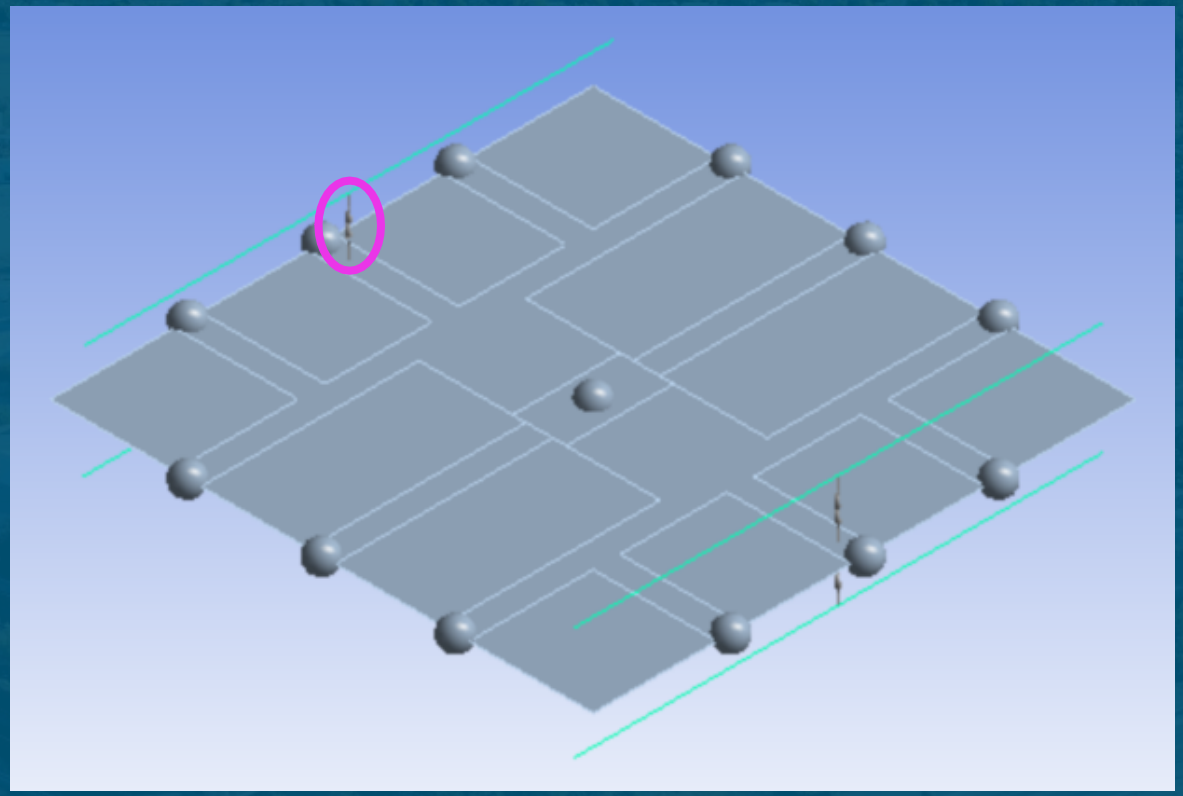
- Results: Connection too stiff, unrealistic behavior





Adding Damping Bars to the Model

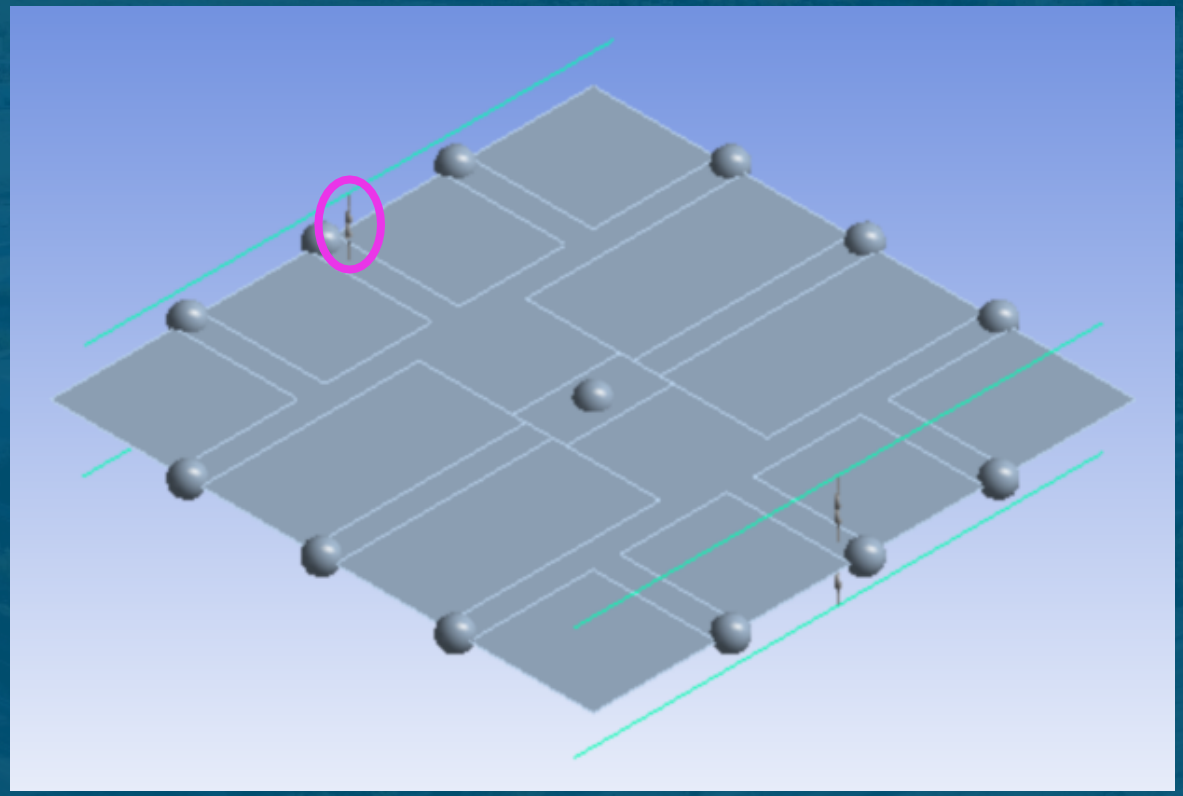
Approach #2: Model bars as beams, attach with one spring each



Adding Damping Bars to the Model

Approach #2: Model bars as beams, attach with one spring each

- Results: Not enough constraint, beams movement not closely tied to plate



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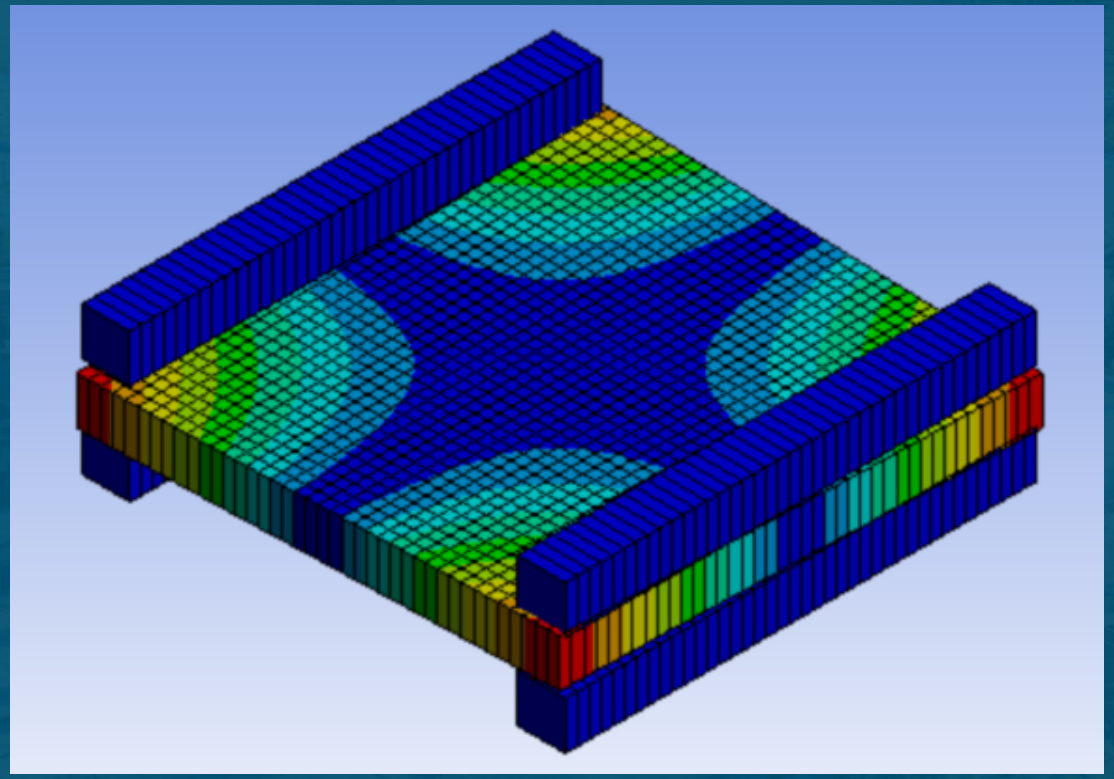
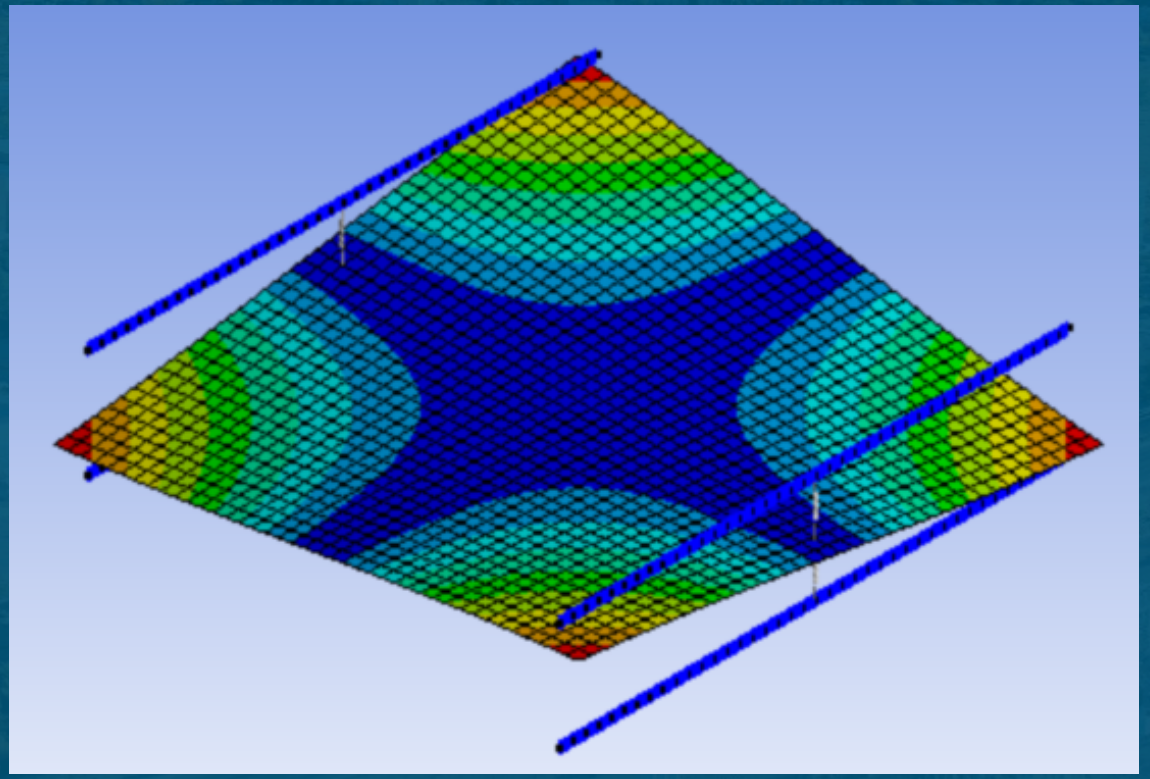


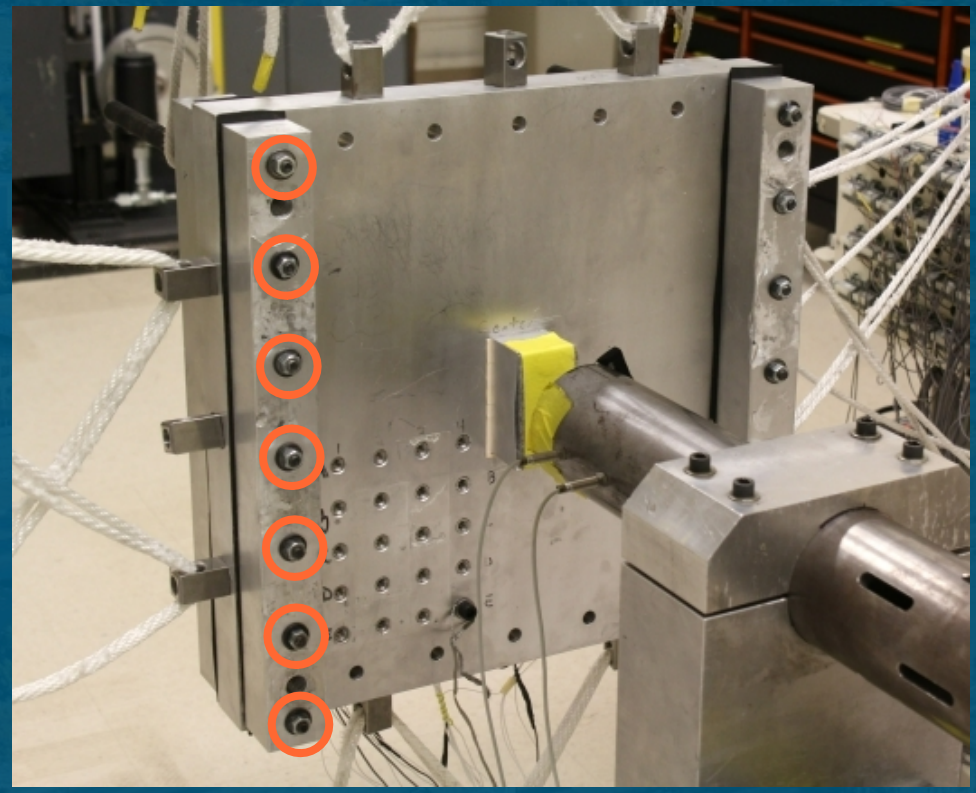


Adding Damping Bars to the Model

Approach #2: Model bars as beams, attach with one spring each

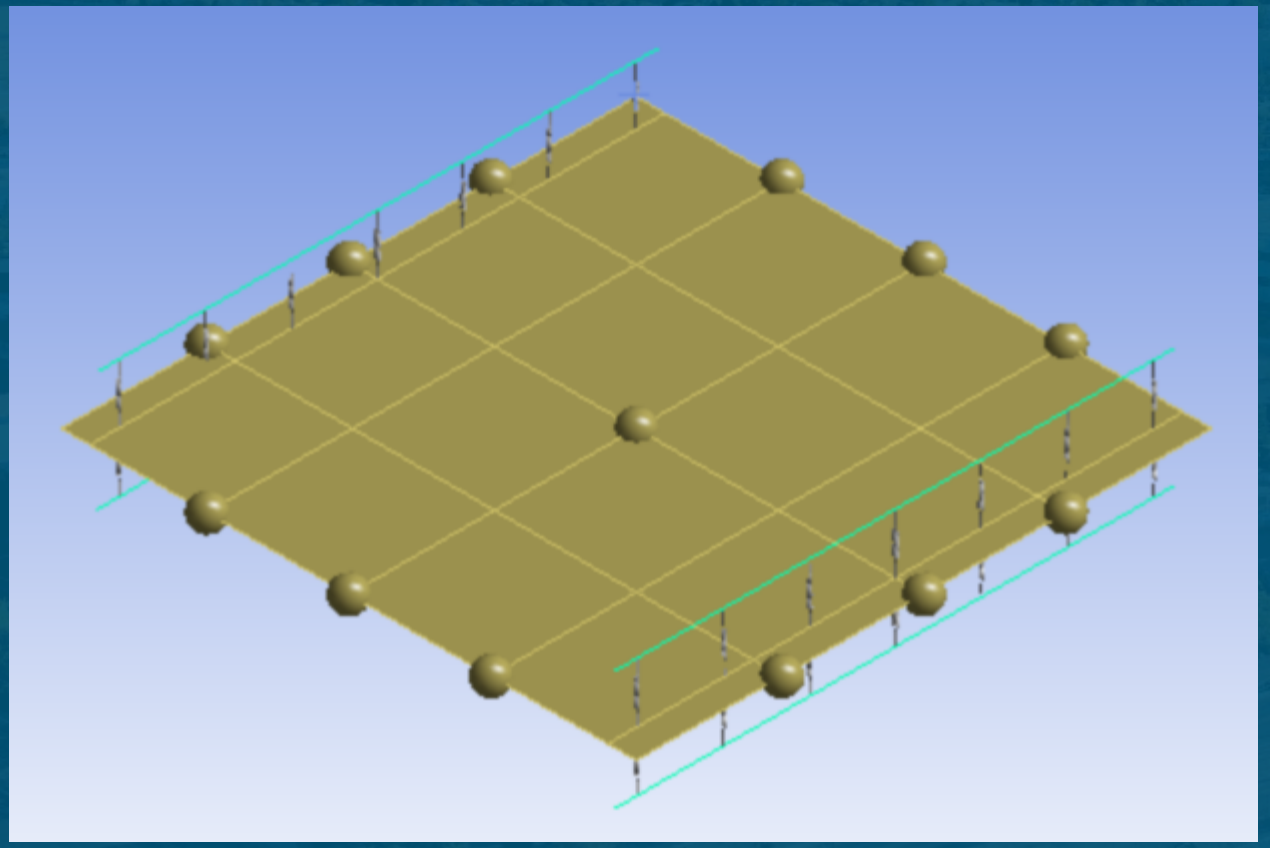
- Results: Not enough constraint, beams movement not closely tied to plate

Seven bolts connect the bars to the plate



Adding Damping Bars to the Model

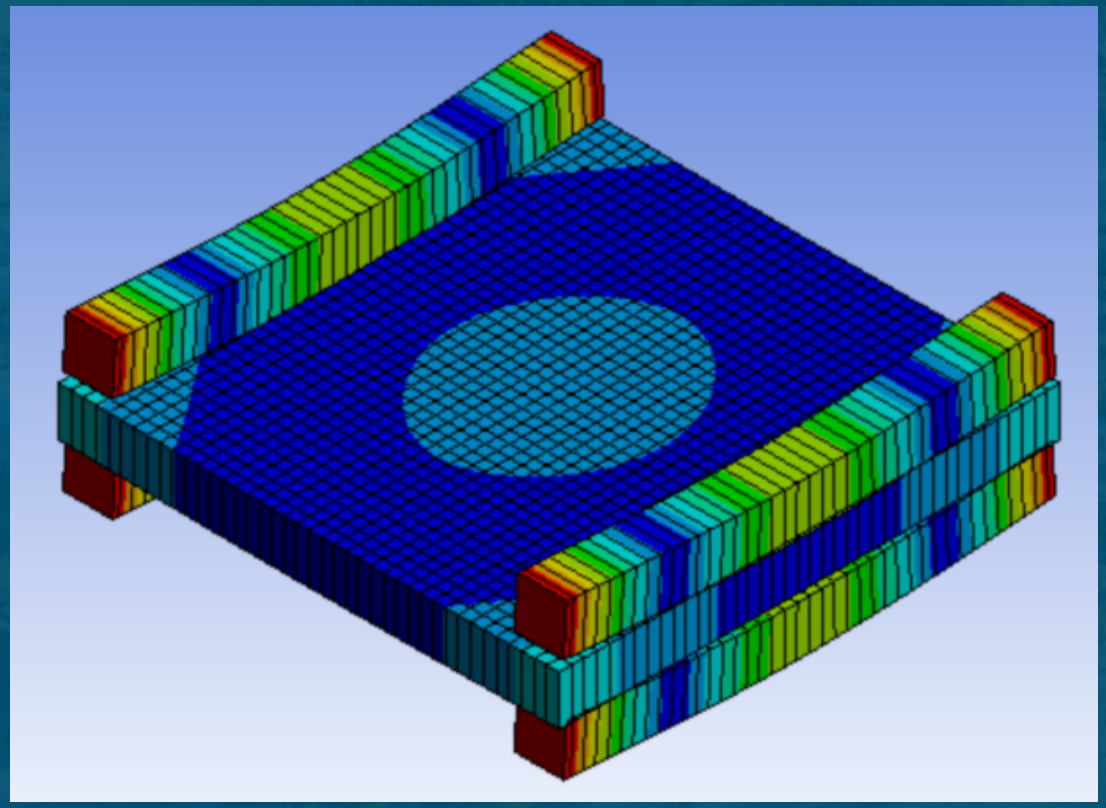
Approach #3: Model bars as beams, attach with 7 springs each



Adding Damping Bars to the Model

Approach #3: Model bars as beams, attach with 7 springs each

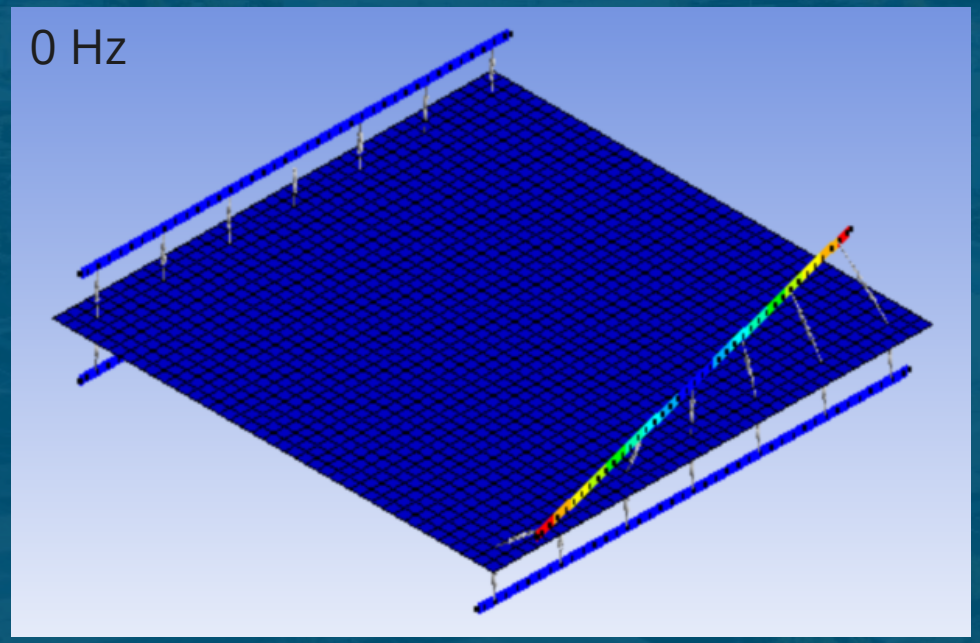
- Results: Better movement of bars with plate, still not enough constraint

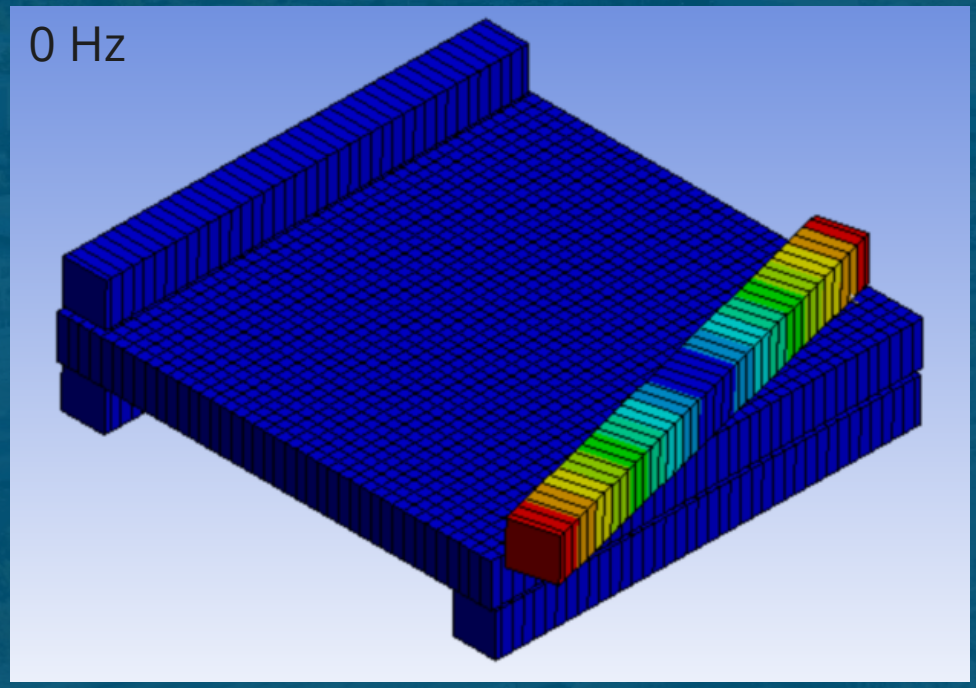


Adding Damping Bars to the Model

Approach #3: Model bars as beams, attach with 7 springs each

- Results: Better movement of bars with plate, still not enough constraint
- Problems: Only longitudinal stiffness (1 direction only)



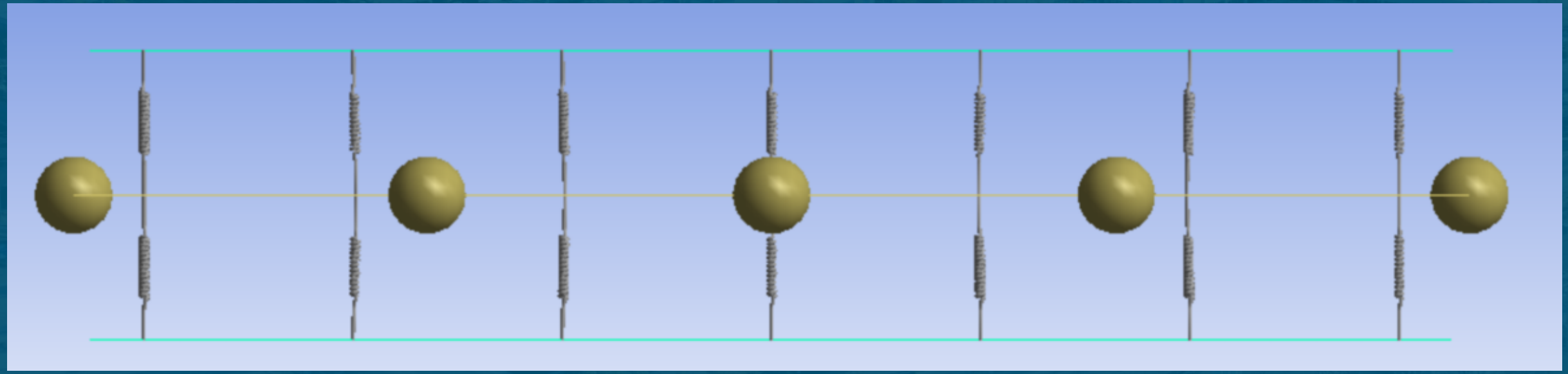


Adding Damping Bars to the Model

Approach #3: Model bars as beams, attach with 7 springs each

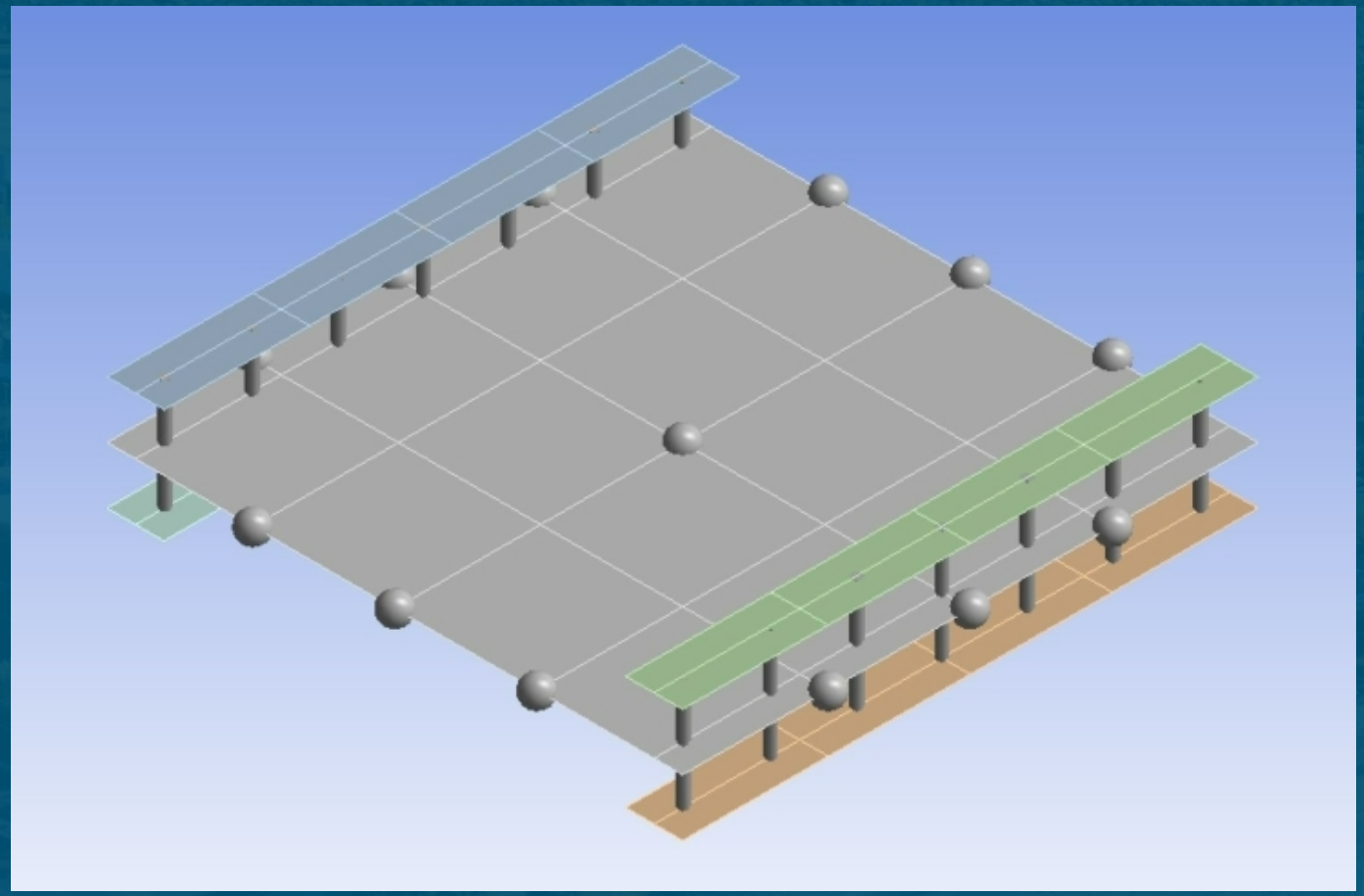
- Results: Better movement of bars with plate, still not enough constraint
- Problems: Only longitudinal stiffness

  Difficult to specify node locations on beam elements



Adding Damping Bars to the Model

Approach #4: Model bars as plates, attach with 7 beams each



Adding Damping Bars to the Model

Approach #4: Model bars as plates, attach with 7 beams each

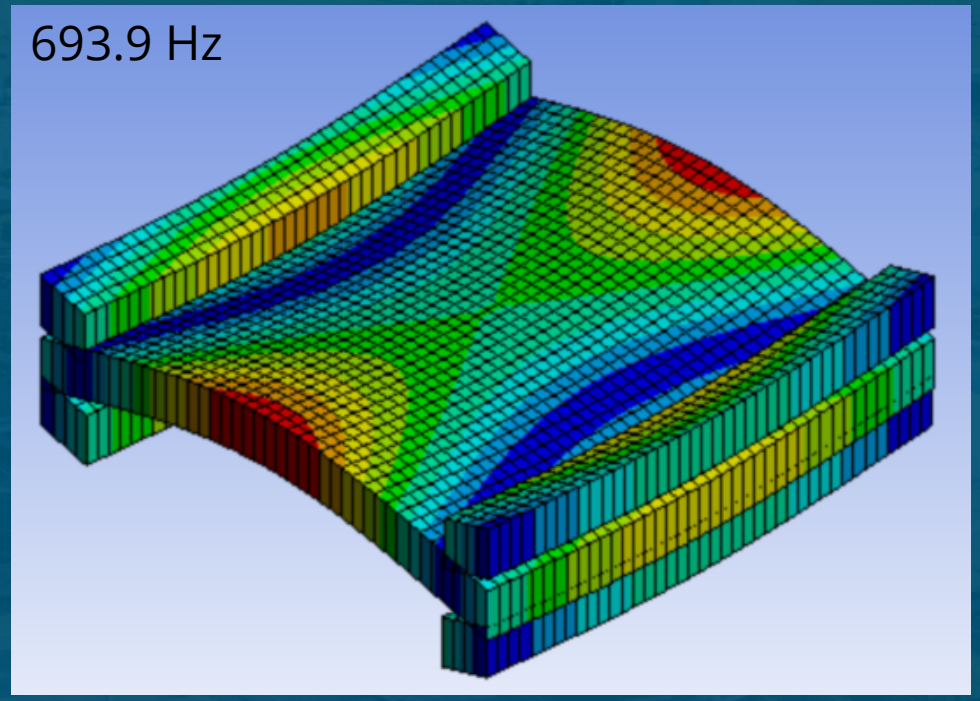
- Results: Matched well with test data, except one mode

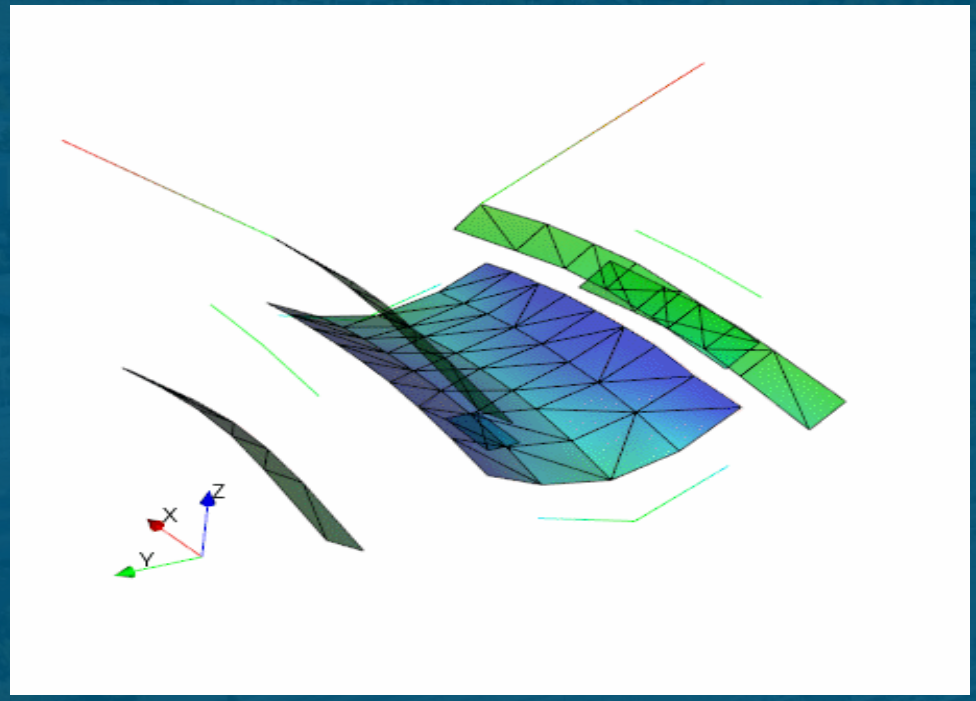
Model Frequency (Hz)	Test Frequency (Hz)	% Difference
388.3	390.8	0.6%
693.9	582	19.2%
985	1001	1.6%
1222	1288	5.1%
1926	2087	7.7%
2144	2216	3.2%
2293	2345	2.2%
2452	2397	2.3%

Adding Damping Bars to the Model

Approach #4: Model bars as plates, attach with 7 beams each

- Results: Matched well with test data, except one mode

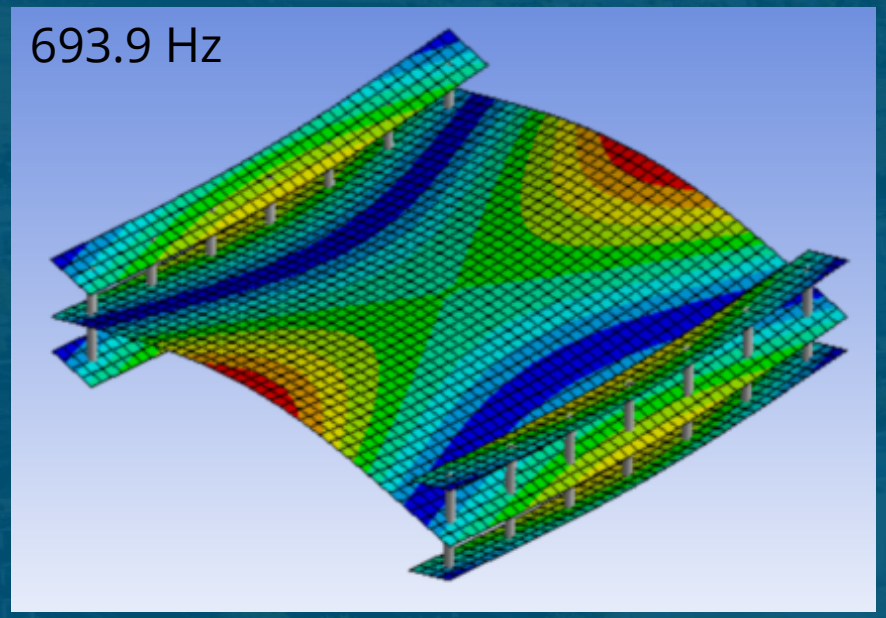


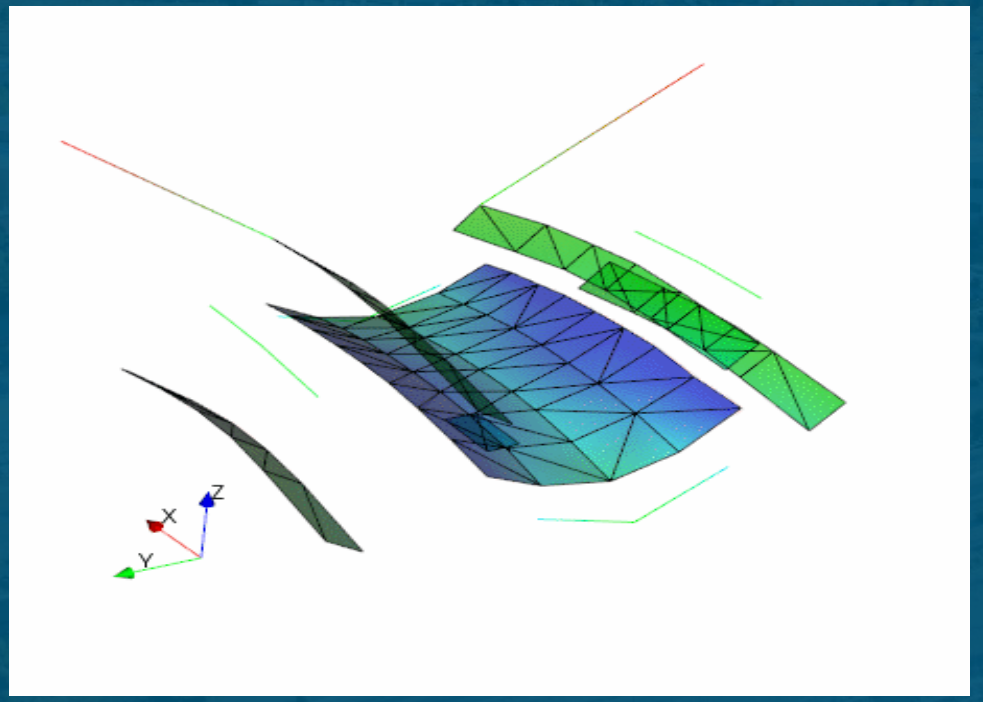


Adding Damping Bars to the Model

Approach #4: Model bars as plates, attach with 7 beams each

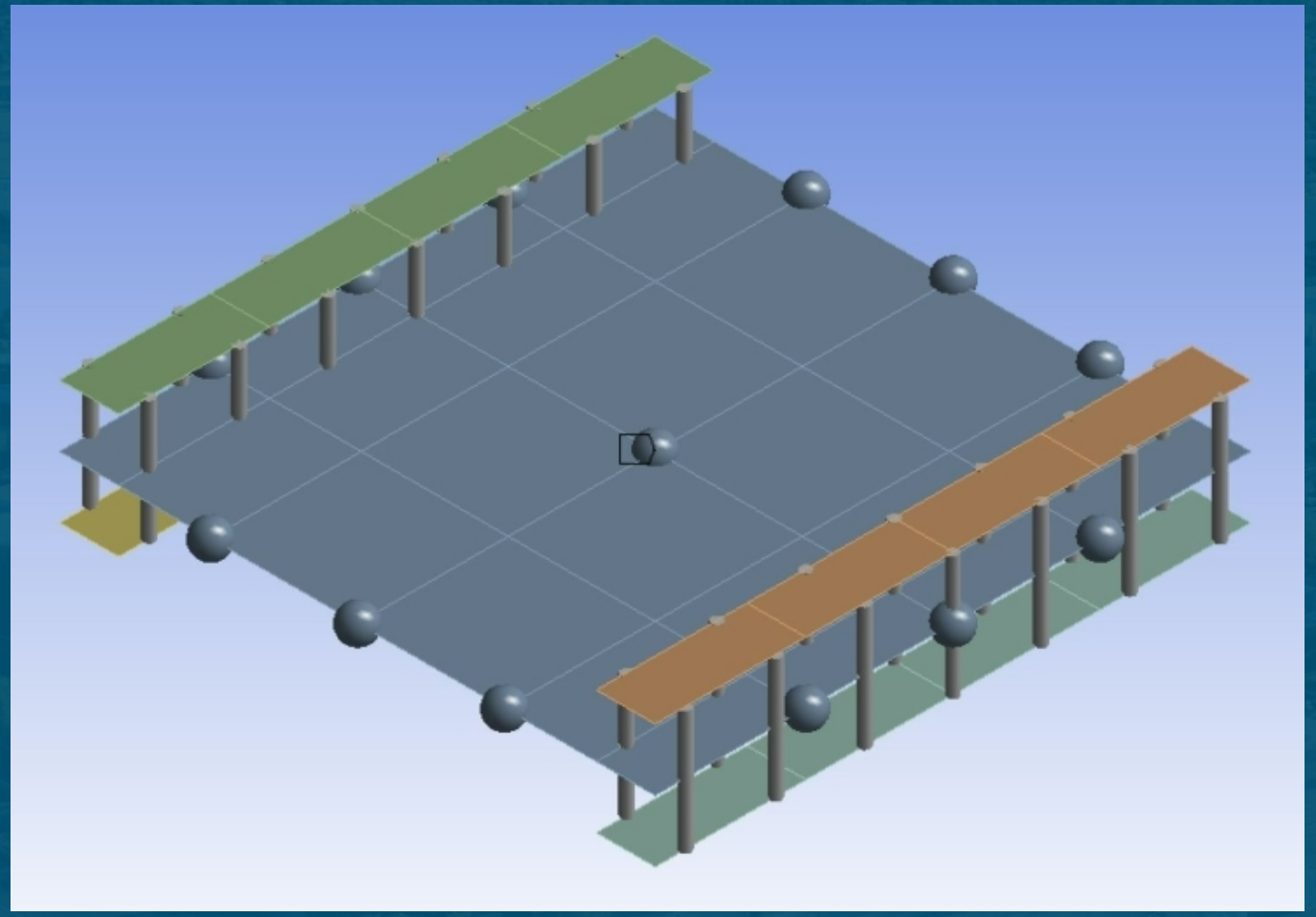
- Results: Matched well with test data, except one mode – out of phase



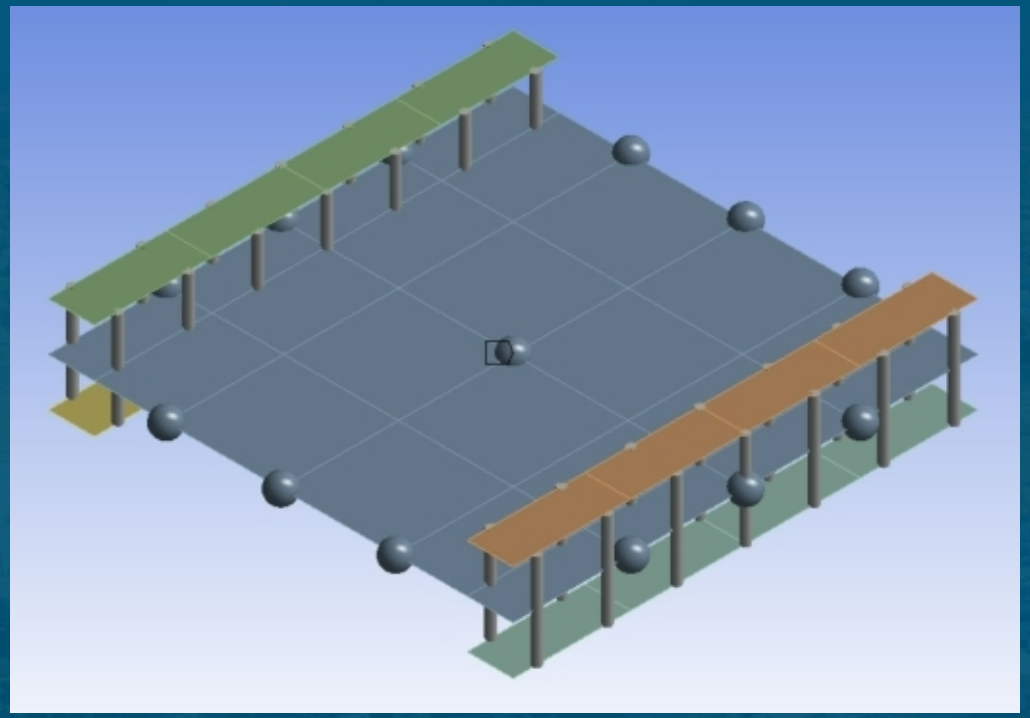


Adding Damping Bars to the Model

Approach #5: Model bars as plates with 2 rows of 7 beams each



Final Model of Plate with Damping Bars



Model Frequencies (Hz)	Test Frequencies (Hz)	% Difference	MAC Value
403.7	390.8	3.31	0.998
575.3	582.0	1.16	0.991
921.0	-------	-------	-------
1008.7	1001.5	0.72	0.900
1224.8	-------	-------	-------
1241.9	1288.0	3.58	0.991
2026.6	2087.2	2.90	0.901
2149.9	2215.5	2.96	0.910
2377.6	2345.0	1.39	0.951
2452.5	2397.4	2.30	0.983
2771.3	2799.5	1.01	0.873

Evolution of Model for Plate with Damping Bars

Approach #1

~~Bars are beams, bonded to edges of the plate~~

Approach #2

~~Bars are beams, attached with one spring each~~

Approach #3

~~Bars are beams, attached with 7 springs each~~

Approach #4

~~Bars are plates, attached with 7 beams each~~

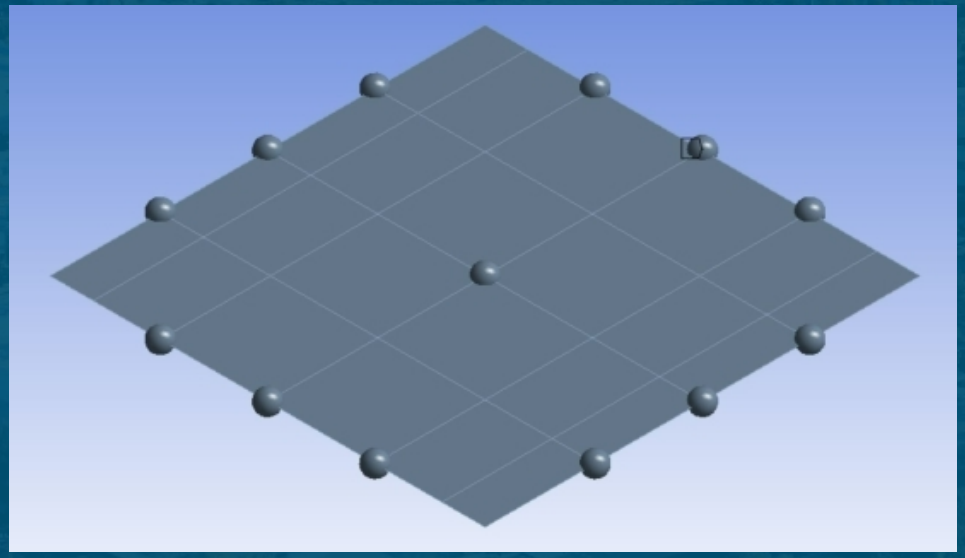
Approach #5

Bars are plates, attached with 2 rows of 7 beams each

Conclusions

Modeling the Bare Plate

- Small masses cannot be ignored
  - Considerable impact on modal frequencies - especially with large displacements



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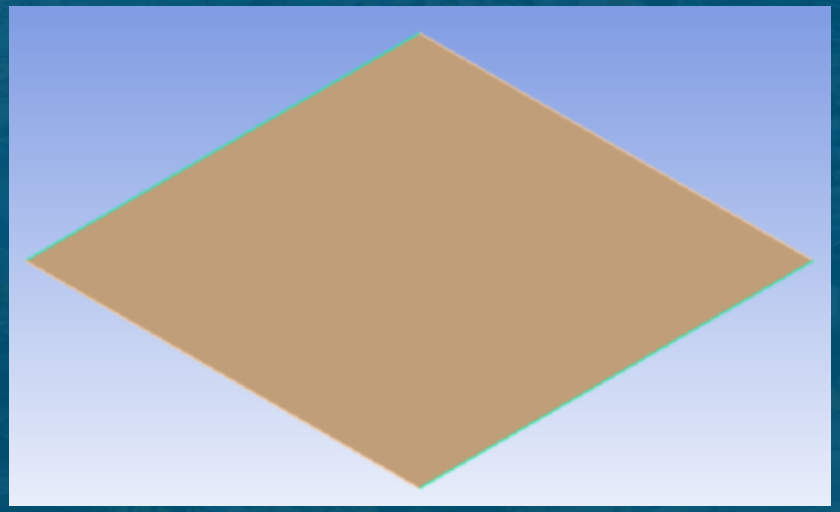
Adding the Damping Bars

- Simple bonded contact is too stiff
  - There needs to be relative displacement between the bars and plate



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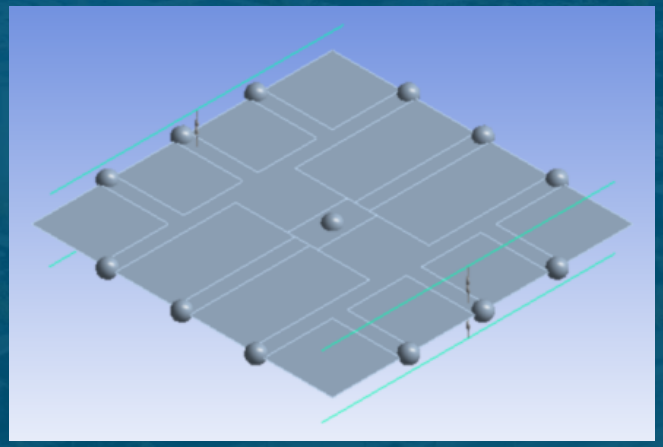
- One spring did not provide enough contact points
  - The damping bars are bolted to the plate at seven points – model must reflect that



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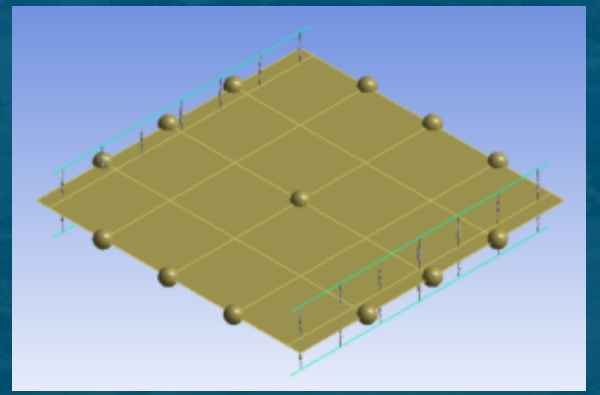
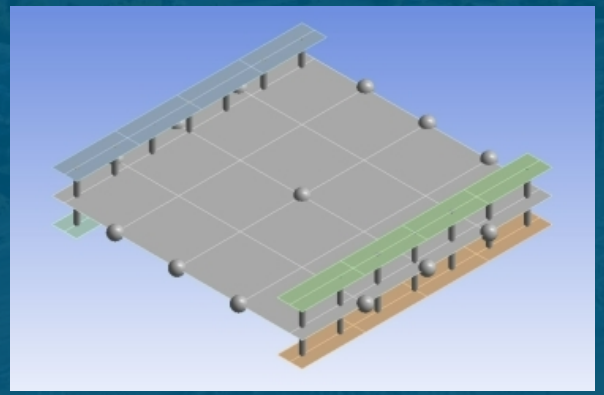
- Simple bonded contact is too stiff
  - There needs to be relative displacement between the bars and plate
- One spring did not provide enough contact points
  - The damping bars are bolted to the plate at seven points – model must reflect that
- Need constraint in multiple directions
  - The bars twist and rotate when hit





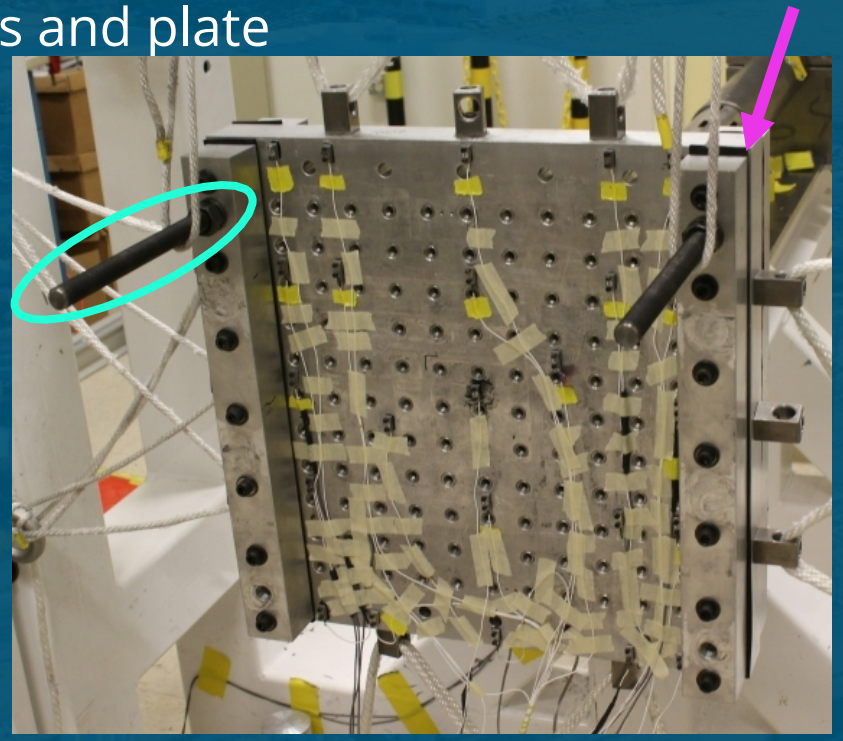
Conclusions

Modeling the Bare Plate

- Small masses cannot be ignored
  - Considerable impact on modal frequencies - especially with large displacements

Adding the Damping Bars

- Simple bonded contact is too stiff
  - There needs to be relative displacement between the bars and plate
- One spring did not provide enough contact points
  - The damping bars are bolted to the plate at seven points
- Need constraint in multiple directions
  - The bars twist and rotate when hit
- Some items were okay to leave out
  - Rods and rubber



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