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Structural Evaluations of Bridges with Smartphones

Garrett P. Martindale
University of Nebraska-Lincoln, g.martindale93@gmail.com

Dean Whitfield
University of Nebraska-Lincoln, deanlwhitfield@gmail.com

Jeremiah Dixon
University of Nebraska-Lincoln, jeremiahddixon@gmail.com

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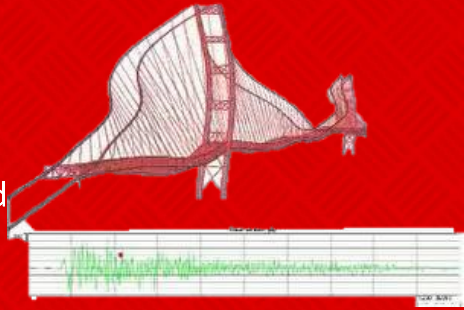
Structural Evaluations of Bridges with Smartphones



Researchers: Garrett Martindale, Jeremiah Dixon & Dean Whitfield
Advisor: Dr. Joshua Steelman

Background

According to the 2013 Report Card for America's Infrastructure, published by the American Society of Civil Engineers (ASCE), the United States has a bridge rating of C+. The C rating is classified by ASCE as a mediocre standing. Infrastructure that is awarded the C rating shows general signs of deterioration and requires attention.

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Example: 1940 Tacoma Narrows Bridge Collapse

YouTube Video

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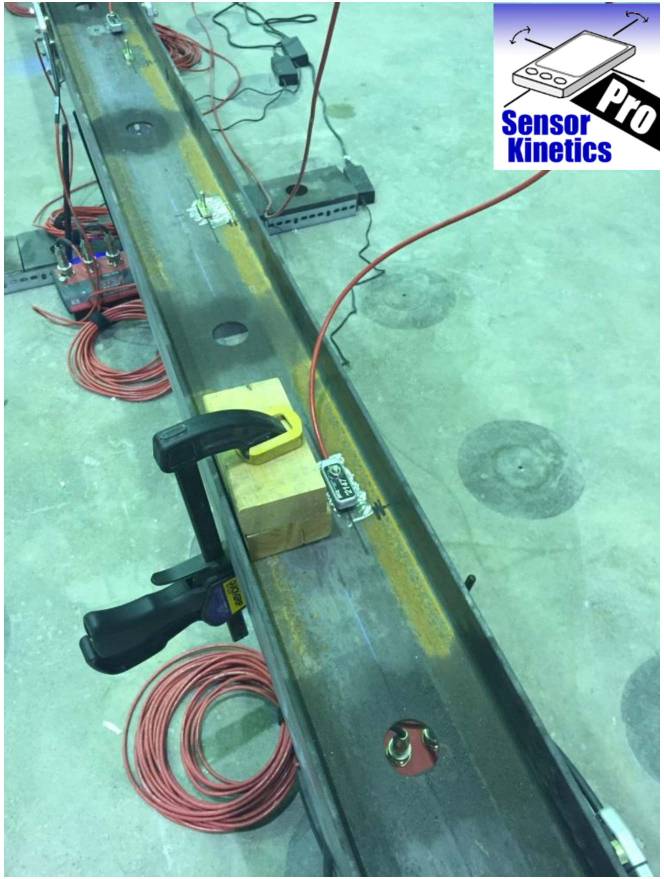
Our Hypothesis

Smartphones have become readily available to anyone and is a relatively cheap device. They have instruments within them that can capture and collect usable data. An application can be downloaded to record the smartphone's acceleration. The acceleration data can be used to evaluate vibrations within structures. Smartphones could ultimately be used to obtain a quick and efficient estimate of the structural behavior of a bridge.



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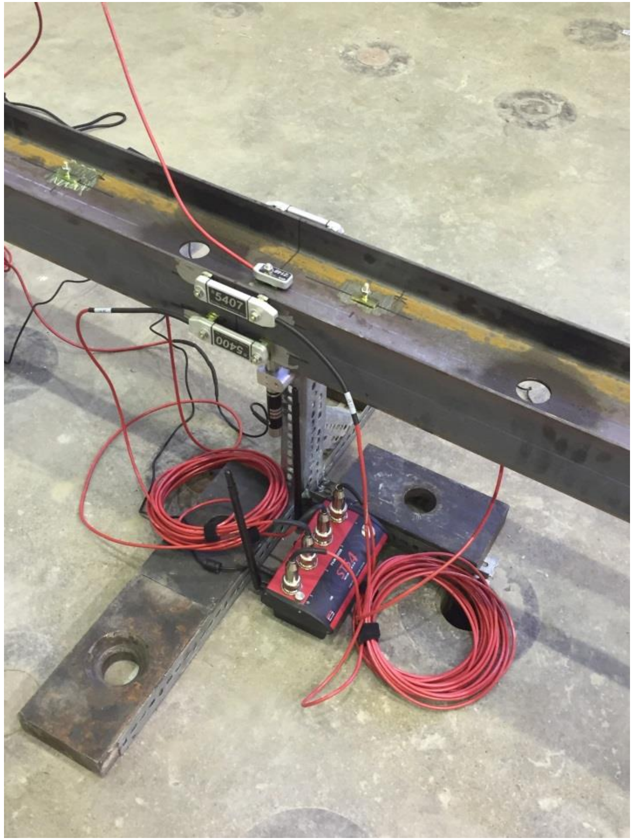
Structural Dynamics

Our analysis used concepts from structural dynamics that mainly focused on the free vibration of a structure. The natural frequency of a structure is directly proportional to its stiffness and inversely proportional to its mass. The lower the natural frequency, the easier it is to record it. Therefore, we determined that a W6x9 beam with a clear span of 22.5’ bending about it weak (Y-Y) axis would produce natural frequencies that would be recordable in the lab.



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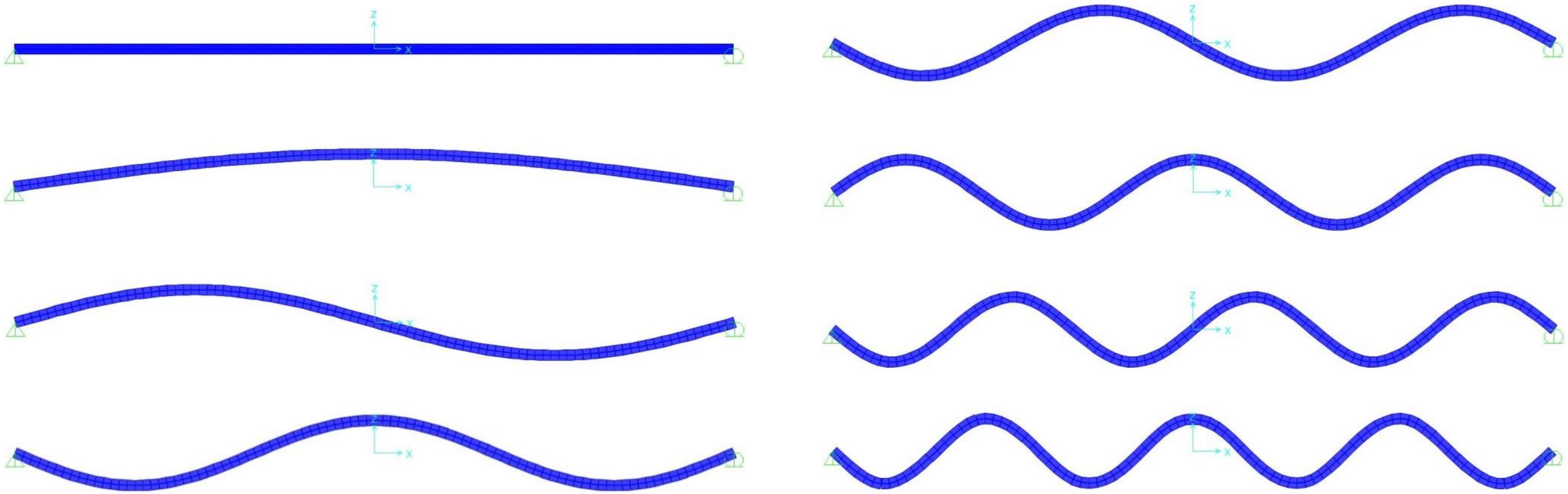
Modal Analysis



A structure can vibrate in different mode shapes.
Higher modes have higher frequencies.

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Matlab

A Matlab code was developed to compute theoretical natural frequency values.

Matlab: 22.5 ft W6x9 Weak Axis ($I = 2.2\ in^4$)				
Weight (lb/ft)	**f_1 (Hertz)**	**f_2 (Hertz)**	**f_3 (Hertz)**	**f_4 (Hertz)**
9	3.906	15.624	35.135	62.350
59	1.526	6.102	13.723	24.352
109	1.123	4.490	10.096	17.916
159	0.929	3.717	8.359	14.834
209	0.811	3.242	7.291	12.938

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SAP2000

A structural analysis model was generated in SAP2000 to obtain natural frequencies of a structure.

SAP2000: 22.5 ft W6x9 Weak Axis ($I = 2.2\ in^4$)				
Weight (lb/ft)	**f_1 (Hertz)**	**f_2 (Hertz)**	**f_3 (Hertz)**	**f_4 (Hertz)**
9	3.878	15.500	34.821	61.757
59	1.523	6.088	13.675	24.255
109	1.121	4.481	10.066	17.853
159	0.928	3.711	8.336	14.785
209	0.810	3.237	7.272	12.897

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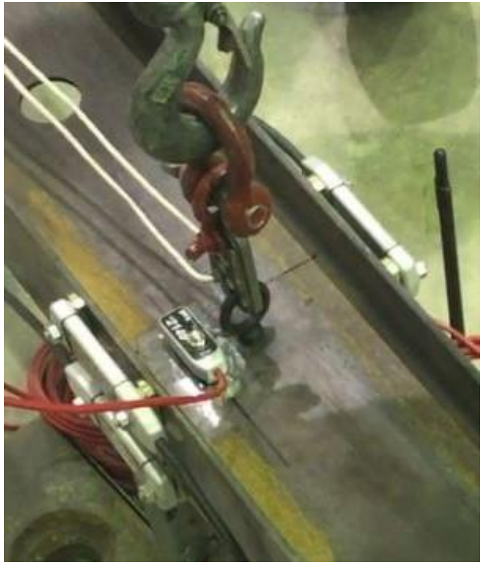
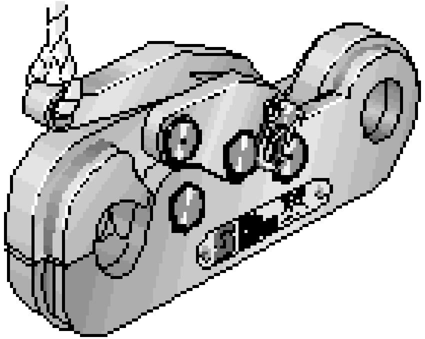
Method of Testing

A quick release mechanism was required to instantaneously release the force from the beam to excite it into free vibration.





Sea Catch Models

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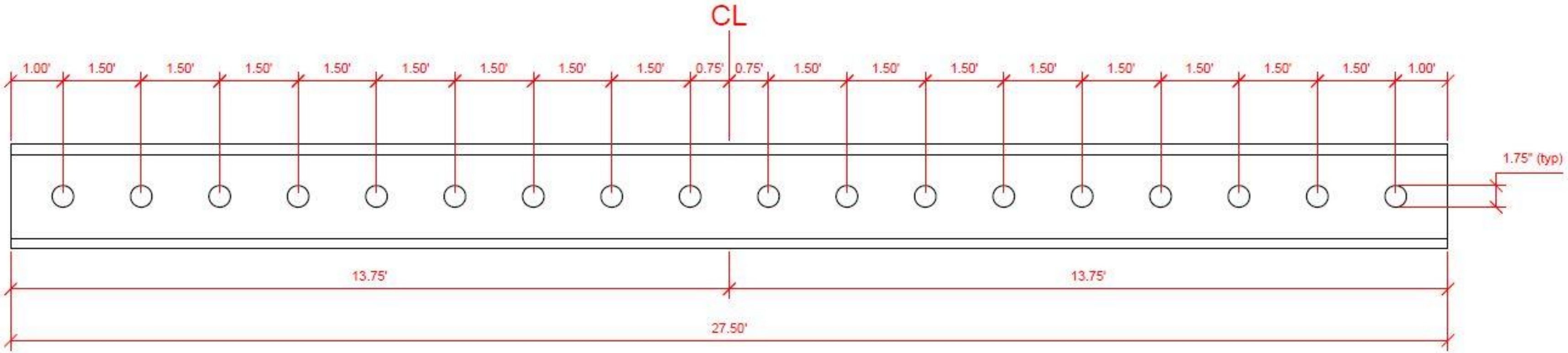
Structural Testing Element

W6X9 27.5 ft long beam



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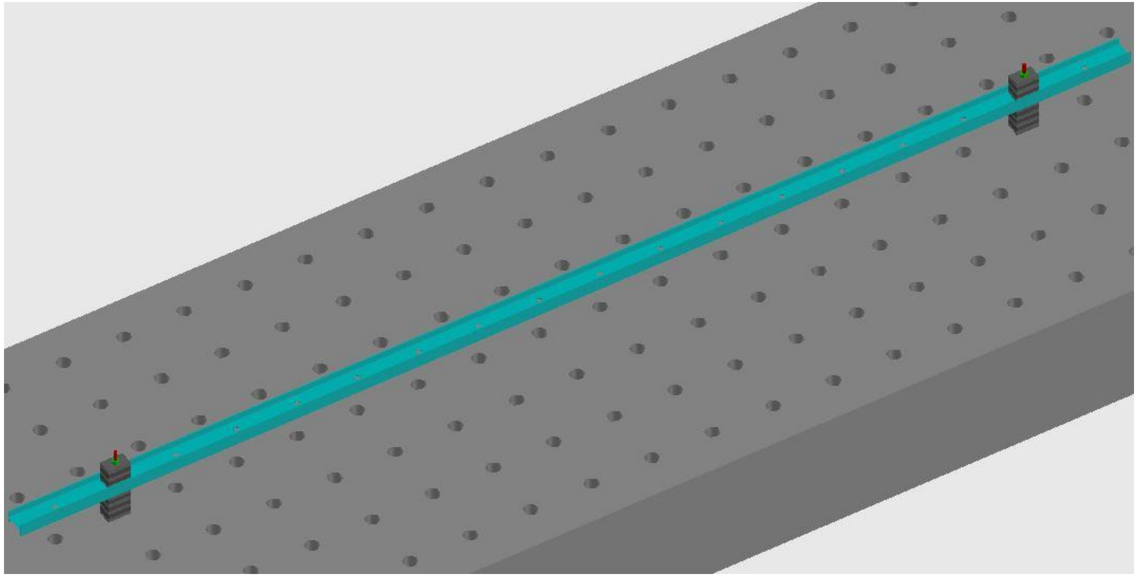
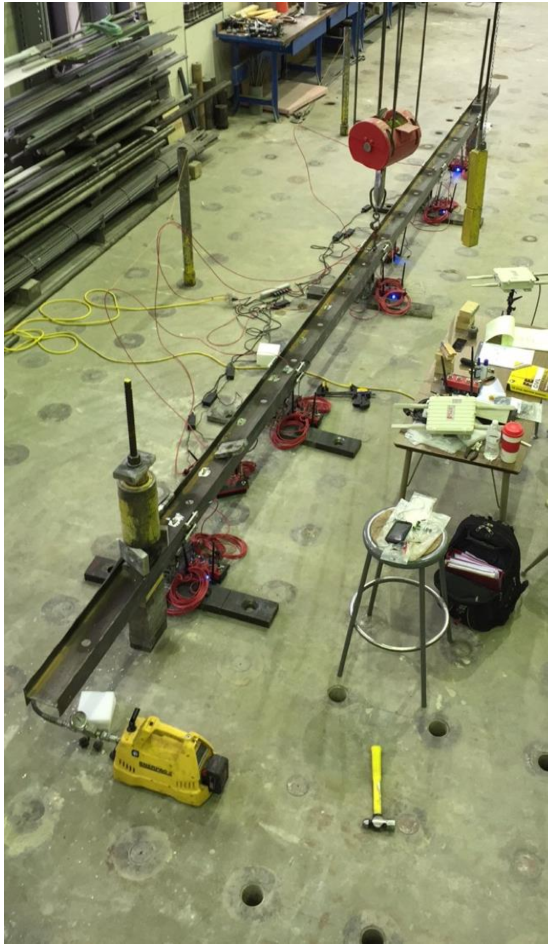
Test Layout





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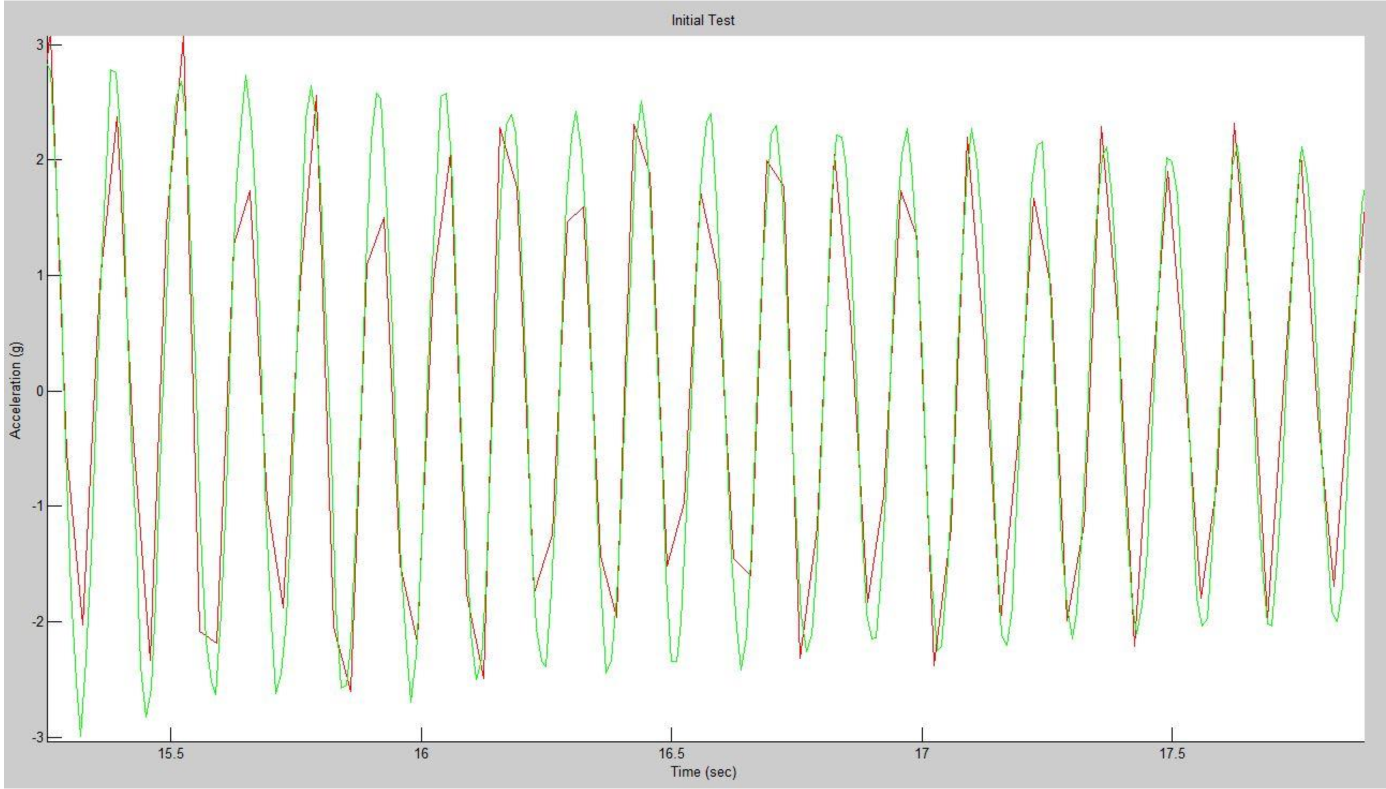
Initial Trial ~7.75 Hz

Comparison



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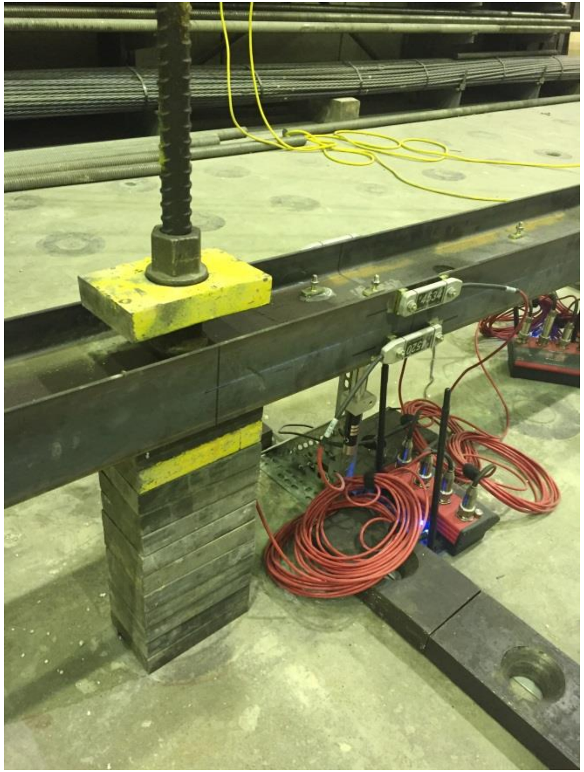
Alterations

After comparing the frequencies collected from the sensors to the our calculated values, we determined that we had more of a fixed-end than a pinned-end support.

We decided to redesign the beam supports. The new supports comprise of two metal spheres that allow for a smaller contact point with the beam which created more of a pinned-end connection.



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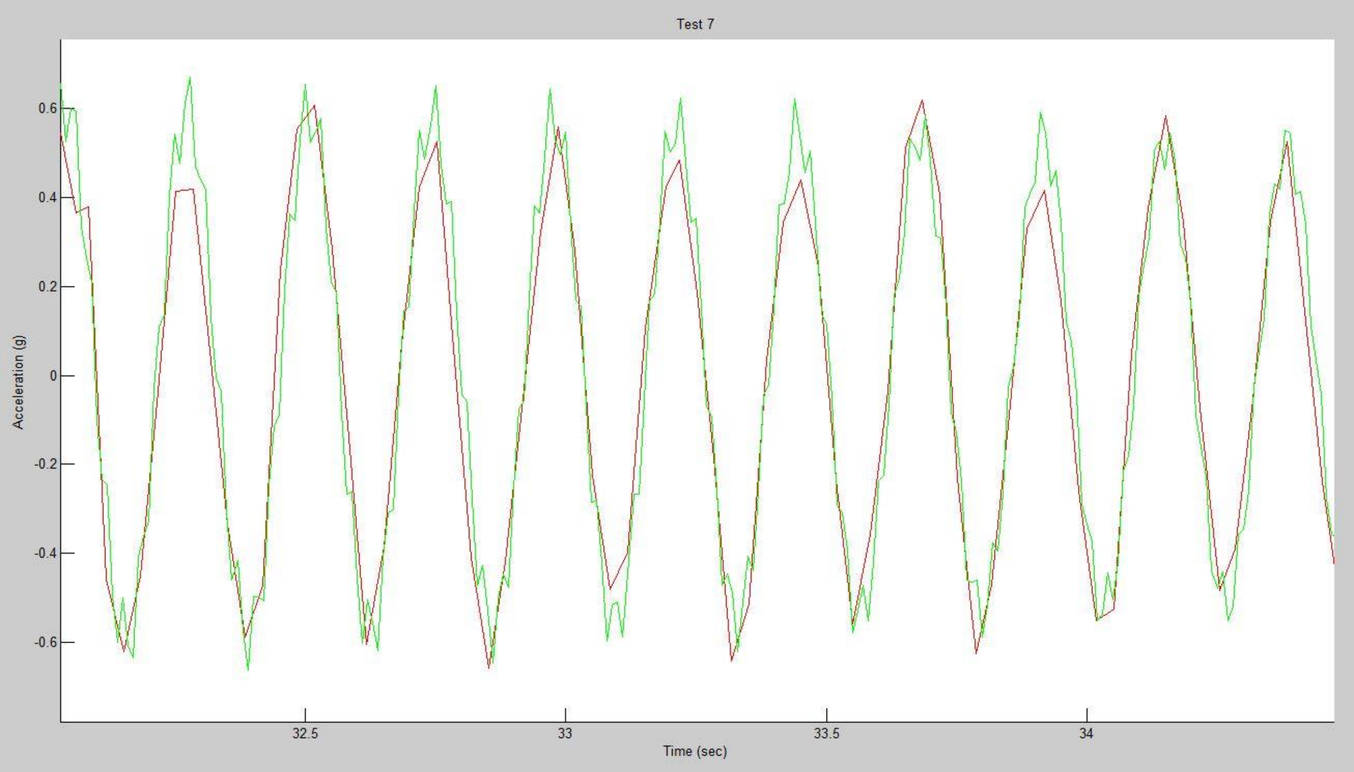
Final Trial ~4.5 Hz

Comparison



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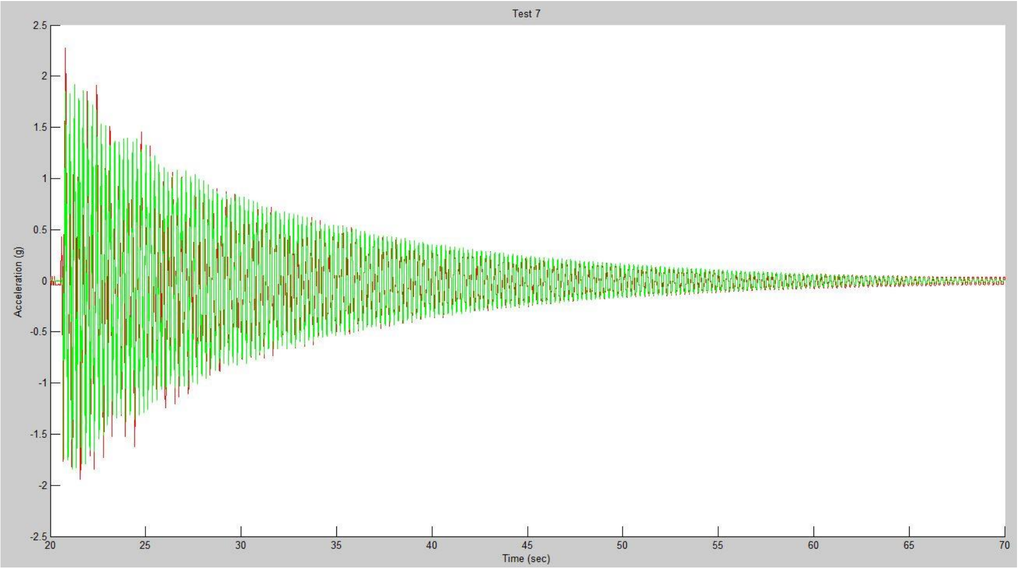
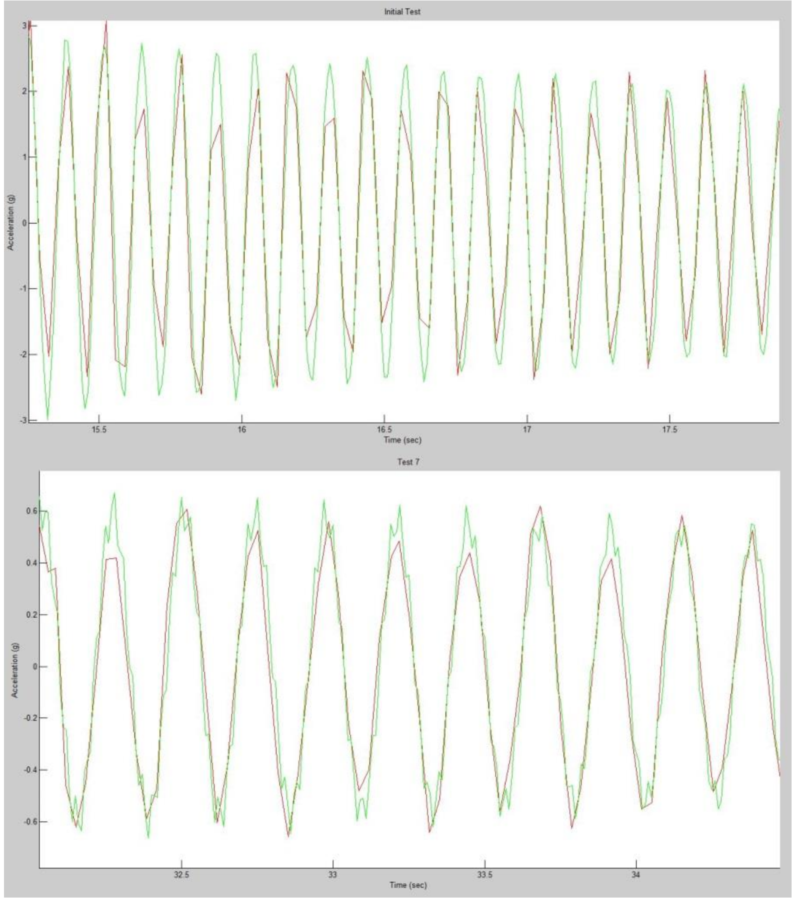
Results





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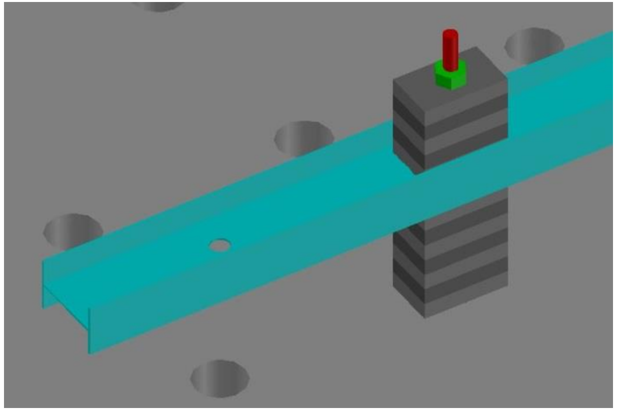
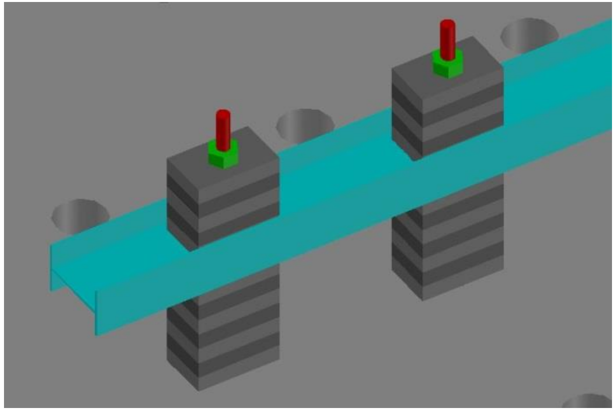
Comparisons



Pinned Ends



Fixed Ends

Initial Trial

Final Trial

SAP2000: 22.5 ft W6x9 Weak Axis (I = 2.2 in^4)				
Weight (lb/ft)	**f_1 (Hertz)**	**f_2 (Hertz)**	**f_3 (Hertz)**	**f_4 (Hertz)**
9	3.88	15.50	34.82	61.76
59	1.52	6.09	13.68	24.26
109	1.12	4.48	10.07	17.85
159	0.93	3.71	8.34	14.78
209	0.81	3.24	7.27	12.90

SAP2000: 22.5 ft W6x9 Weak Axis (I = 2.2 in^4)				
Weight (lb/ft)	**f_1 (Hertz)**	**f_2 (Hertz)**	**f_3 (Hertz)**	**f_4 (Hertz)**
9	8.78	24.17	47.26	77.85
59	3.45	9.49	18.56	30.57
109	2.54	6.99	13.66	22.50
159	2.10	5.79	11.31	18.64
209	1.83	5.05	9.87	16.26

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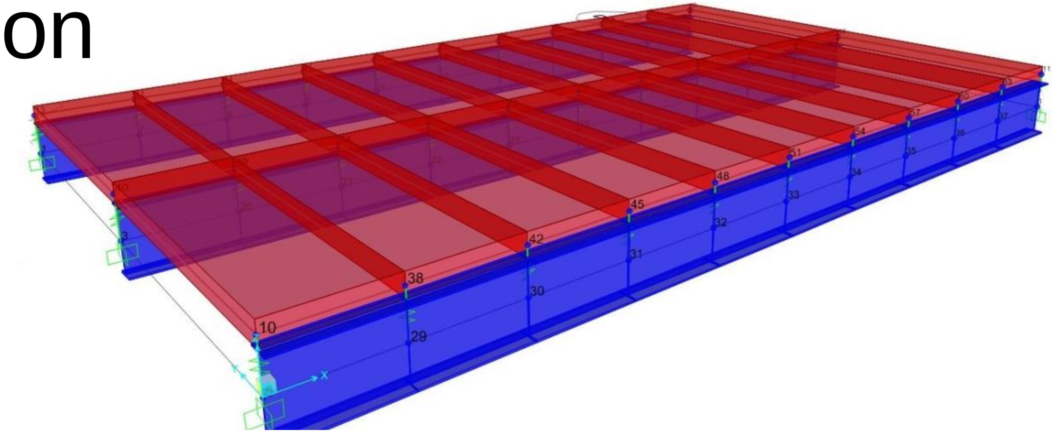
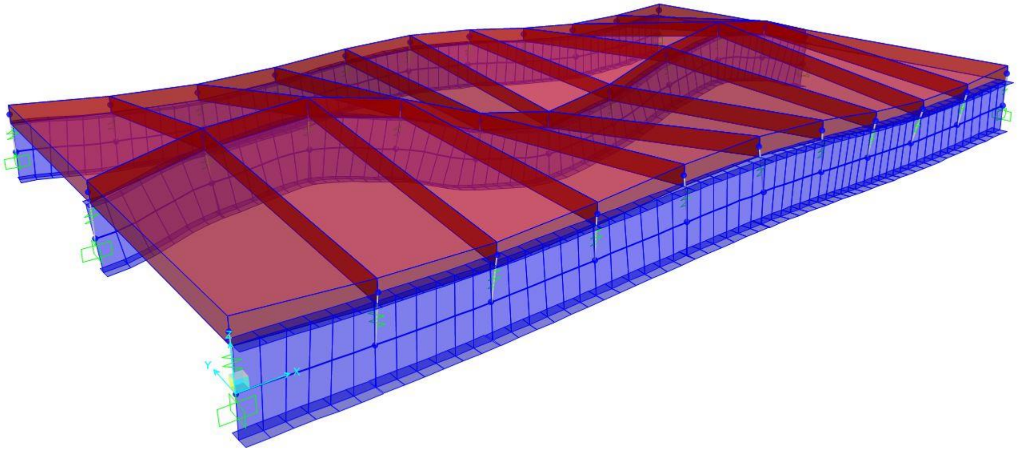
Finalized Conclusion

Compared to certified BDI sensors, a smartphone accelerometer delivers comparative results that share around a 90% relationship. We predict that smartphone will play a big role in future bridge analysis and inspections.





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