Bridge Scour Detection of the Feather River Bridge in Yuba City, CA through the Use of Finite Element Modeling and Infrasound

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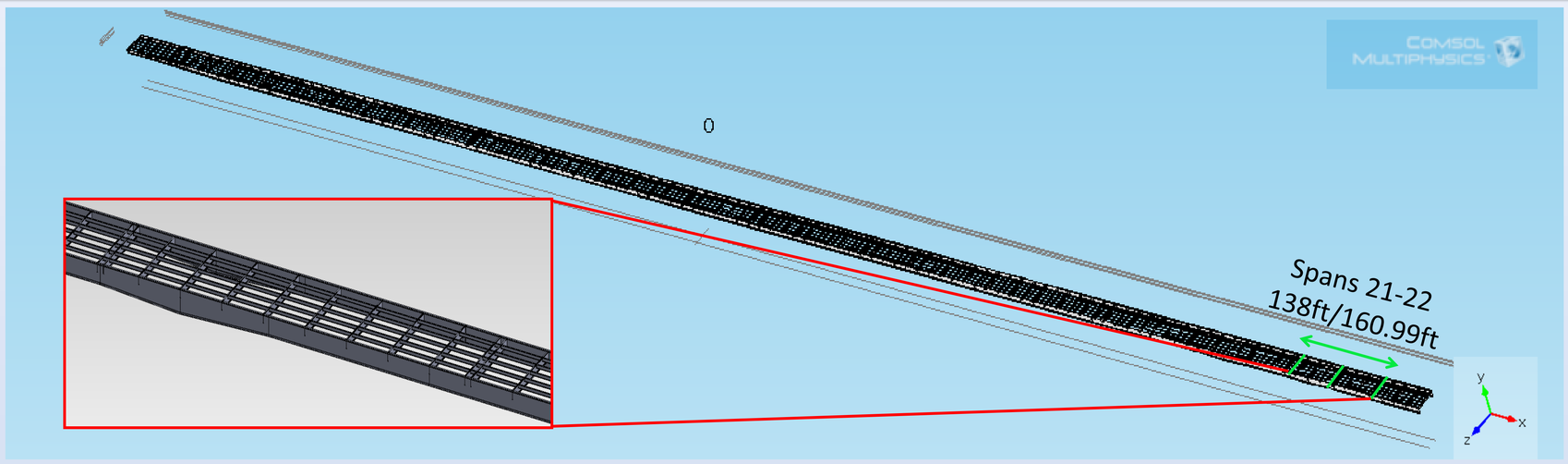
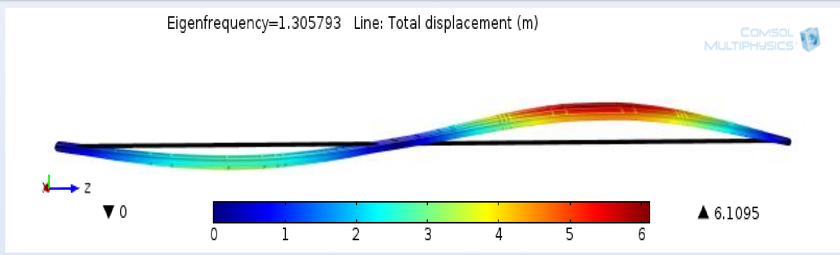
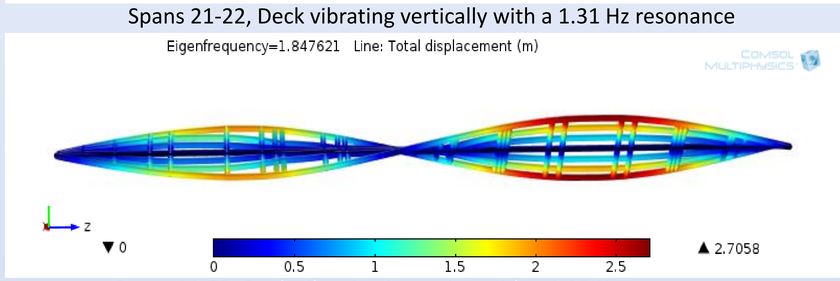


Feather River Bridge , 24 span multi-girder bridge model, imported from SolidWorks



Spans 21-22, Deck vibrating vertically with a 1.31 Hz resonance



Spans 21-22, Deck vibrating in torsion with a 1.85 Hz resonance

Introduction

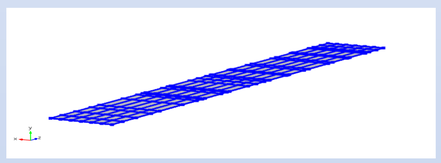
Ongoing studies by the US Army Engineer Research and Development Center are investigating infrasound, low-frequency acoustics, as a means of scour detection and assessment at bridge piers. Scour at bridge piers and abutments is a commonly encountered issue for both military and civil works structures. Current research involves the Feather River Bridge in Yuba City, CA. A recent field deployment will allow characterization of scour on a known scour-critical structure with validation from a comparison of infrasound data, numerical modeling, and previously conducted on-site inspections.

A Finite Element model has been developed for the multi girder bridge located in Yuba City, CA. The model was constructed using 3-D Euler beam elements representing the superstructure members. This model is being used to investigate the frequency of the bridge's main spans 21-22 out of the 24 total spans. These two spans were the main focus for the COMSOL model due to maximum span length and scoured pier location.

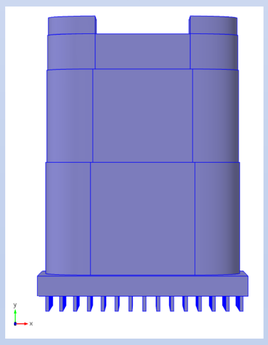
Multi-girder Bridge (Feather River Bridge) in Yuba City, CA

A second finite element has been partially developed for the model scoured pier. Initially, the model consist of the original drawings of the bridge pier without the retrofit and is fixed at the bottom of the pier. Modifications will be made in the future to include the updated retrofit and the earth surrounding the base of the pier based on the scour records. Making these few adjustments will affect the natural frequency of the pier.

FEM Feather River Bridge



3-D Euler Beam Multi-girder Bridge model



3-D Model of Pier 22

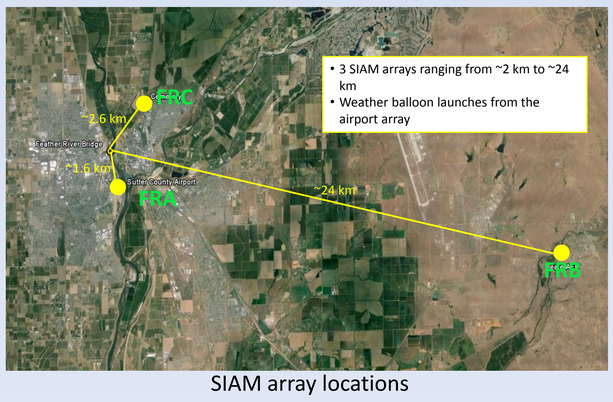
Using COMSOL Multiphysics (4.3a)

- Multi-girder Bridge model
  - 3-D Euler Beam Elements
  - Bridge pinned at each end and also pinned between Span 21 and Span 22
  - 9 in. Shell element deck
  - Steel frame with concrete decking
- Pier Model
  - Solid Mechanics Element
  - Concrete Material
  - Fix at bottom of pier

Infrasound Setup for Feather River Bridge

Seismic-Infrasound-Acoustic-Metrological (SIAM) array set up:

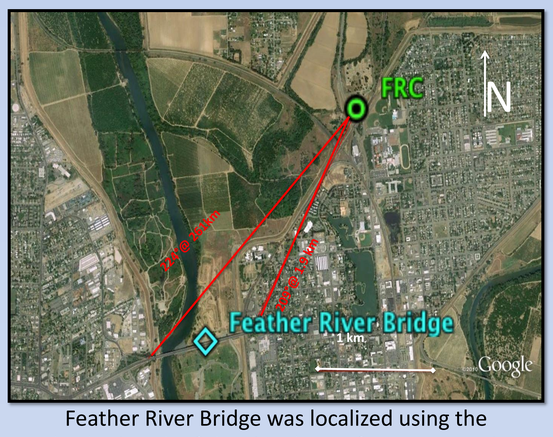
- Three SIAM array's were set up around the bridge.
- The first array was set up 1.6 km South East of the bridge (FRA)
- The second array was set up 24 km South East of the bridge (FRB)
- The third array was set up 2.6 km North East of the bridge (FRC)
- Weather balloon was launched for a full 24 hrs in 6 hour increments
- Data was collected for 7 full days



SIAM array locations

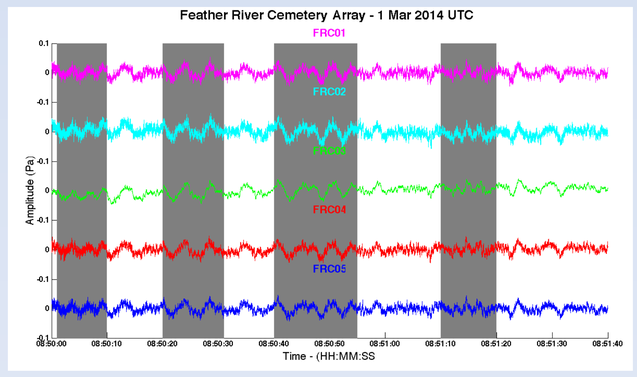
Processing of SIAM Array Data

Initial data processing utilized InfraTool to identify by hour, times of coherency across each array as well as a backazimuth for the detections. A time varying, continuous-wave signal was identified and signal characteristics were further investigated using GeoTool. The backazimuths for the coherent hours identified in InfraTool corresponded to a band which aligns with the Feather River Bridge location from 209° to 224°.



Feather River Bridge was localized using the backazimuth of the signal seen from array FRC

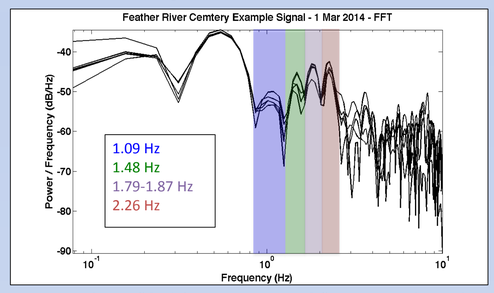
This identified day and time were investigated for packetized signals in GeoTool with the signal filtered using a 3-pole Butterworth filter between 1 and 4 Hz, seen below, with the frequency range indicated by finite element modeling discussed in a future section. Fourier analysis on the identified signal packets confirmed coherency across the array in the expected frequency range. Frequency wave number analysis then confirmed the signal source at the backazimuth of the Feather River Bridge. Additional filtering of some background noise will be needed to locate the bridge from all arrays and to investigate other coherent signals.



Feather River Bridge signal collected on array FRC

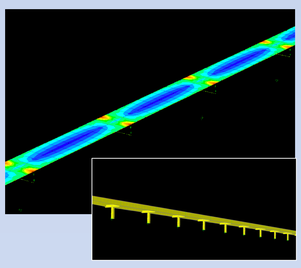
FE Model Frequencies compared to Infrasound Frequencies

The FE model of the superstructure (Spans 21-22) determined the fundamental modal frequencies of the structure under dead load. The mode shape associated with the 1.31 Hz resonance shows the deck vibrating vertically. The mode shape associated with the 1.85 Hz resonance show the deck vibrating in torsion.



Frequencies of bridge processed from FRC location

Mode	Frequency (Hz)
1	1.04
2	1.06
3	1.10
4	1.20
5	1.37
6	1.59



First 6 modes found of simplified bridge model using SAP2000

The data processed from the FRC array shows frequencies that are comparable to the frequencies found from the simplified bridge model. The vertical mode (1.31 Hz) is comparable to the SAP2000 program but is around a 12% difference from what the FRC array shows. Further processing of the data could show a 1.30 Hz. The torsion mode (1.85 Hz) is seen in the FRC array processed data.

Conclusions

Modal frequencies from the finite element analysis of the superstructure and backazimuth to source confirm the infrasound signals identified in the collected field data are associated with the Feather River Bridge.

Acknowledgments

Special thanks to Mr. Kevin Flora and CALTRANS on their supportive efforts during our current research of Feather River Bridge and previous field work.