Vibration And Noise Analysis Of The Feather River Bridge

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Introduction: The U.S. Army Engineer Research and Development Center (ERDC) is conducting research using infrasound arrays to detect and monitor structures, as well as for dynamic structural characterization of large infrastructure. Previous studies have determined that structures radiate acoustic energy within the infrasonic passband. This is typically defined as sound below the 20 Hz threshold, while propagating several kilometers away from the source with little attenuation. Efforts have been made to use this information to assess and monitor structures at standoff distances. As a continuation of previous studies investigating the Feather River Bridge, an acoustic model, with air as the medium, of the bridge has been developed in order to better understand the acoustic energy the structure emits while vibrating. This model was implemented with the COMSOL acoustic module, via the pressure acoustic physics and frequency domain study, using data collected from a vibrational analysis model of the bridge completed in the COMSOL structural mechanics module. The acoustic model was evaluated for the first few natural frequencies of the bridge to obtain the acoustic radiation and the sound pressure level for each mode.

Figure 1. Side views of the main spans from the Feather Rive Bridge

Problem: Remote assessment of infrastructure has historically depended upon satellite imagery or information revealed by physical inspection.

Solution: Use infrasound acoustics in combination with seismic, meteorological and audible acoustic methods to determine fundamental modes of movement for bridges without line of site or direct involvement by personnel.

Computational Methods: The Feather River Bridge (FBR) vibrates at certain frequencies when loads are applied to it (e.g. trucks, cars, etc.), transmitting this energy to the surrounding fluid resulting in an acoustic wave radiation. To simulate the phenomenon several analyses were performed:

Structural Mechanics

- **Eigenfrequency Analysis:** Determined fundamental modes of vibration.
- **Vibration Analysis:** Computed the main span's vibration under a load condition.
  - Shell, Solid, and Beam interface combination
  - Time dependent analysis
  - Force load data

Acoustics

- **Acoustic Analysis:** Computed the sound pressure levels the span emits.
  - Mesh CFL criterion is met, CFL=0.1=$^{c\,\Delta t}/_{h_{min}}$
  - Pressure Acoustic, Frequency Domain interface
    - Noise Source: vibration analysis' acceleration result
  - Time to Frequency FFT

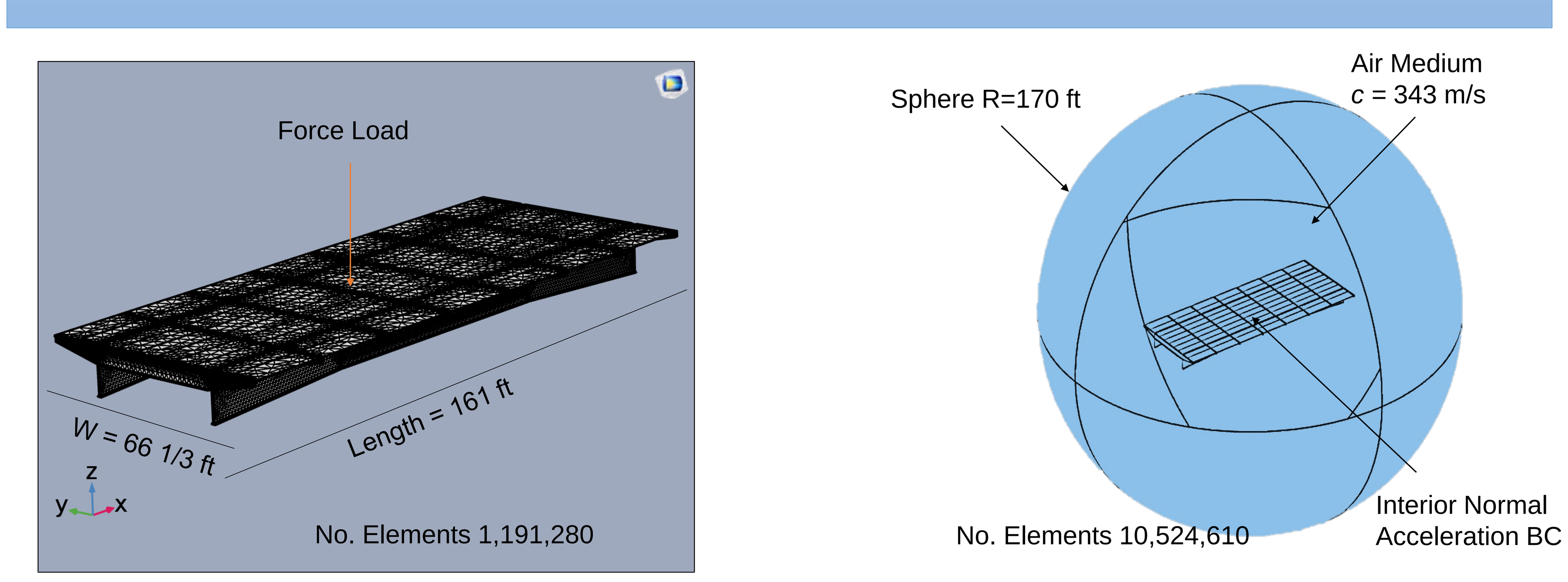

Figure 2. The geometry and mesh on the left was used for the structural mechanics analyses. For the acoustic analysis the geometry and mesh on the right was used.

Eigenfrequencies: The finite element model (FEM) of the main span developed in COMSOL determined the fundamental modes of vibration. The FEM produced frequencies of 2.04 Hz, 7.14 Hz, and 12.21 Hz. The goal was to confirm that the fundamental modes were in the infrasound pass-band, between 0.1 to 20 Hz and that it closely behaved as the actual span.

Eigenfrequency 2.04 Hz	Eigenfrequency 7.14 Hz	Eigenfrequency 12.21 Hz

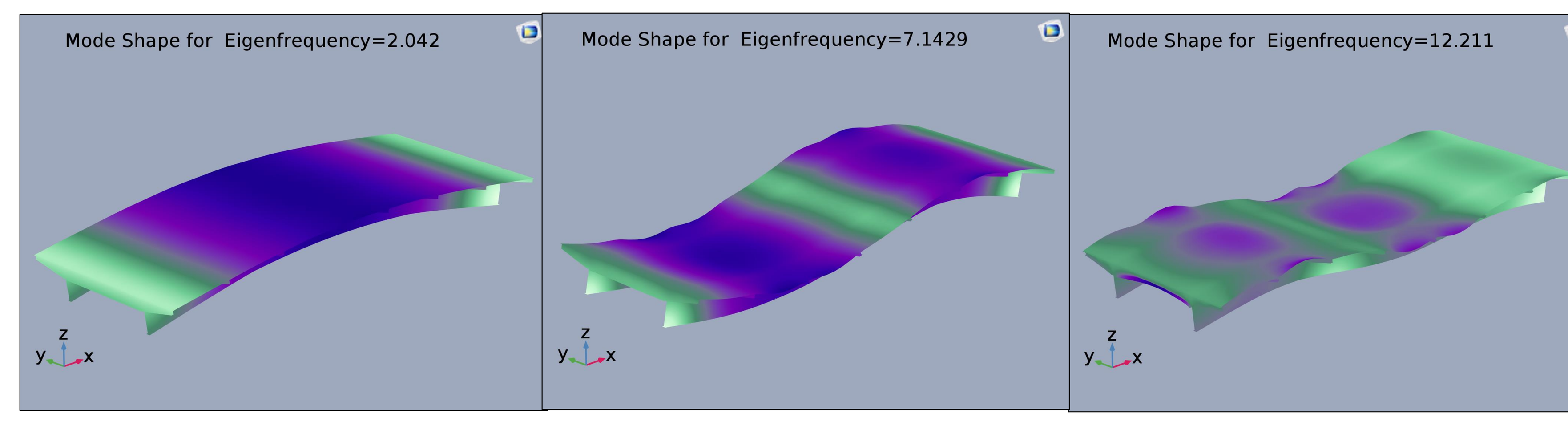

Figure 3 . Finite Element Analysis - First 3 Eigenfrequency modes

Vibration Analysis: A combination of Shell, Solid, and Beam interfaces were used to complete the vibrational analysis. A force excitation was simulated on the bridge model in order to excite the structure. The data used for the force excitation has a transient shock force up to 30,000 N. The figure below (Figure 4) shows how the vibration propagates throughout the span's deck.

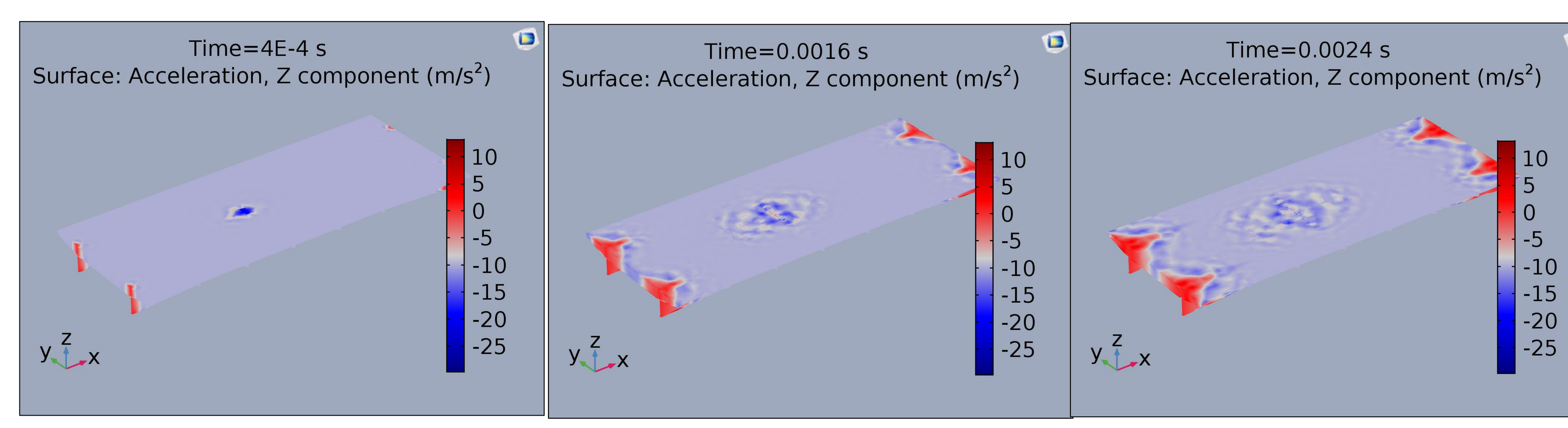

Figure 4. Surface acceleration, Z component due to the transient force load.

Acoustic Model: From this analysis the magnitudes of the energy emitted for the different frequencies of interest were analyzed.

- Time to Frequency FFT study was used on the surface acceleration results.
- Figure 5 show the sound level pressure that is emitted by the span at 2 Hz.
  - Higher near the surface and dissipates as it travels away from the span.

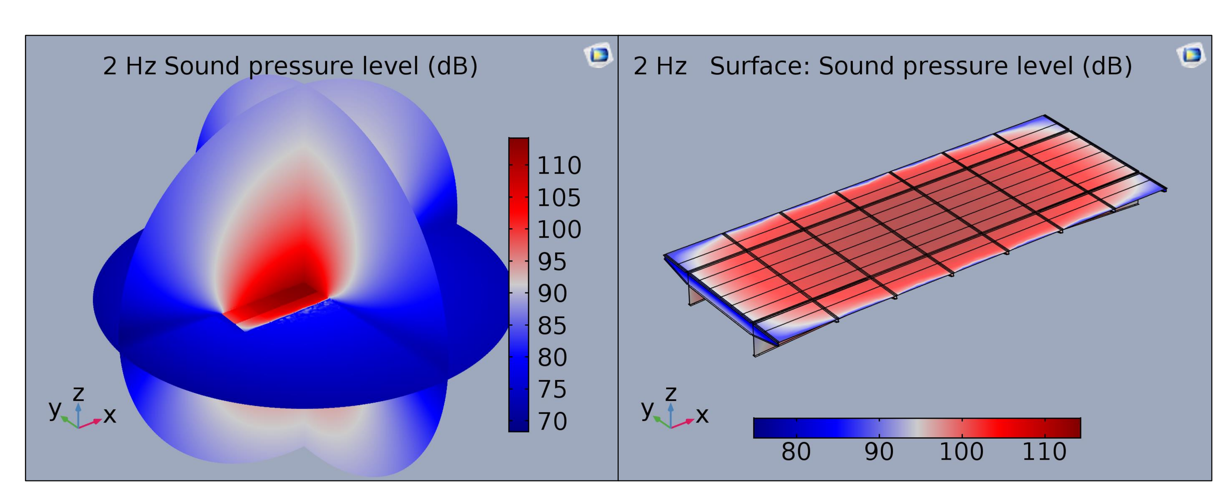

Figure 5. Sound Pressure Level for for the near field and span surface at 2 Hz.

- Frequency to Time FFT study
  - Transformed the results of the range of frequencies into the time domain.
  - Allows us to visualize the transient wave propagation as seen in figure 6.
    - Easy to observe the difference in pressure throughout the medium

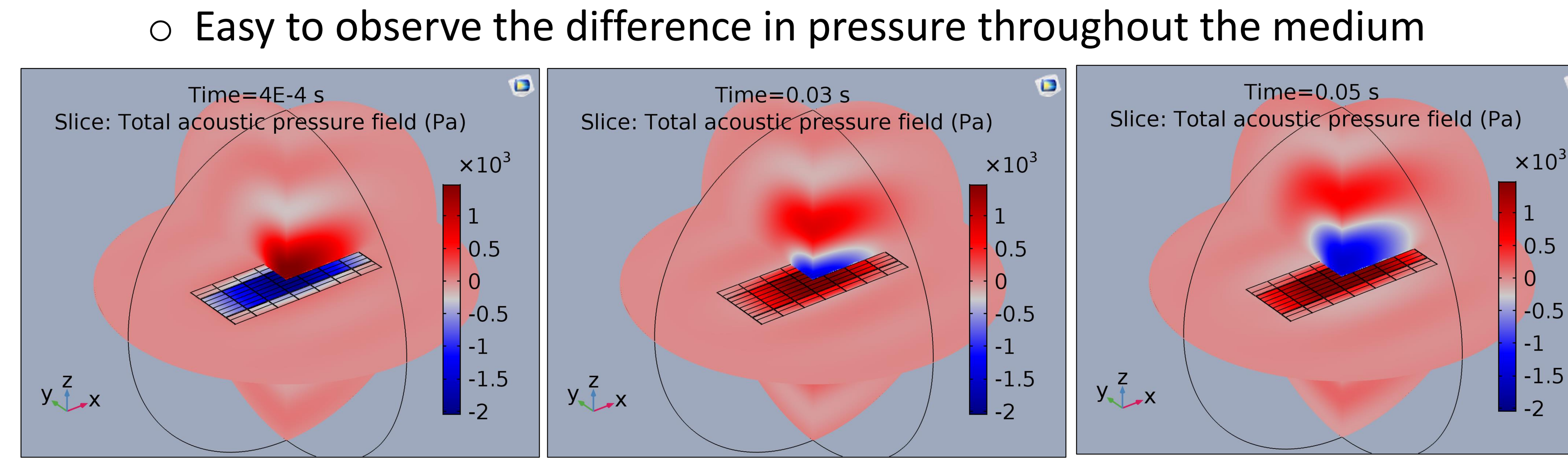

Figure 6. Acoustic pressure field which shows the transient wave formation.

Conclusions

- The structural fundamental modes are in the infrasound passband (< 20 Hz).
- The solutions from the vibrational and acoustic analysis gives us the information needed to estimate the pressure amplitude at certain distances from the source.

References:

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