Dynamic Site Characterization and Ambient Vibration Analyses of Site & Bridge

Brady R. Cox[1], PhD, PE

[1]Department of Civil, Architectural and Environmental Engineering, The University of Texas, Austin, USA.

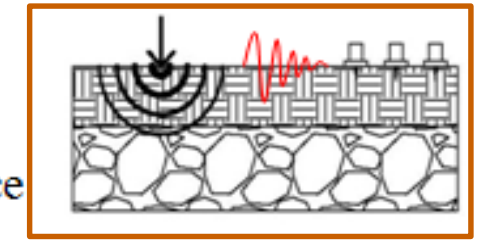
NHERI Workshop on Soil-Foundation-Structure Interaction (SFSI)
Rutgers University, New Brunswick, NJ; 3 August 2017

Longhorns

Dynamic Site Characterization: Surface Wave Testing

Acquisition

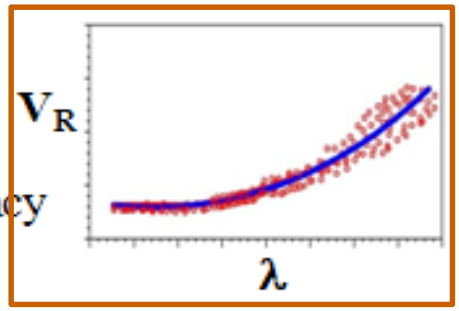
Field Data Collection:
Measurement of stress waves at the ground surface



Combined active linear arrays and passive 2D arrays

Processing

Dispersion Curve:
Rayleigh Wave Phase Velocity vs. Wavelength/Frequency



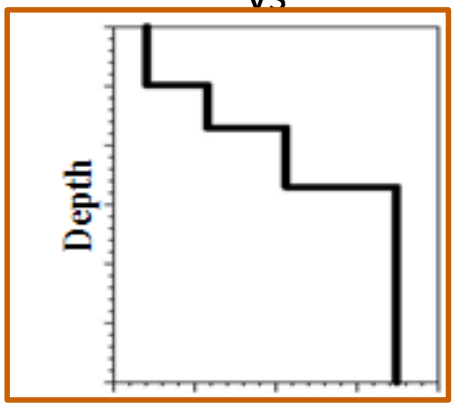
Robustly determined by experts: part of "site signature"

Inversion

Shear Wave Velocity Profile:
Variation of Small Strain Shear Modulus vs. Depth

$$G_{max} = \rho V_S^2$$

Vs



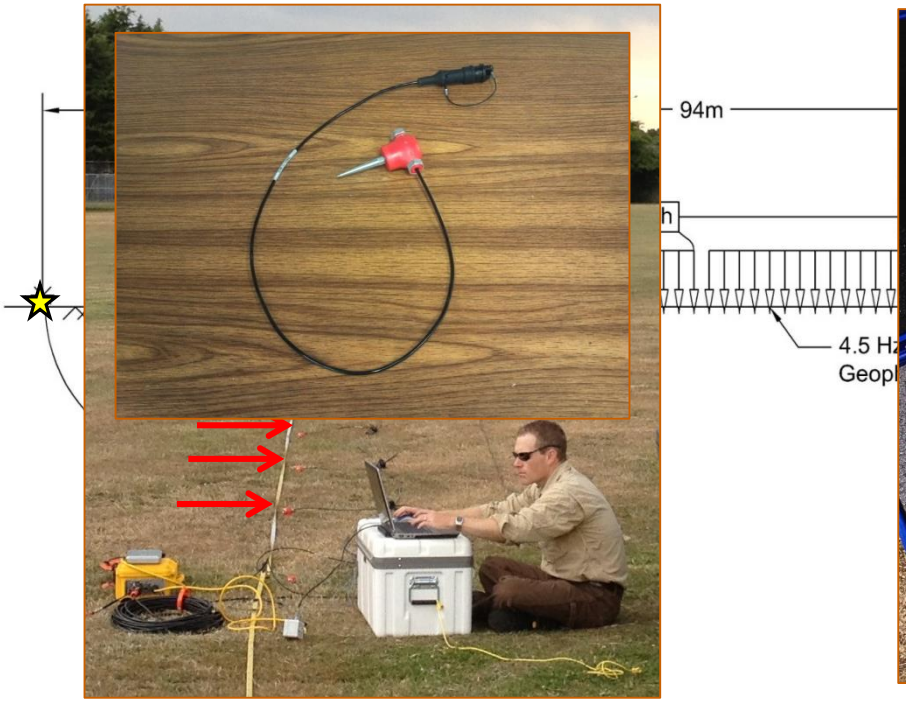
Still challenging for experts: highly non-unique

Surface Wave Acquisition: My Typical Approach

- Combined linear-array, active-source MASW and 2D-array, passive-source MAM
- Required to generate broadband dispersion curve ("site signature")
- I cannot recommend linear-array, passive testing (e.g. ReMi) … talk to me after

Active-Source MASW Testing

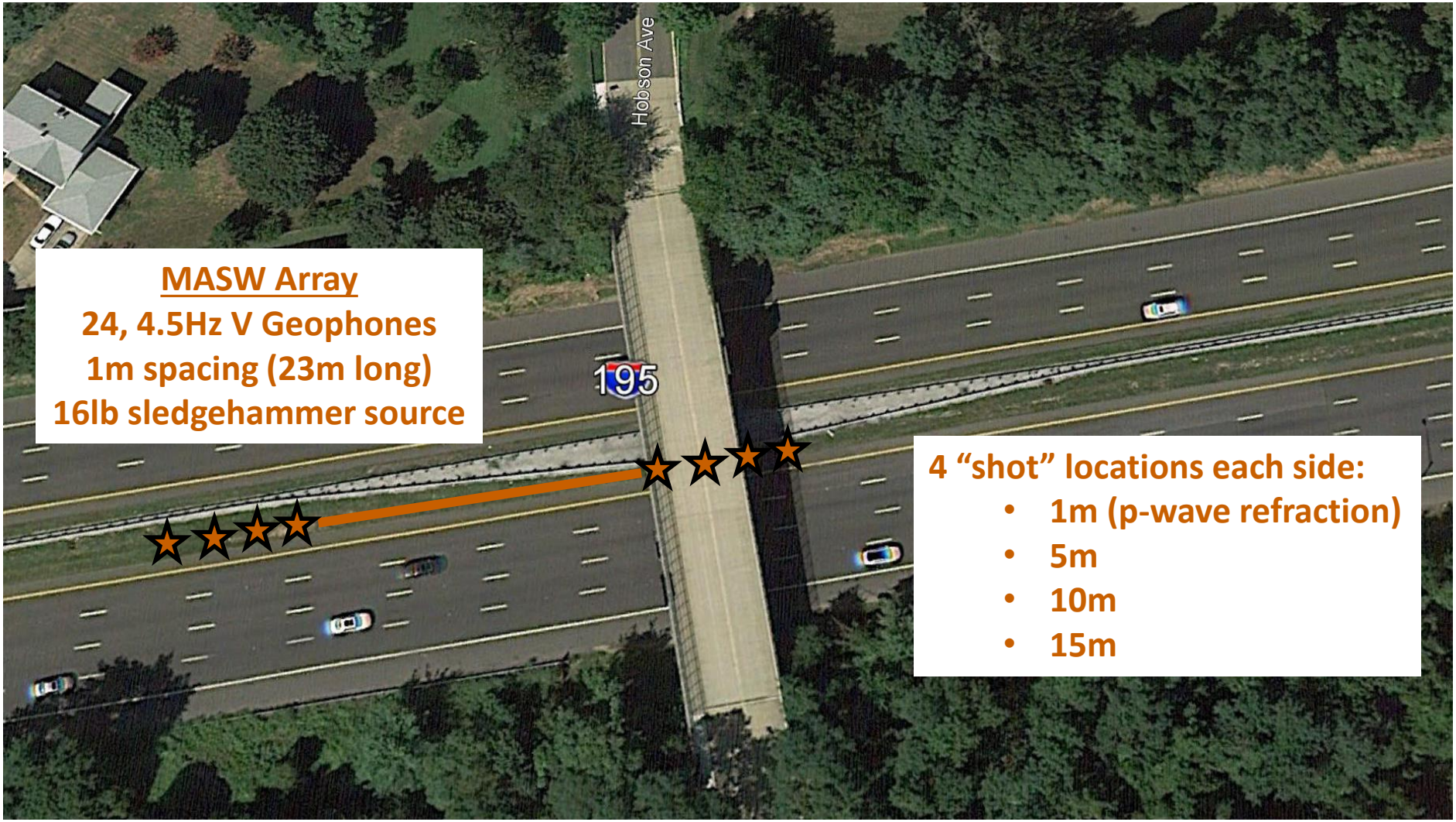
(cross section)



Passive-Source MAM Testing

(plan view)

Hobson Ave Bridge: Surface Wave Testing



Our Typical MASW Processing

- Frequency domain beamformer (FDBF) or standard FK

2D Transformation

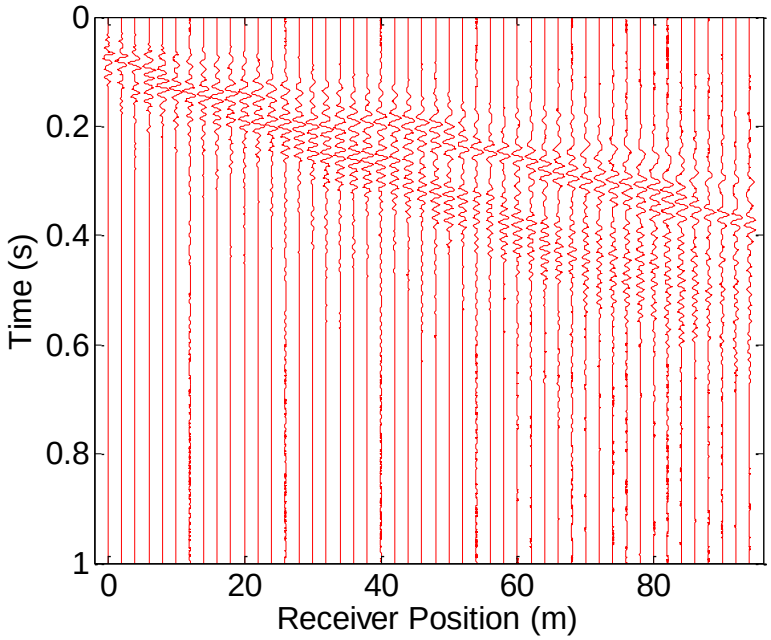
Time (t) → Frequency (F)

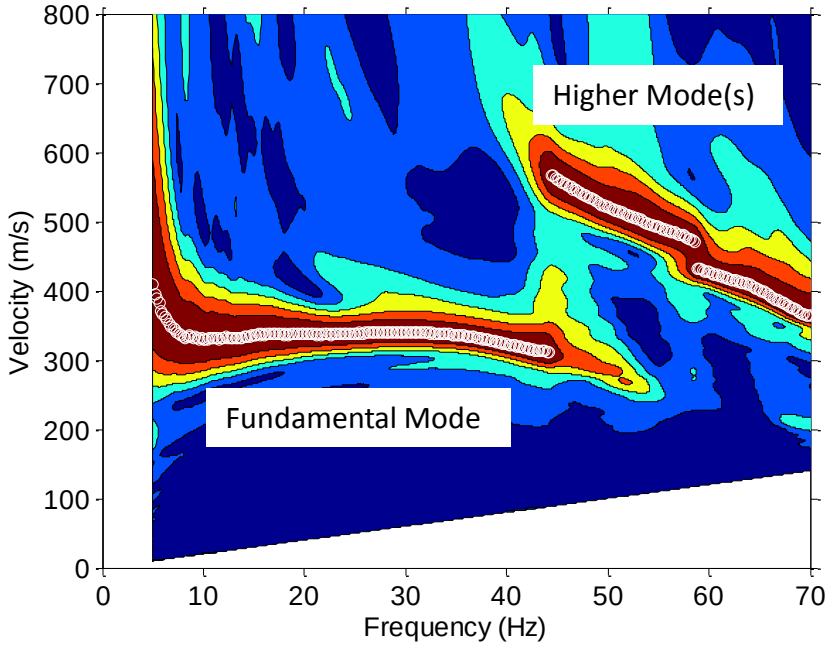
Space (x) → Wavenumber (K)

$V_R = F\,(2\pi/K)$

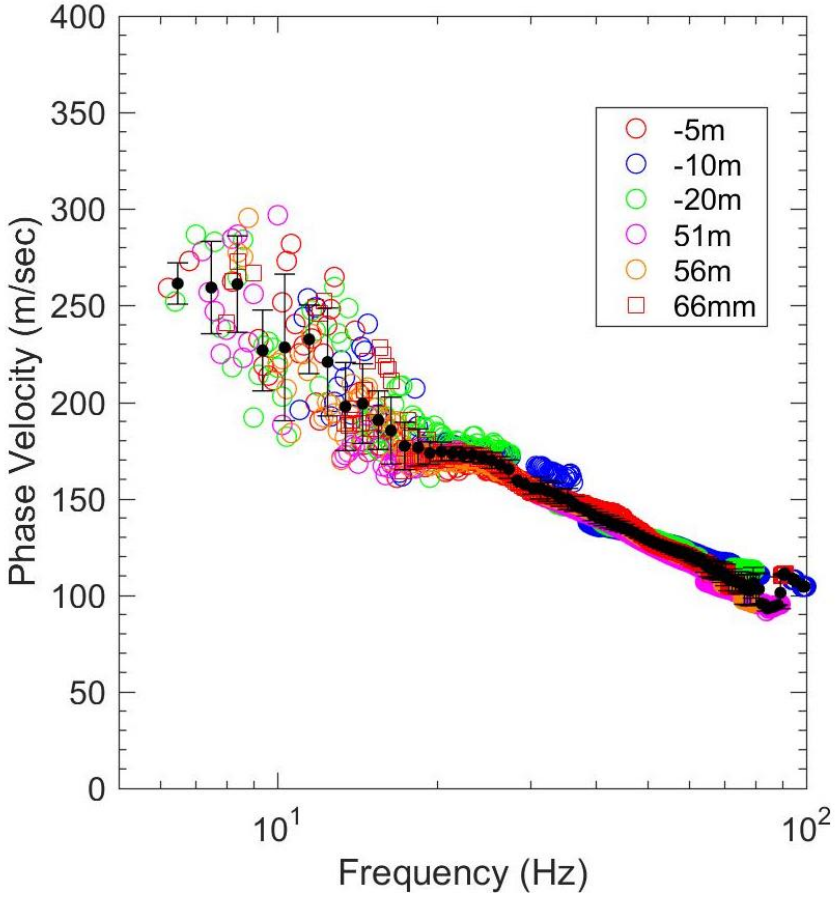
$$G_{ij}(f) = \frac{1}{M}\sum_{m=1}^{M} S_{im}(f)S_{jm}^{*}(f)$$

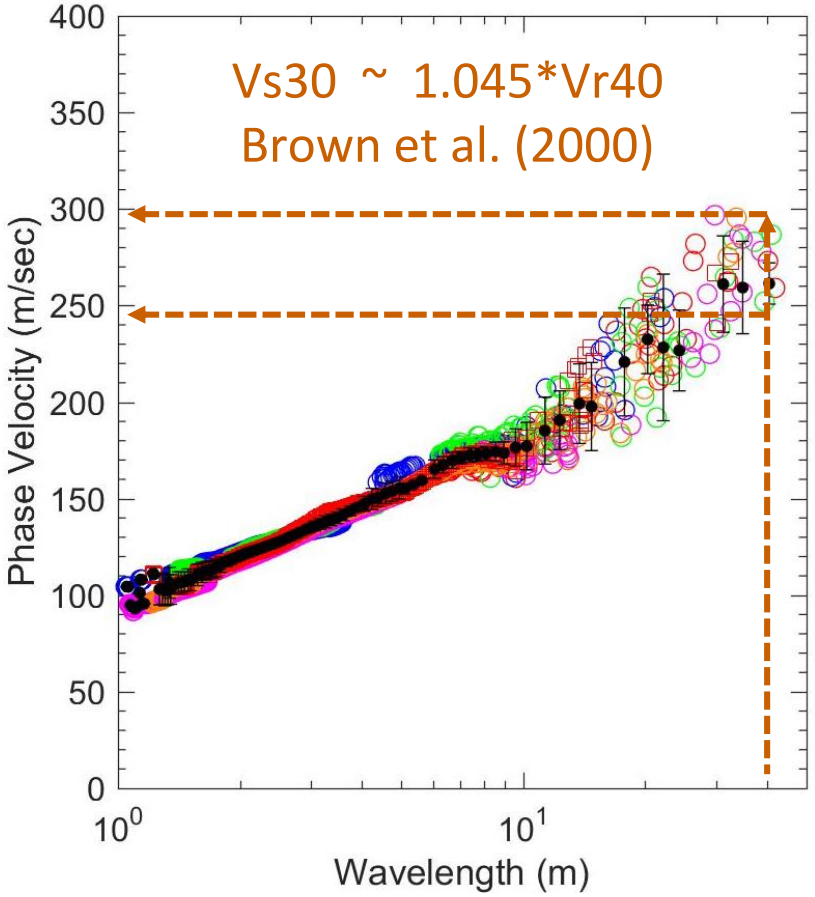
$$F(f,k) = \sum_{i=1}^{N}\sum_{j=1}^{N} G_{ij}(f)\cdot e^{ik(x_i - x_j)}$$





Hobson Ave Bridge: Dispersion Data

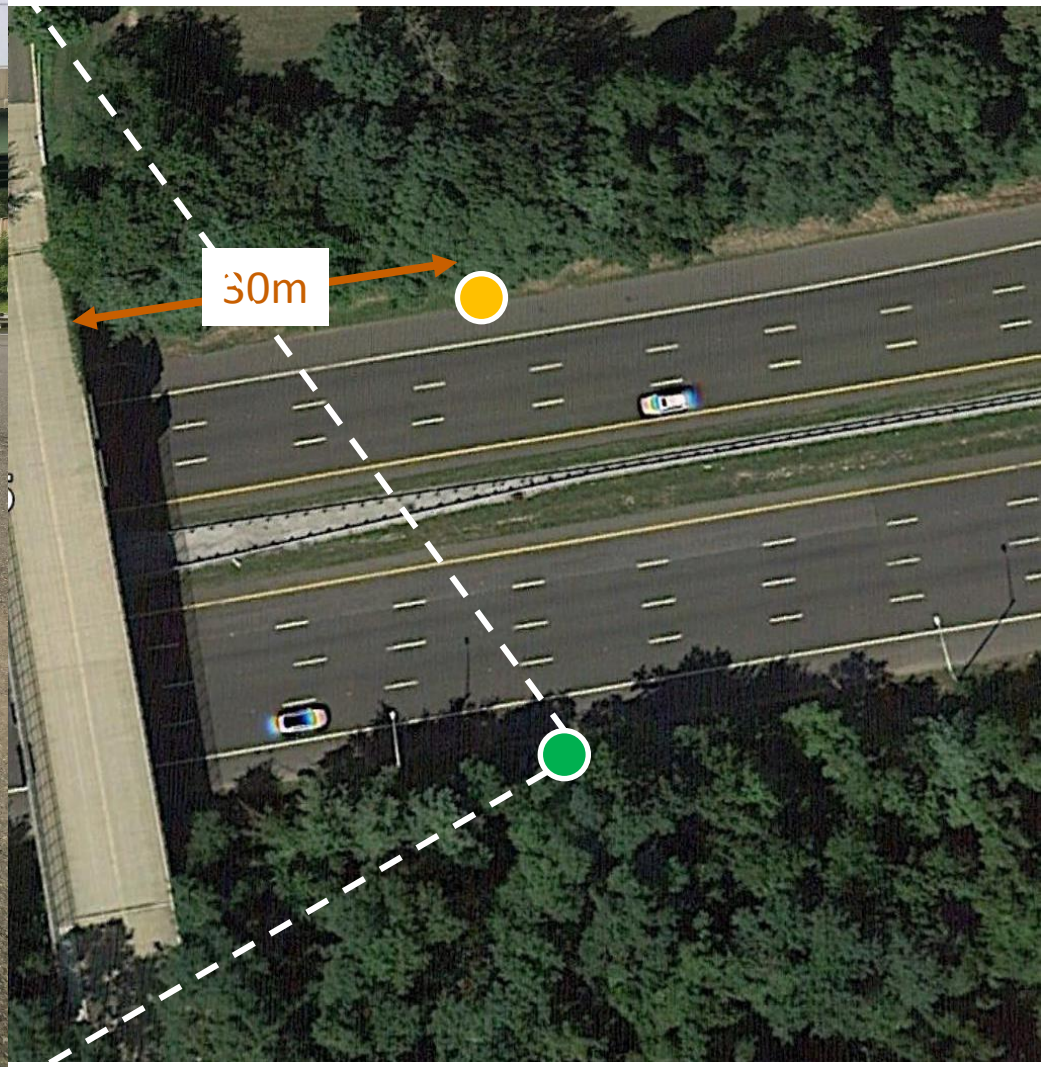




Site Class D

Ambient Vibration Testing: Freefield Soil

Ambient Vibration Testing: Freefield Soil

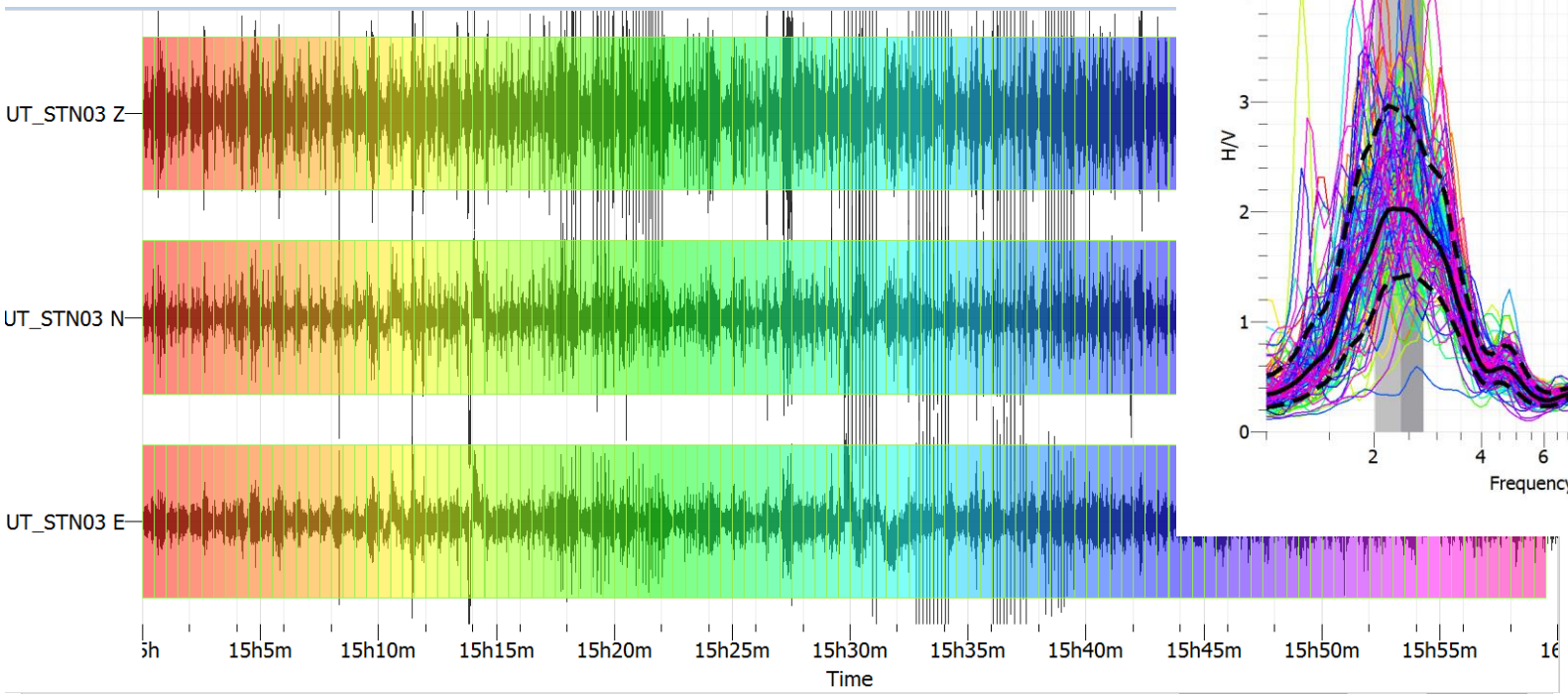


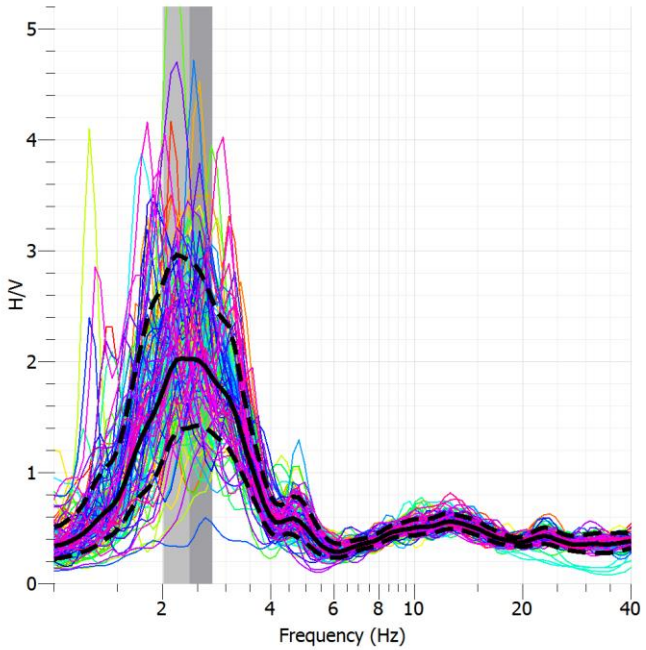
Horizontal-to-Vertical (H/V) Spectral Ratios

$$H/V = \frac{FAS\ (H(t))}{FAS\ (V(t))}$$

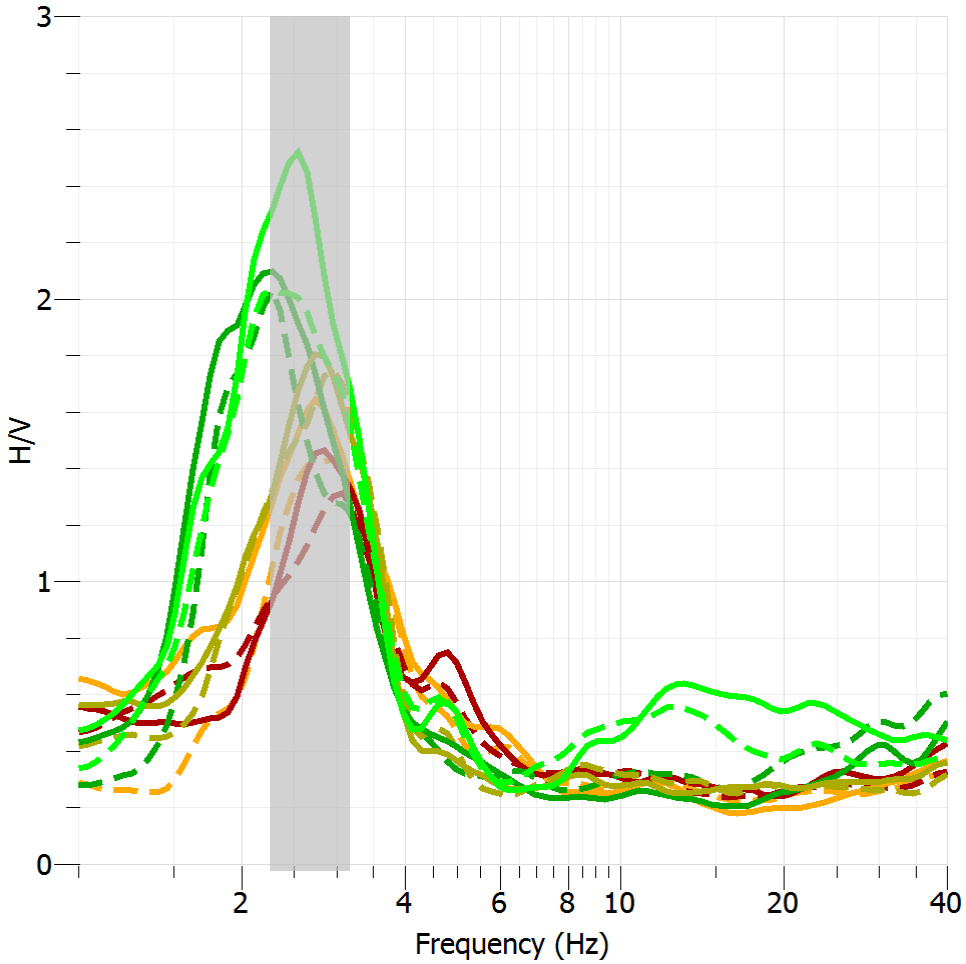
$$f_0 \sim \frac{Vs_{avg}}{4*H_{soil}}$$

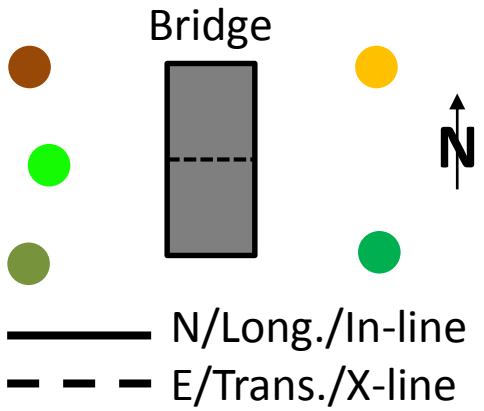
- Indication of fundamental site frequency (f_0)
- Used to constrain depth to bedrock during surface wave inversion





H/V Results: Freefield Soil

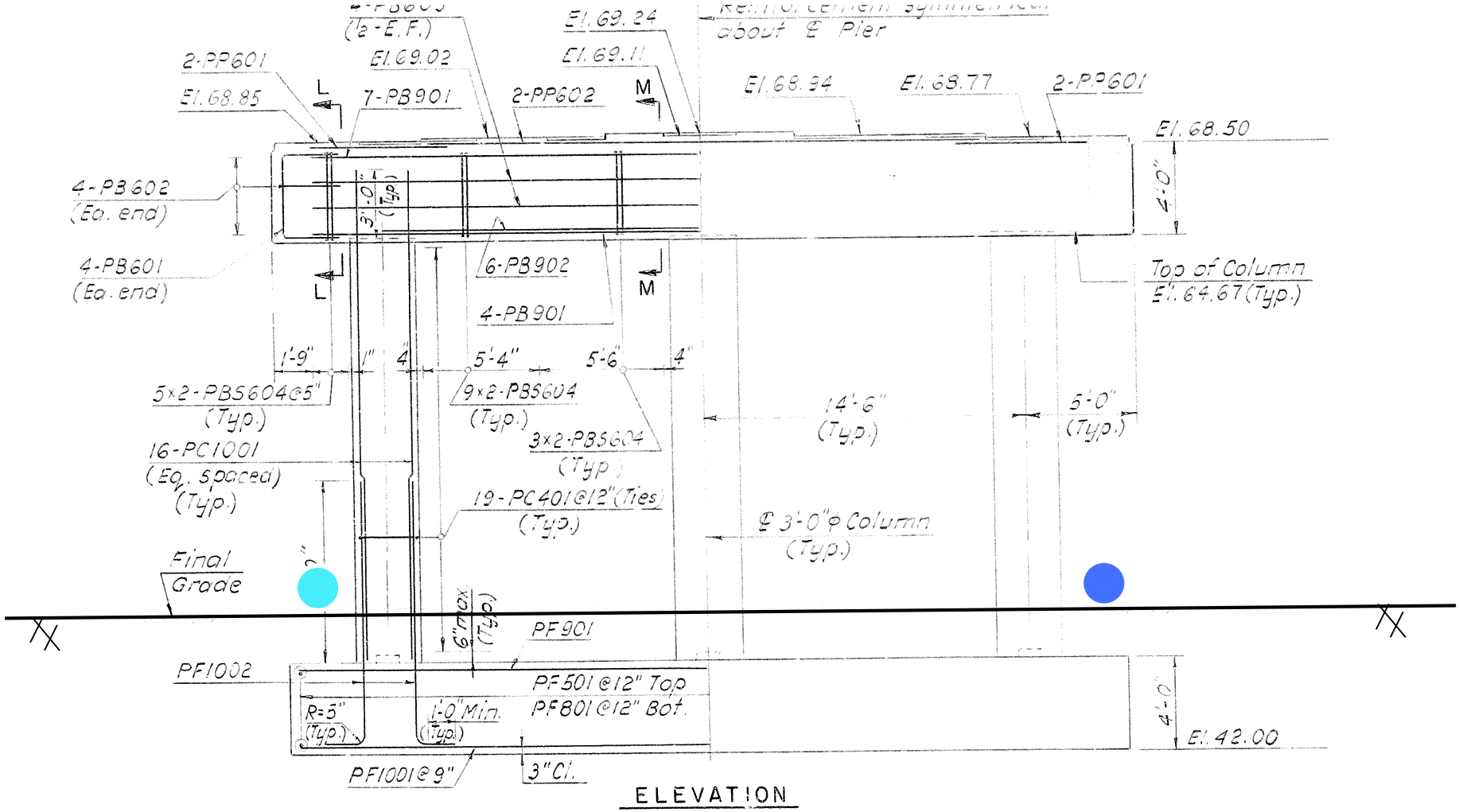




$f_{0\ site}$ ~ 2.25 – 3.0 Hz

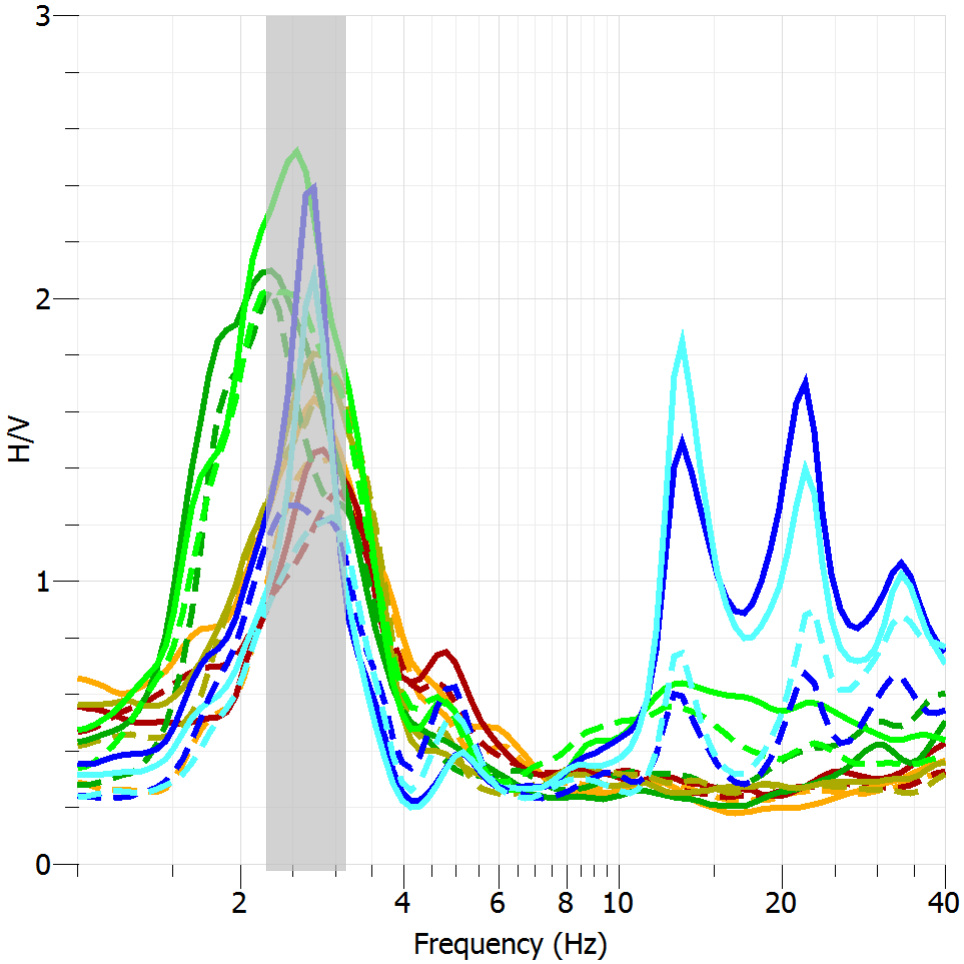
Ambient Vibration Testing: Nearfield Soil

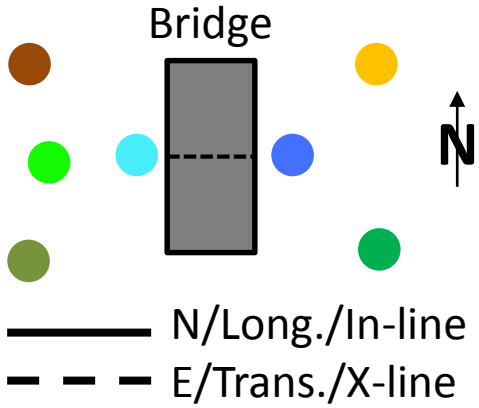
Ambient Vibration Testing: Nearfield Soil



ELEVATION

H/V Results: Nearfield Soil



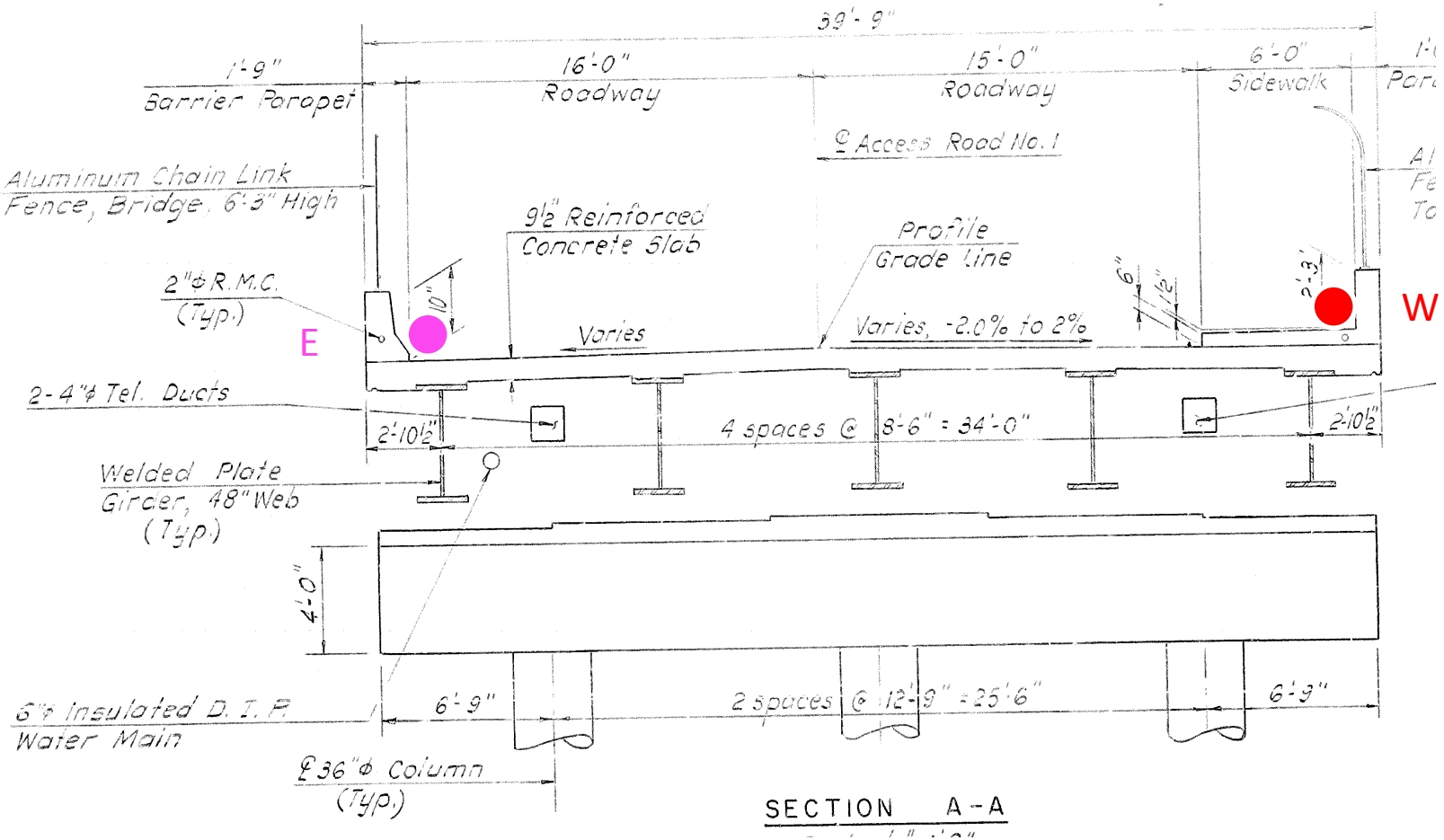


$f_{0\ site}$ ~ 2.25 – 3.0 Hz

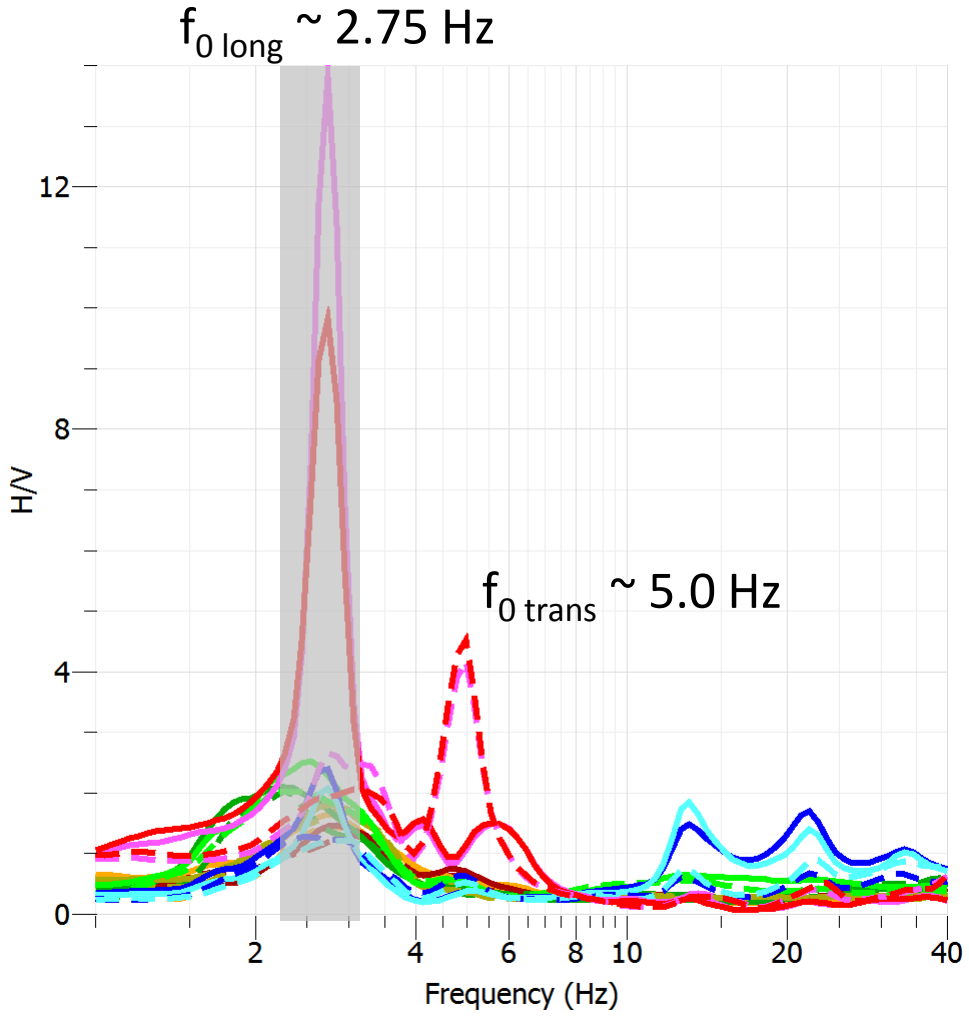
Ambient Vibration Testing: Bridge Deck

Ambient Vibration Testing: Bridge Deck

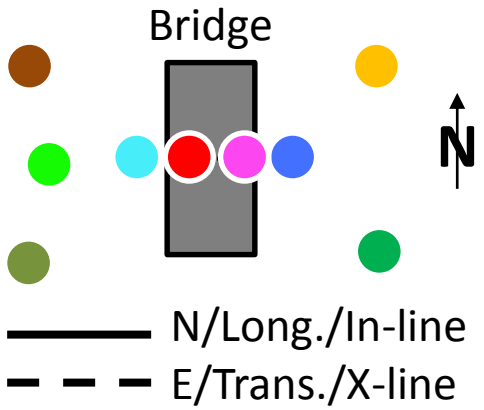
Looking from North to South… mirror image



H/V Results: Bridge Deck



$f_{0\ site}$ ~ 2.25 – 3.0 Hz



- Why H/V on structure?
- Is the site controlling folong or is folong controlling the site?

Forced Vibration Tests with T-Rex
Very…Very Preliminary Results

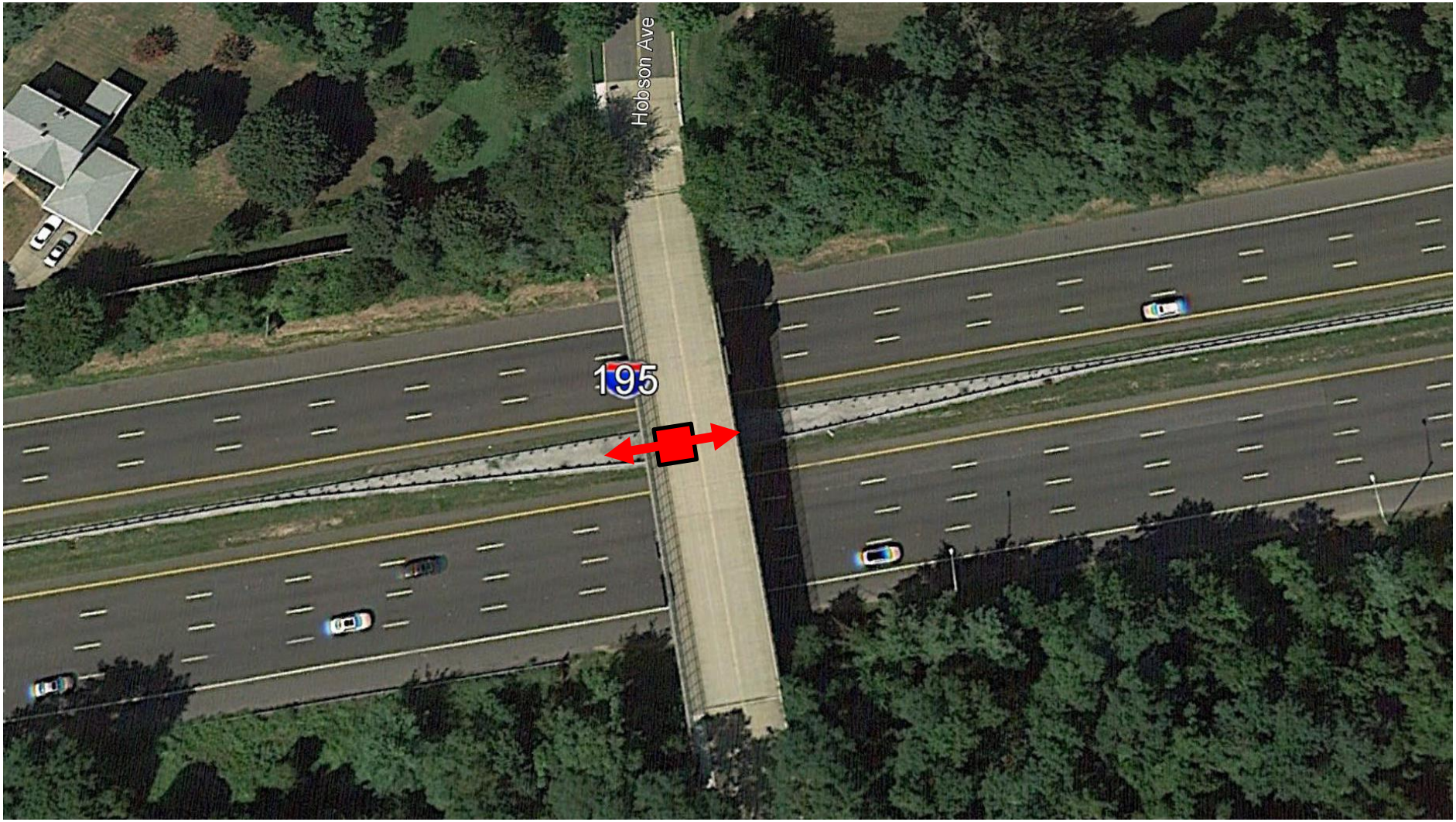
Farnyuh Menq[1], PhD

[1]Department of Civil, Architectural and Environmental Engineering, The University of Texas, Austin, USA.

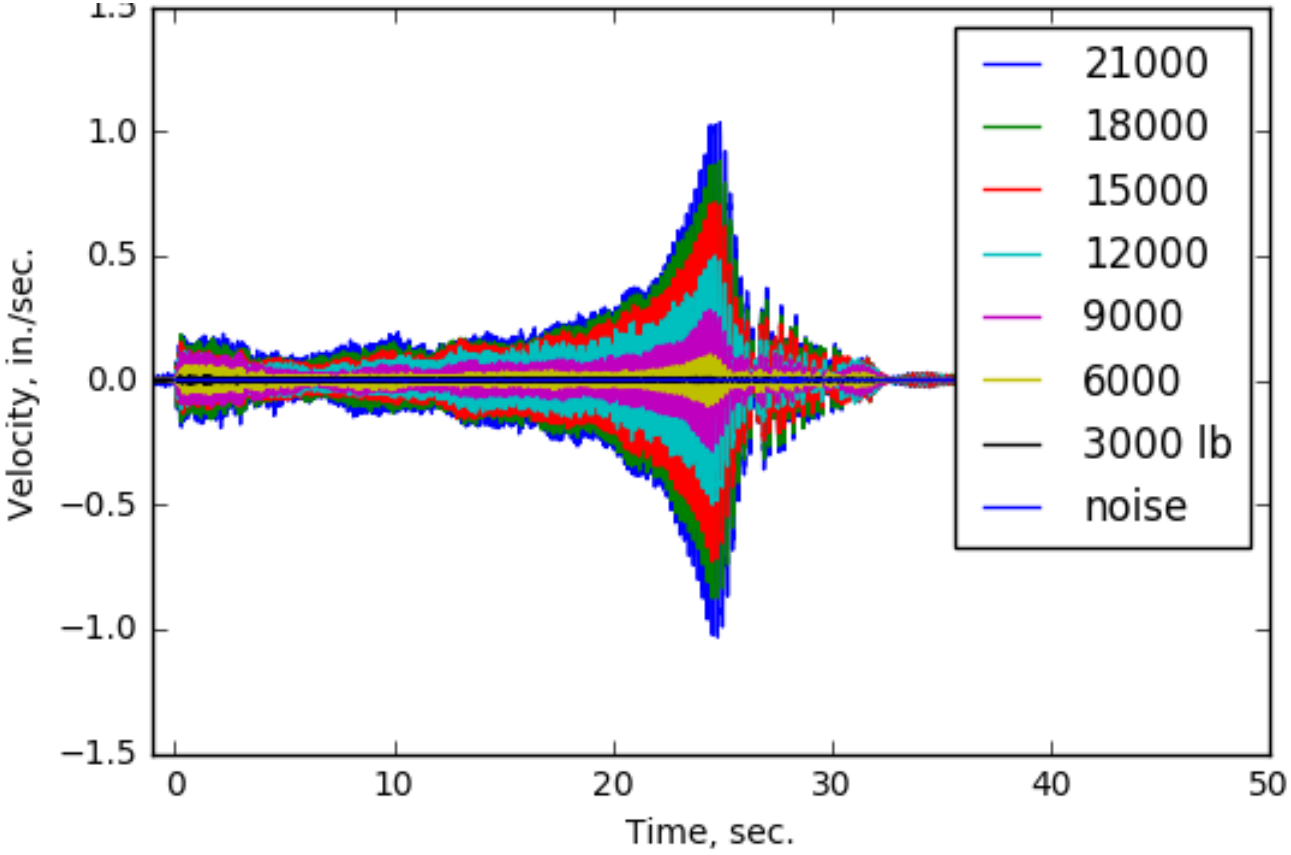
NHERI Workshop on Soil-Foundation-Structure Interaction (SFSI)
Rutgers University, New Brunswick, NJ; 3 August 2017

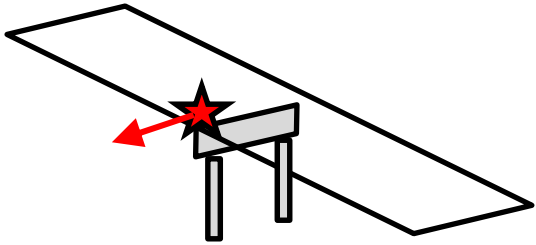
Longhorns

T-Rex Over Middle Bent: Horizontal X-Line Shaking

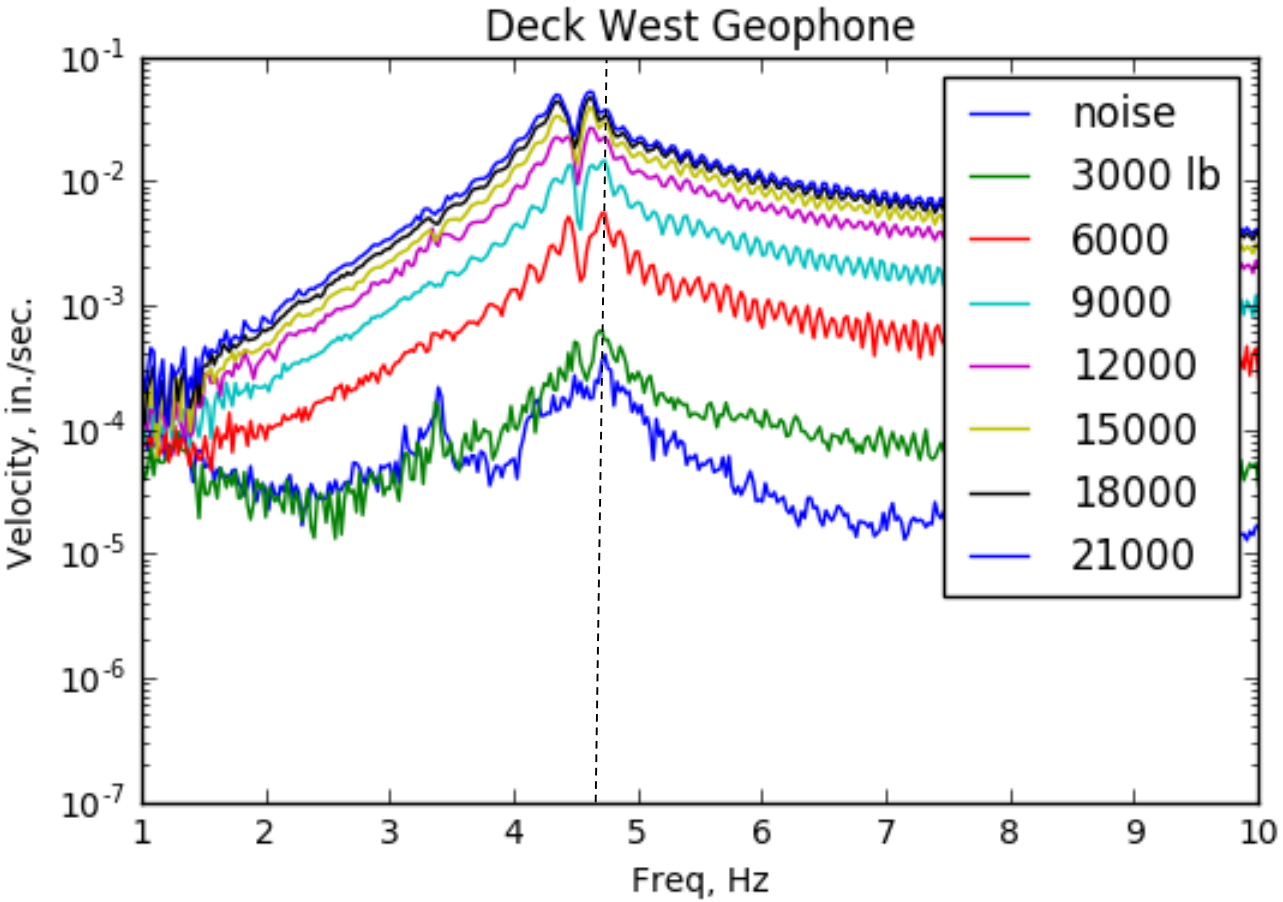


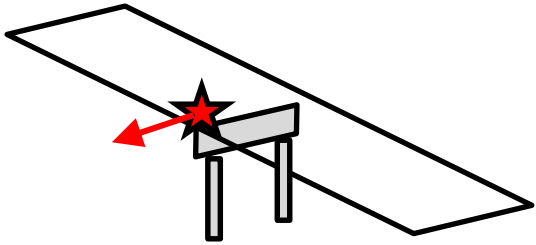
Deck West Horizontal X-Line Geophone Chirp from 15Hz – 1Hz



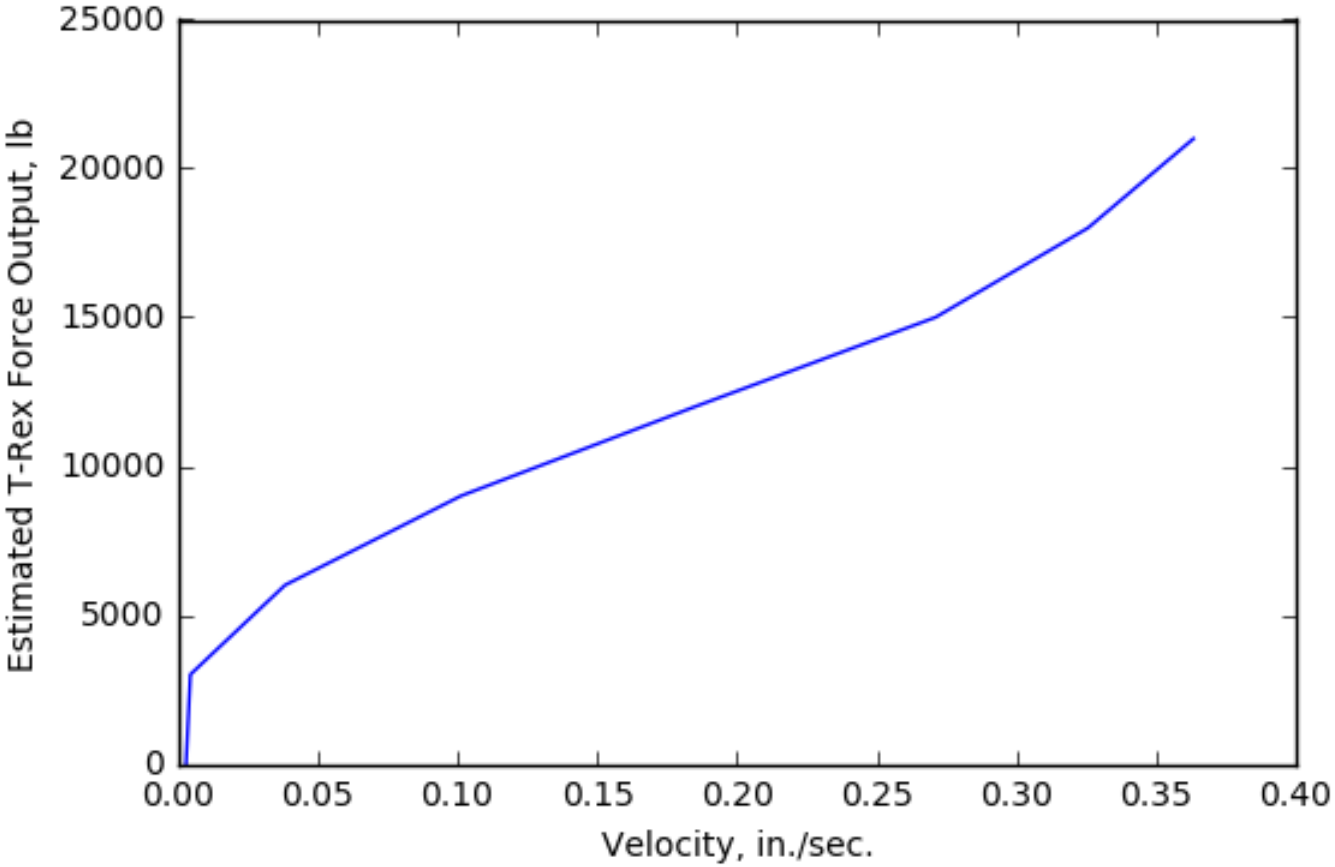


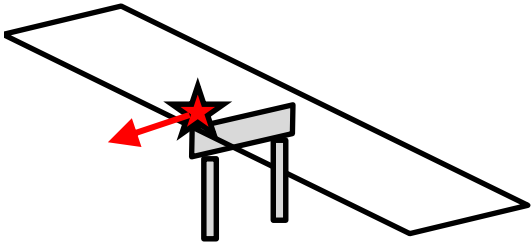
Deck West Horizontal X-Line Geophone Reduction in Resonant Frequency



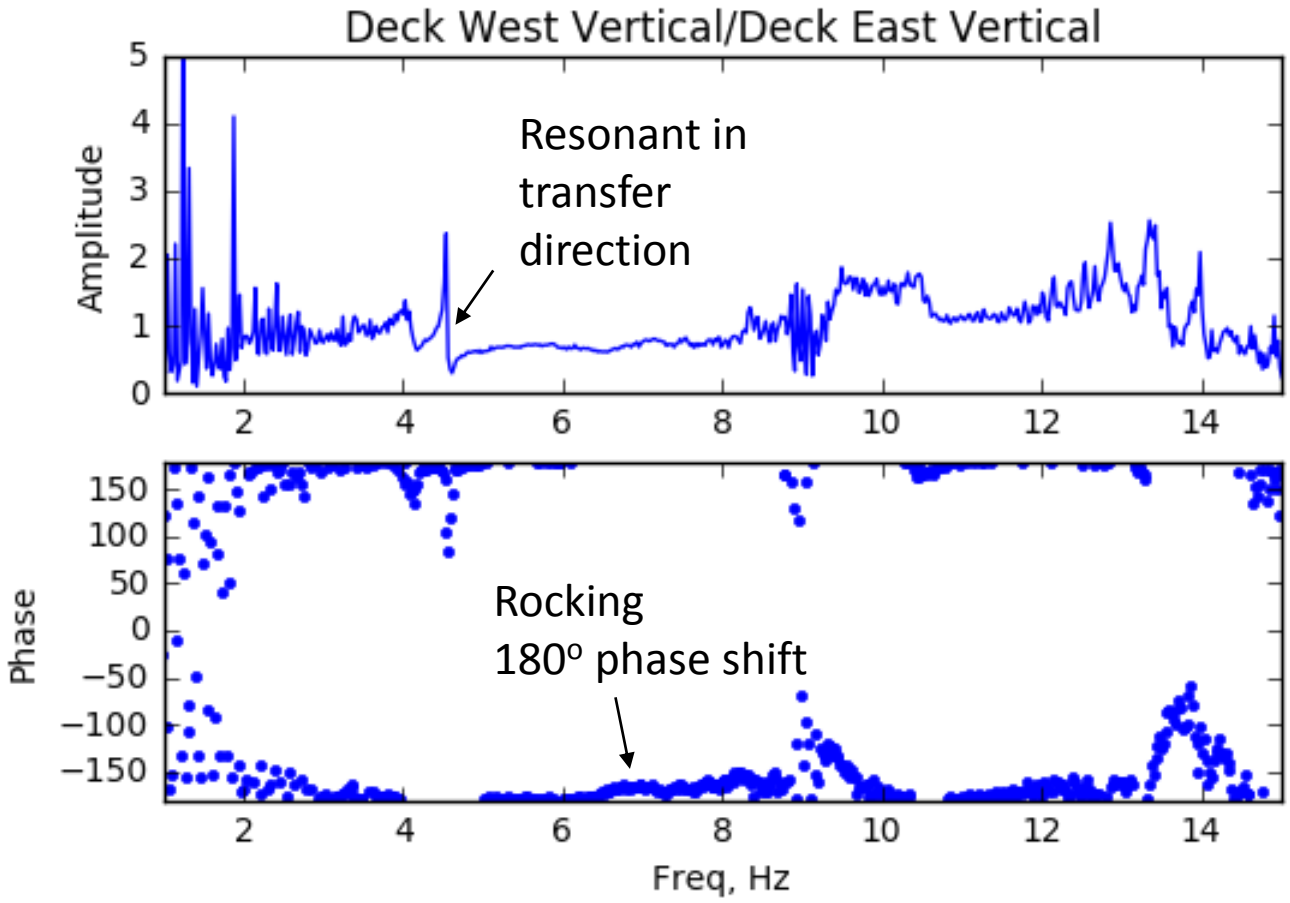


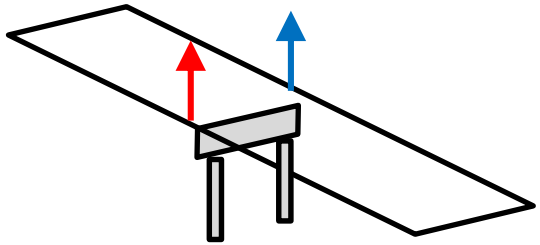
Deck West Horizontal X-Line Geophone
Peak Particle Velocity v.s. T-Rex Force Output



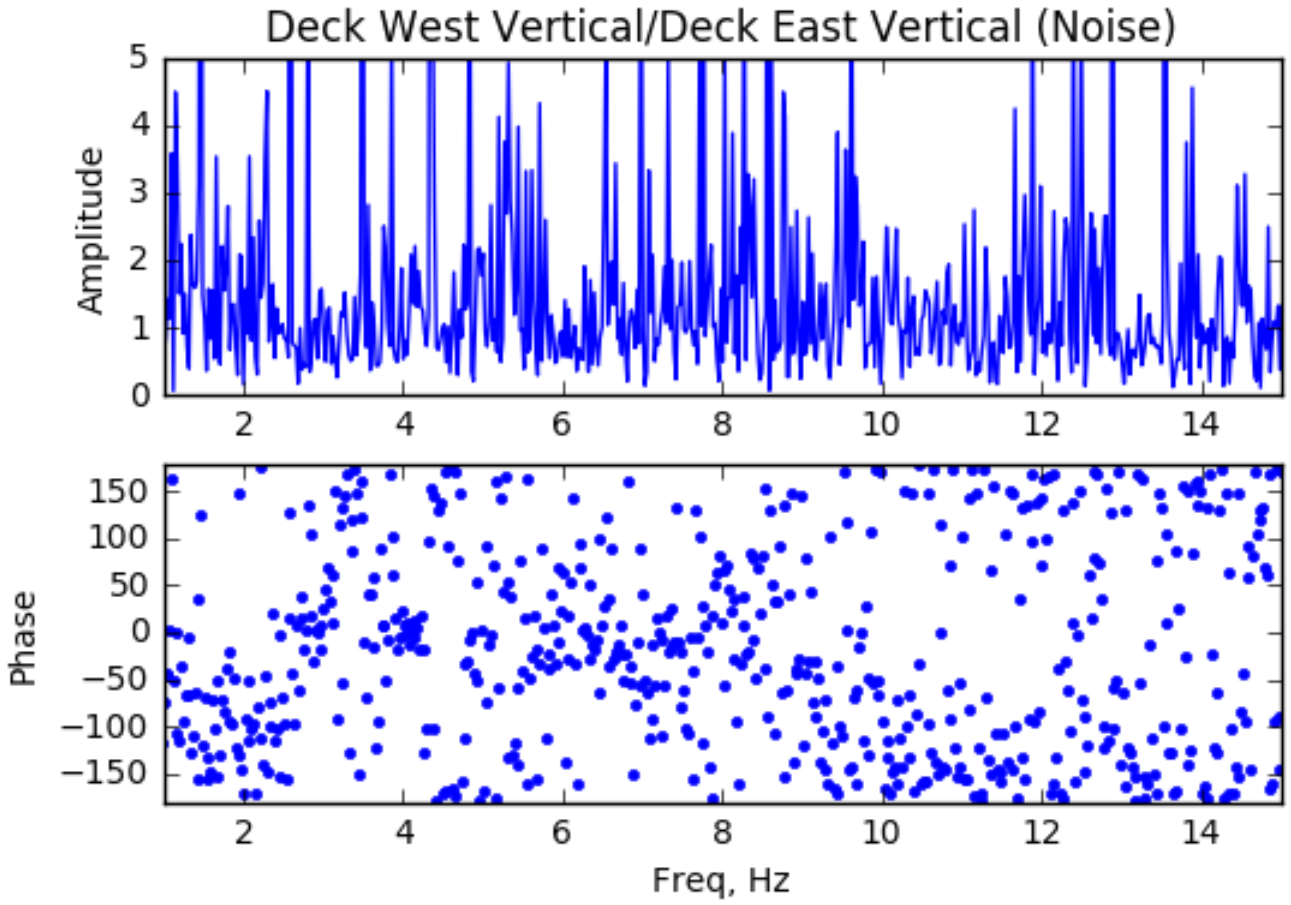


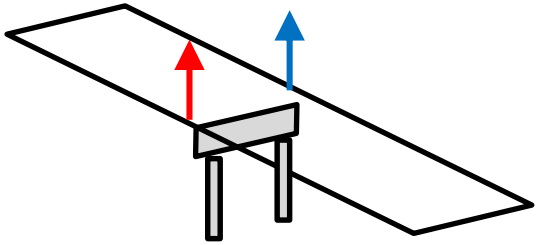
Transfer Functions: T-Rex Shaking Vertical Geophones: Deck West/Deck East





Transfer Functions: Noise
Vertical Geophones: Deck West/Deck East





Acknowledgements

- NSF
  - This work was supported by U.S. National Science Foundation (NSF) grant CMMI-1261775. However, any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of NSF.

- NHERI@UTexas

- Design Safe-CI and Texas Advanced Computing Center