Dynamic Site Characterization and Ambient Vibration Analyses of Site & Bridge

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Dynamic Site Characterization: Surface Wave Testing

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

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

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

Combined active linear arrays and passive 2D arrays

Robustly determined by experts: part of “site signature”

Still challenging for experts: highly non-unique

\[ G_{\text{max}} = \rho V_S^2 \]
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

MASW Array
24, 4.5Hz V Geophones
1m spacing (23m long)
16lb sledgehammer source

4 “shot” locations each side:
- 1m (p-wave refraction)
- 5m
- 10m
- 15m
Our Typical MASW Processing

- Frequency domain beamformer (FDBF) or standard FK

**2D Transformation**
- Time (t) → Frequency (F)
- Space (x) → Wavenumber (K)

\[ V_R = F \left( \frac{2\pi}{K} \right) \]

**Mode Jumps**

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

\[ F(f, k) = \sum_{i=1}^{N} \sum_{j=1}^{N} G_{ij}(f) \cdot e^{ik(x_i-x_j)} \]
Hobson Ave Bridge: Dispersion Data

Vs30 \sim 1.045 \times Vr40
Brown et al. (2000)

Site Class D
Ambient Vibration Testing: Freefield Soil

3-comp broadband

30m

30m

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NHERI@UTexas - Hobson Ave Bridge Testing
Ambient Vibration Testing: Freefield Soil
Horizontal-to-Vertical (H/V) Spectral Ratios

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

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

\[ f_0 \approx \frac{V_{S_{avg}}}{4 \times H_{soil}} \]
H/V Results: Freefield Soil

\[ f_{0\text{ site}} \sim 2.25 - 3.0 \text{ Hz} \]
Ambient Vibration Testing: Nearfield Soil

3-comp broadband

30m
Ambient Vibration Testing: Nearfield Soil
H/V Results: Nearfield Soil

\[ f_{0 \text{site}} \sim 2.25 - 3.0 \text{ Hz} \]
Ambient Vibration Testing: Bridge Deck

3-comp broadband

30m

30m

Vσ

Vs

30m

broadband
Ambient Vibration Testing: Bridge Deck

Looking from North to South... mirror image
H/V Results:  Bridge Deck

- $f_{0\text{ long}} \sim 2.75 \text{ Hz}$
- $f_{0\text{ trans}} \sim 5.0 \text{ Hz}$
- $f_{0\text{ site}} \sim 2.25 - 3.0 \text{ Hz}$

- 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

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T-Rex Over Middle Bent: Horizontal X-Line Shaking
Deck West Horizontal X-Line Geophone
Chirp from 15Hz – 1Hz

[Graph showing velocity over time for different load cases]
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

Resonant in transfer direction

Rocking 180° phase shift
Transfer Functions: Noise
Vertical Geophones: Deck West/Deck East

Deck West Vertical/Deck East Vertical (Noise)
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