Application of Acoustic and Seismic Excitations for Buried Target Characterization:

Variations in Target Response due to Soil Type and Burial Depth

Leti Wodajo, Craig J. Hickey, and Parsa Bakhtiari Rad

National Center for Physical Acoustics (NCPA)
University of Mississippi

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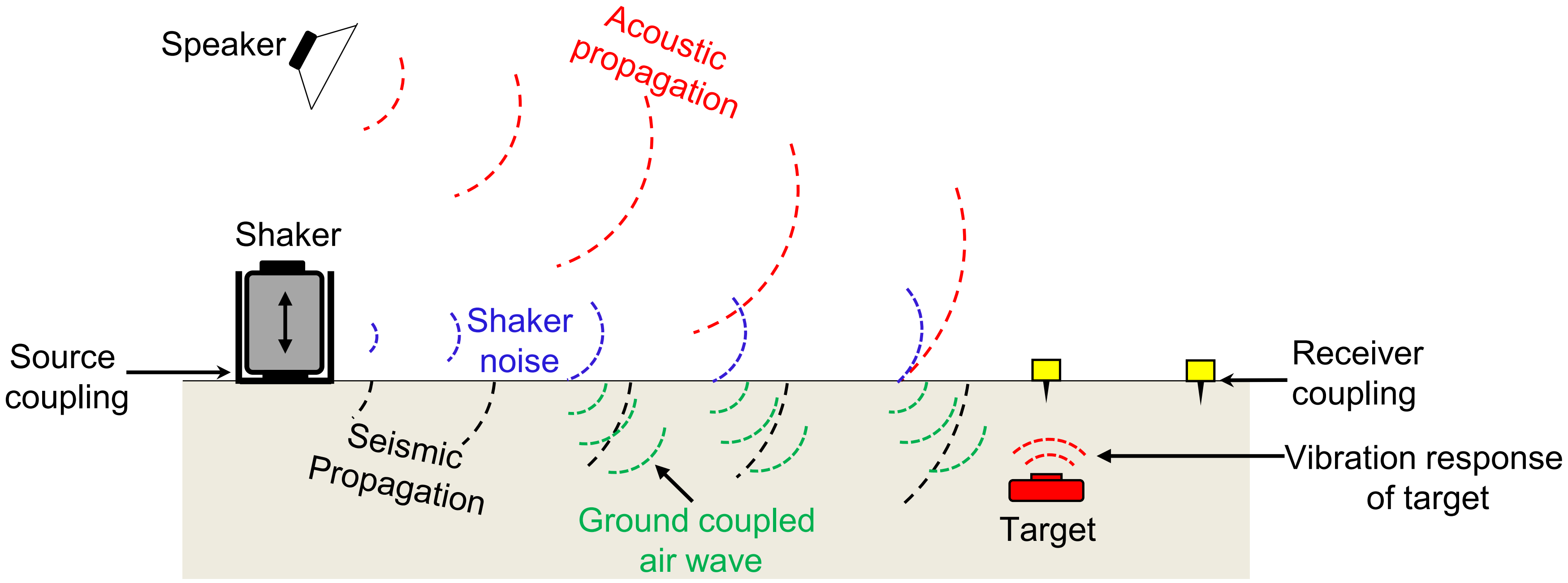
Acknowledgments

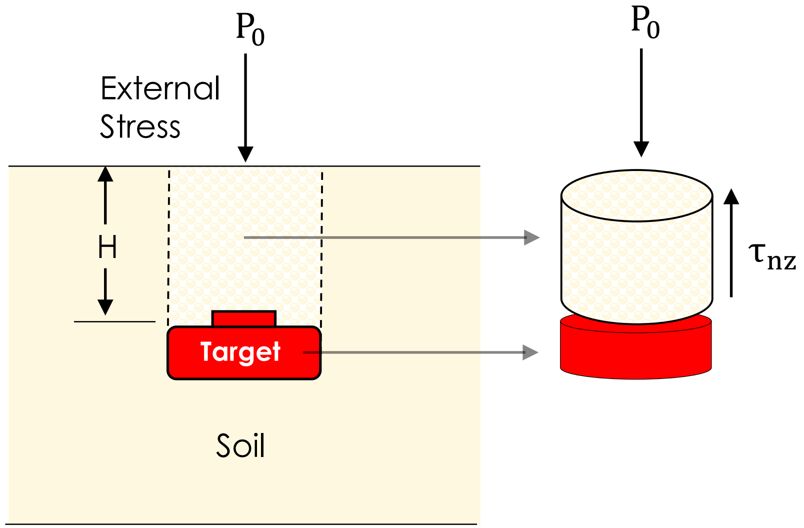
1. Introduction: Seismic and Acoustic Excitation

- **Acoustic excitation**: vibration of the ground is due to ground-coupled air wave (the coupling is local in space and deformation of the ground surface is predominantly perpendicular to the surface)
- **Seismic excitation**: in contact with the surface and produces various seismic waves. Majority of the energy and largest deformation is associated with surface waves. Strongly dependent on soil conditions.



2. Coupled soil-mine system / mine detection

✓ The mine influences the dynamics of the supported soil column; therefore, soil and mine must be treated as a dynamically coupled soil-mine system.



Mine

M_m = mine mass (inertia)
K_m = compression stiffness of the mine
R_m = damping associated with mine compression

Soil: compression

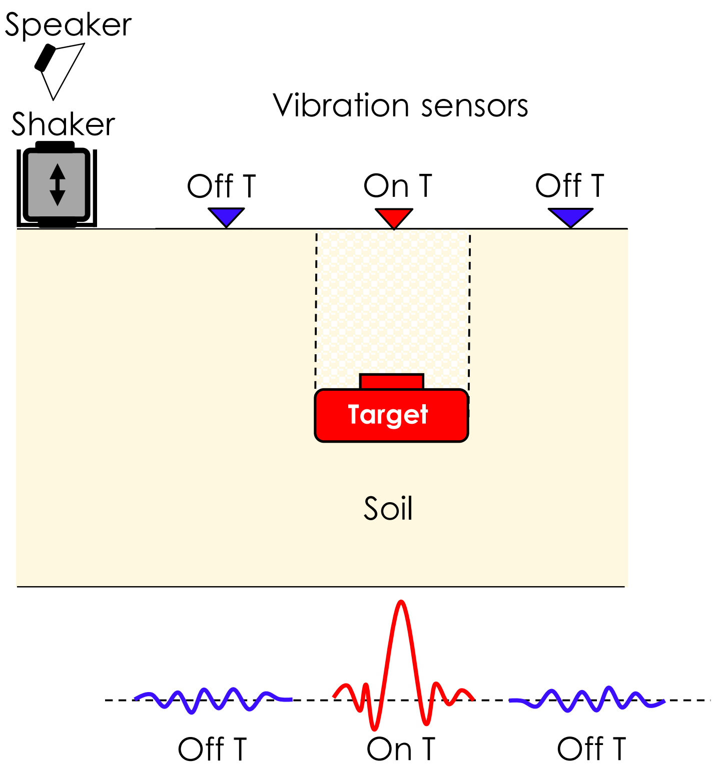
M_s = soil mass (inertia) $\cong \rho AH$
ρ = density of the soil
A = effective area of the upper compliant diaphragm
H = burial depth
K_{s2} = compression stiffness of the soil
R_{s2} = damping associated with soil compression

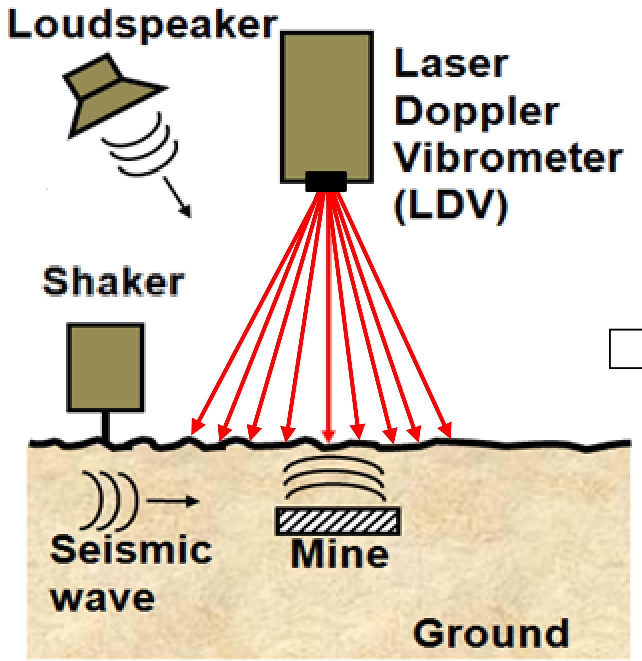
Soil: resisting shear stress (τ_{nz})

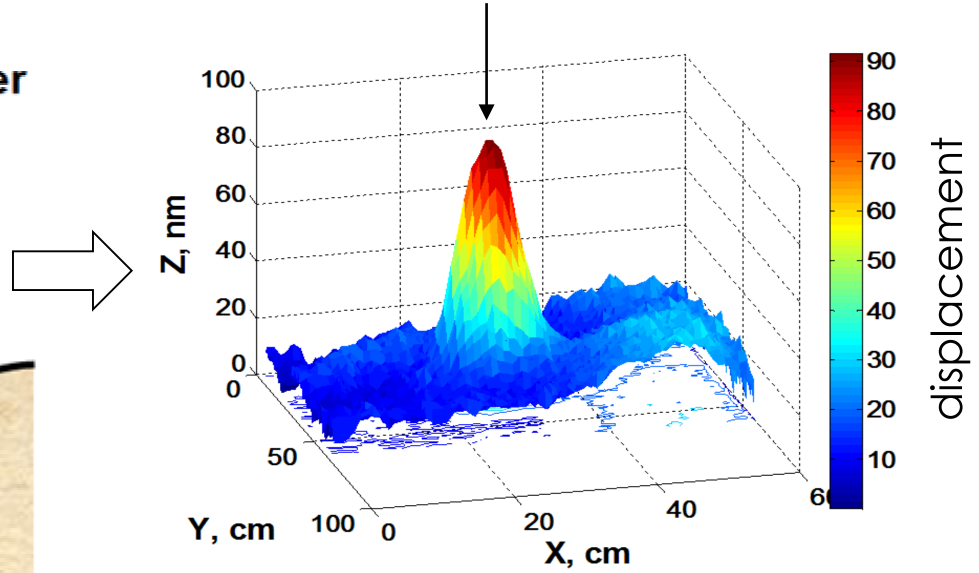
K_{s1} = soil shear resistance (stiffness)
R_{s1} = damping associated with soil shear deformation

2. Coupled soil-mine system / mine detection

✓ When soil is excited with acoustic or seismic waves, it vibrates directly above a buried mine with a greater amplitude than the surrounding soil.







3. Objective

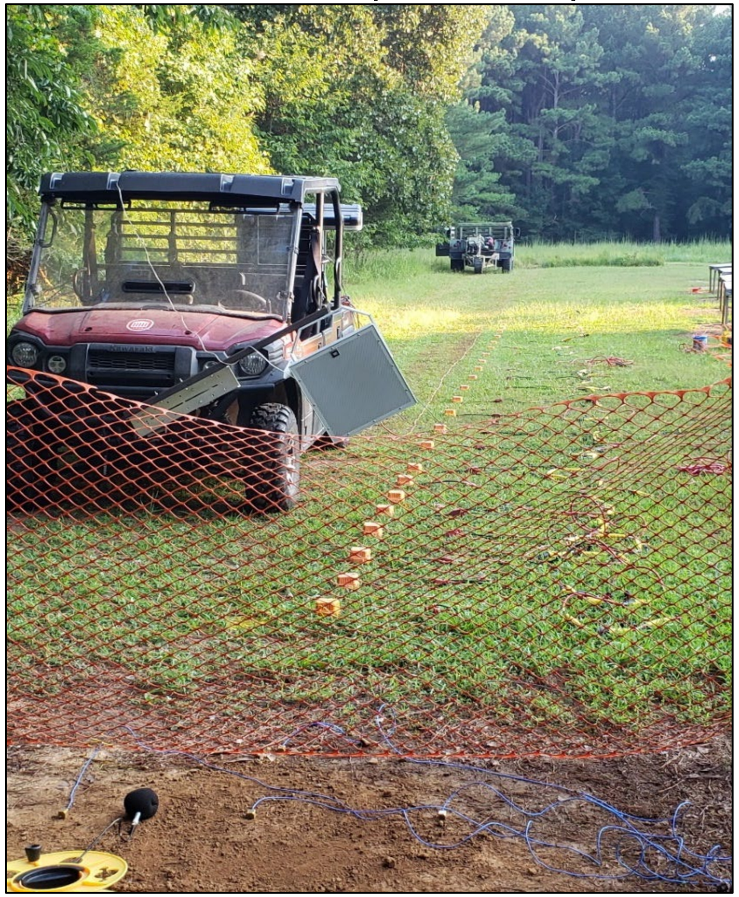
- Factors that affect the response of a buried object to ground excitation include:
  - ✓ type of ground excitation (source type),
  - ✓ soil type,
  - ✓ burial depth,
  - ✓ and type of the buried object (elastic properties).

Therefore, *understanding the response of buried objects is required for a high probability of detection*.

In this study, we study the response of a buried object to acoustic and seismic ground excitations in different soil types and burial depths.

4. Study sites: Audi Acres, Oxford, MS

Grass site (silt loam)



✓ Undisturbed with no vehicular traffic.

	Grass Site	
	P-wave	S-wave
V1	252 m/s	169 m/s
V2	680 m/s	325 m/s
z	1.3 m	2.3 m
Density	≈1600 Kg/m³	

	Limestone Site	
	P-wave	S-wave
V1	355 m/s	275 m/s
V2	703 m/s	210 m/s
z	0.9 m	0.8 m
Density	≈1900 Kg/m³	

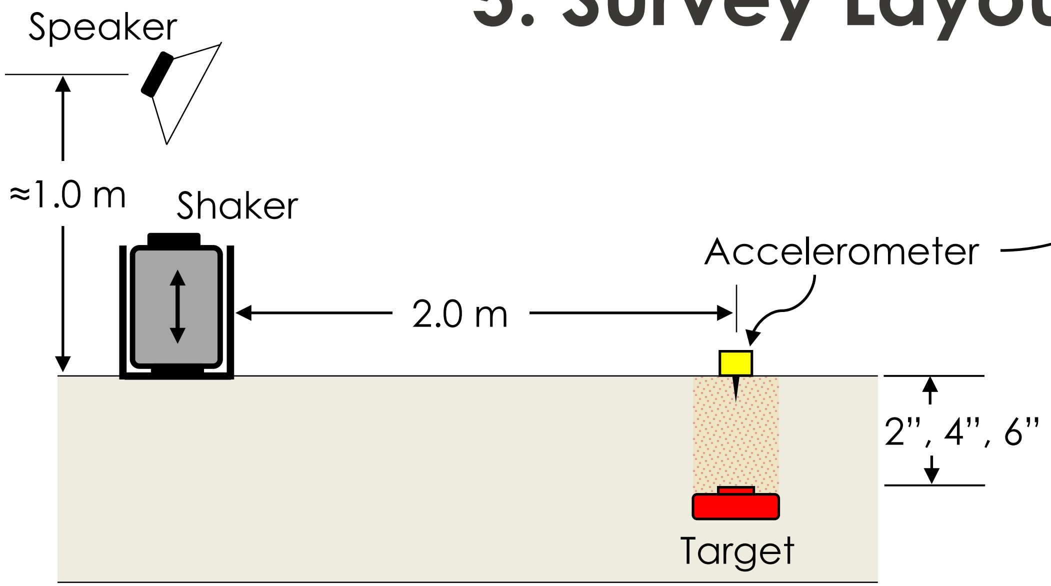
P-wave - using refraction
S-wave – using MASW

✓ It is expected that the hard limestone site has lower ground vibration levels and better shaker coupling.

Limestone site

✓ Constructed more than 15yrs ago as a research site for detecting buried objects.

5. Survey Layout and Specifications



Side view

top view

Target is a VS2.2

- Plastic (RF = 101 Hz in air)
- Dia. = 240 mm, H = 120 mm
- 3.5 Kg (main charge = 2.13 Kg)

Sensor specifications

- ✓ Triaxial, high sensitivity, ceramic shear ICP® accelerometer (356B18)
- ✓ Sensitivity: 1000mV/g

Source specifications

➢ JLB Professional Speaker: model AWC15LF

- Frequency range: 45 Hz – 2.2 kHz
- Maximum SPL:121 dB (peak 127dB)
- Increasing SPL from 20-100Hz then flat to 1kHz

Input signal

- 5 second linear sweep 45Hz – 180Hz
- SPL level @ 1m offset = 110 dB

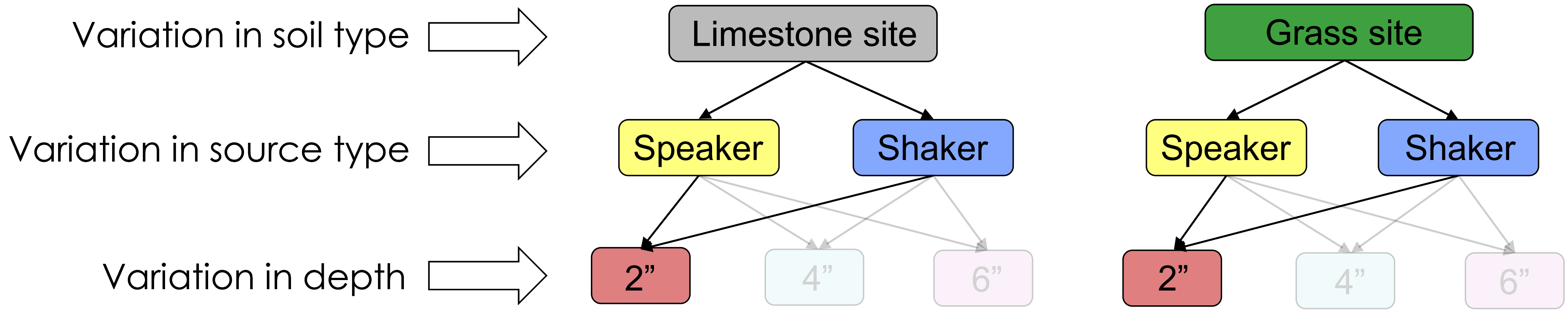
➢ Vibration Test System (VTS), Model VG-100-6

- Frequency range: DC – 6.5 kHz
- Peak force = 110 lbs.

Input signal

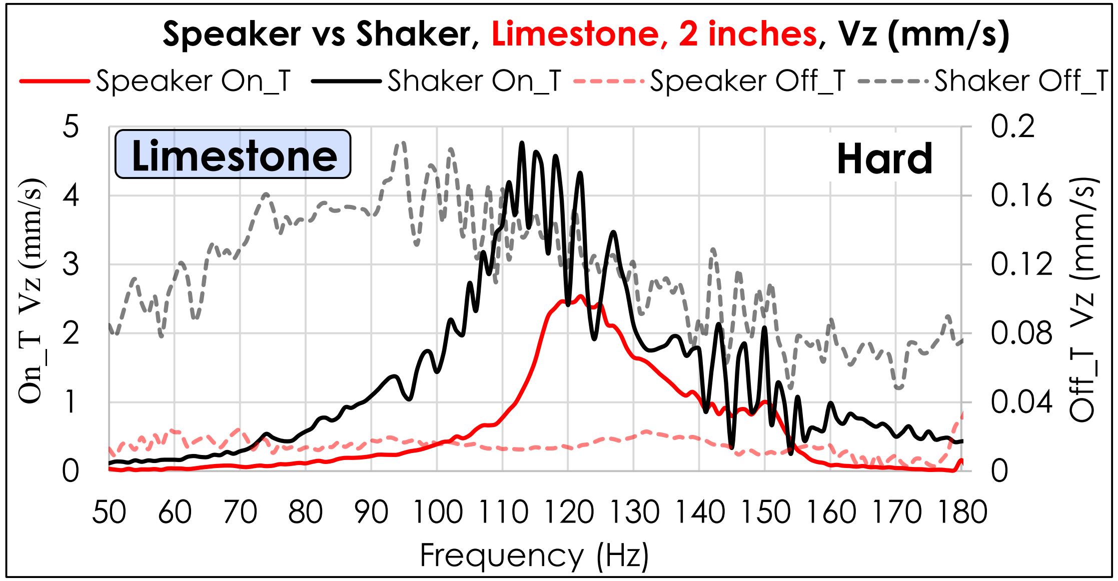
- 5 second linear sweep 45Hz – 180Hz
- Velocity @ 1m offset = 0. 5μm/s

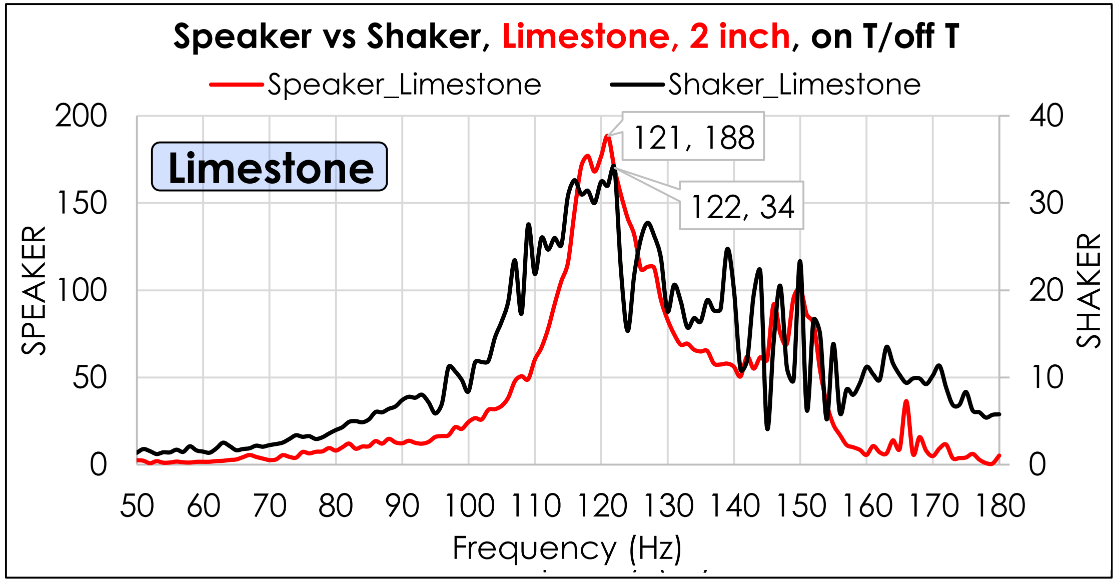
6. Results

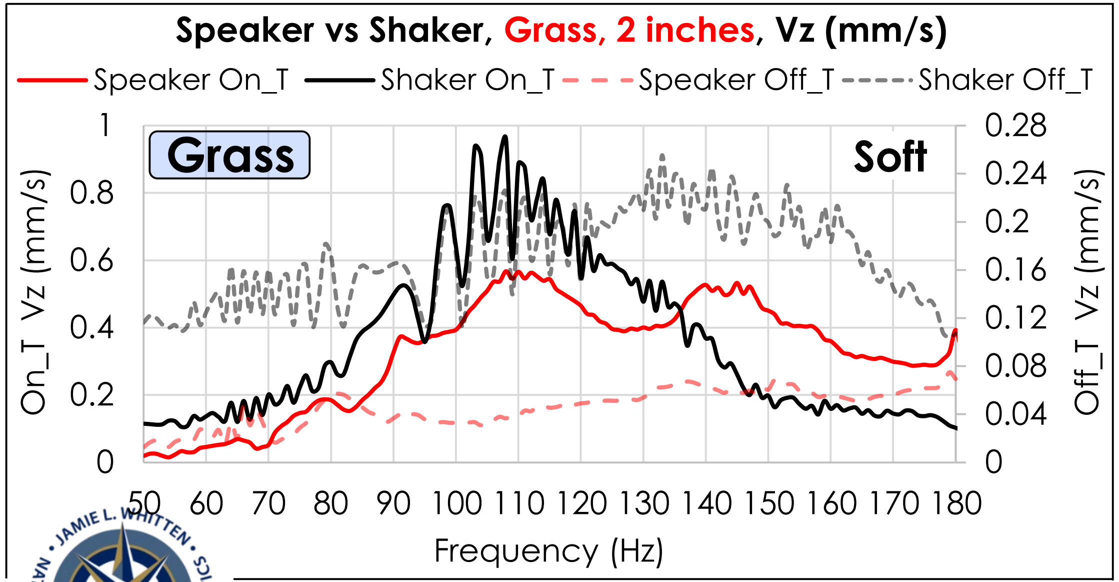


Two source types → Two soil types → One depth

6.1 Results: variation in source (looking at 2" depth)

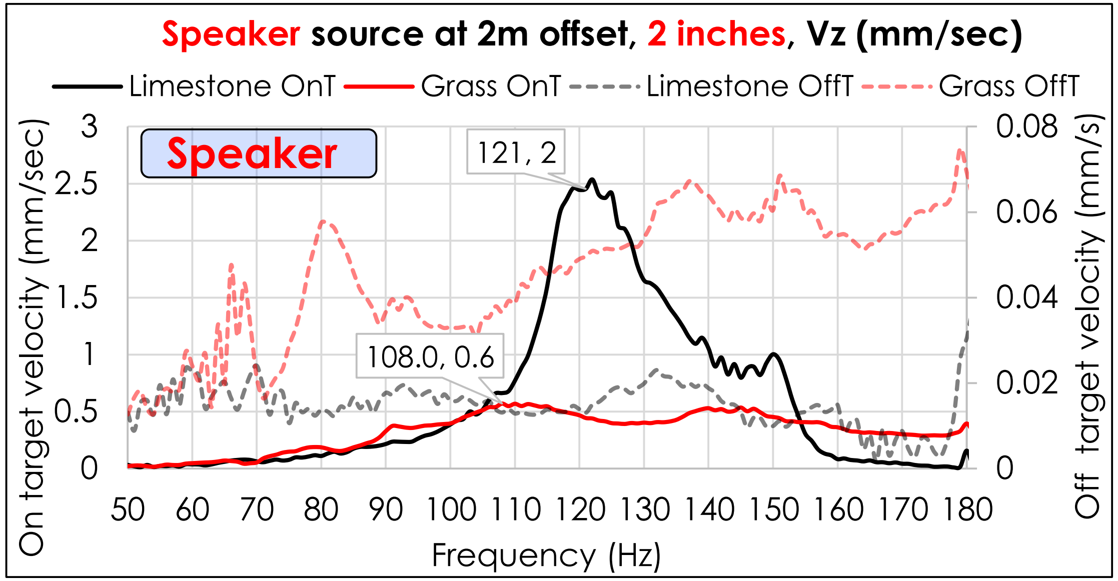


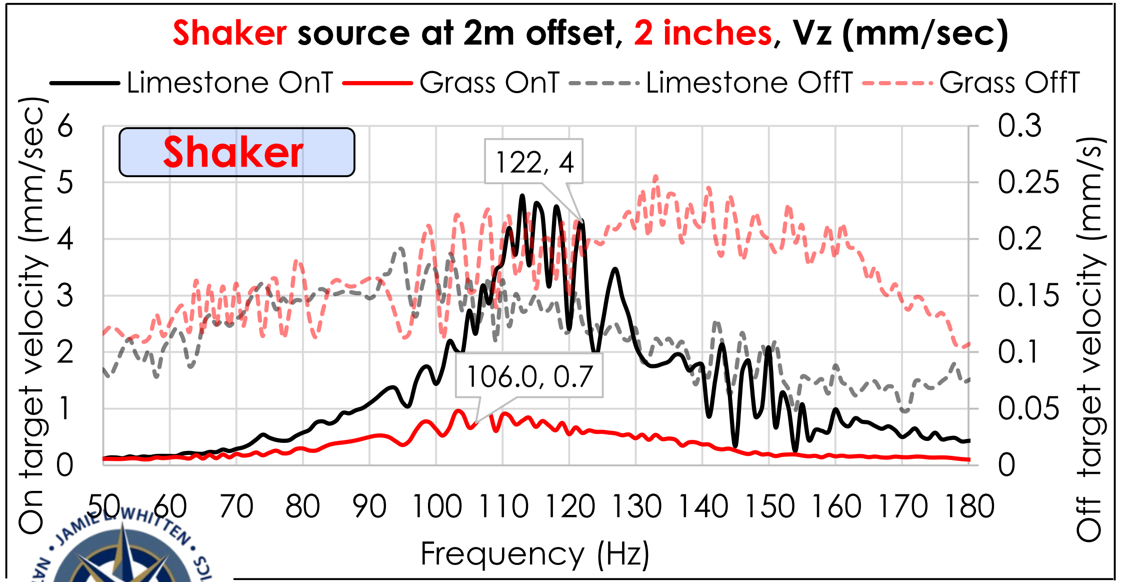




- For both soil types, the shaker produces higher ground vibration than the speaker source.
  - ✓ The level of difference in vibration is more off target compared to on target.
- For both soil types, the speaker source has higher On T/Off T ratio.
  - ✓ This is due to the low off T vibration level from the speaker.
- In both soil types, similar resonant frequency (RF) values are observed from both sources.

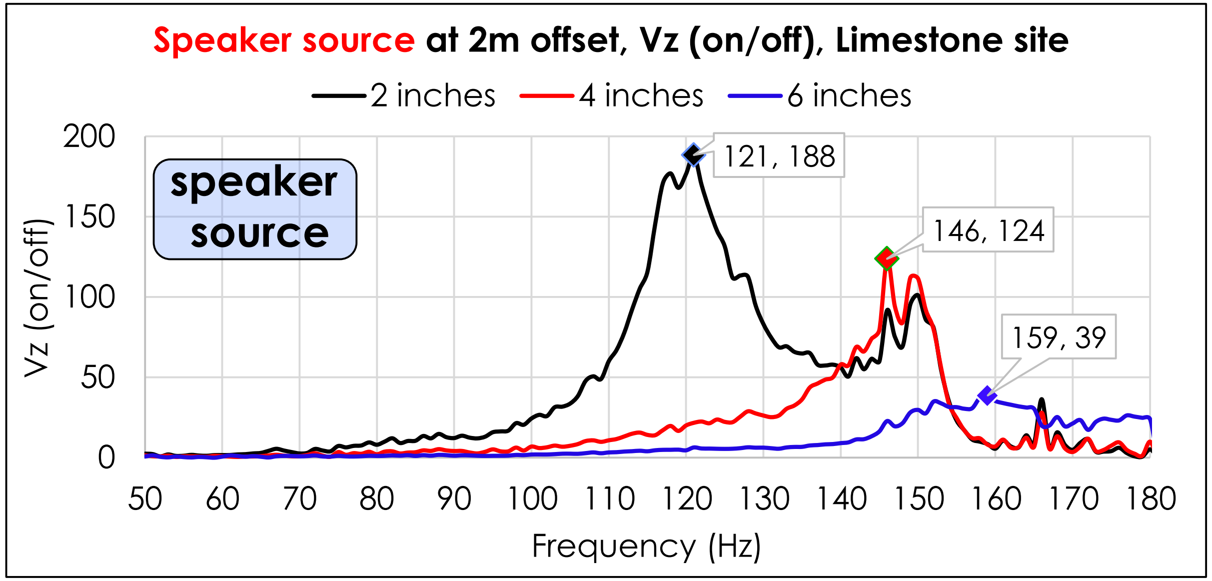
6.2 Results: variation in soil type (looking at 2” depth)

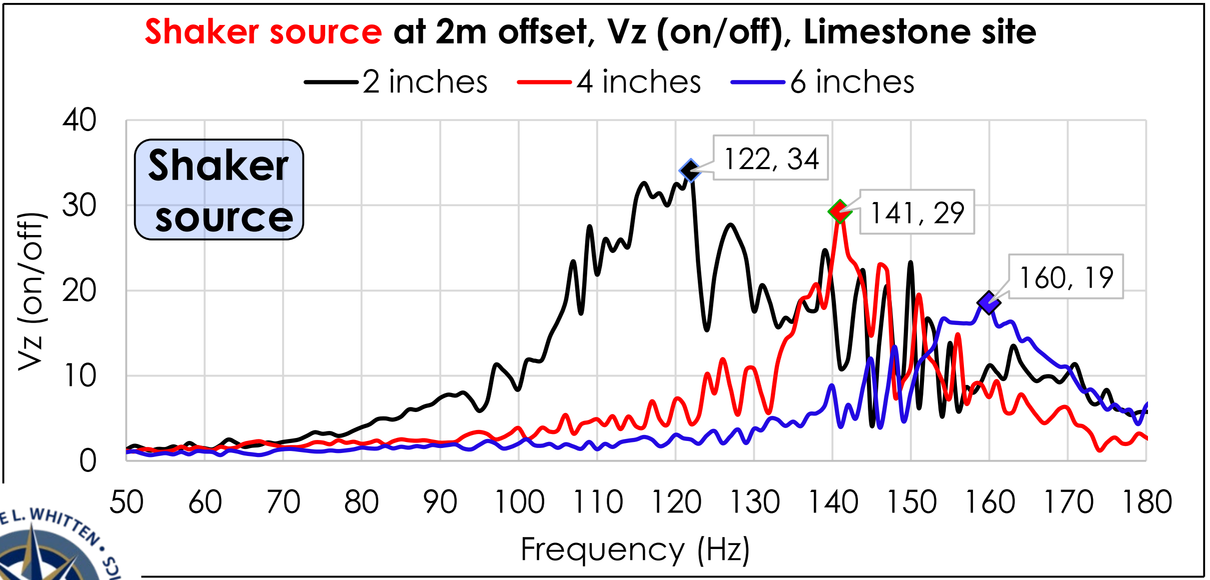




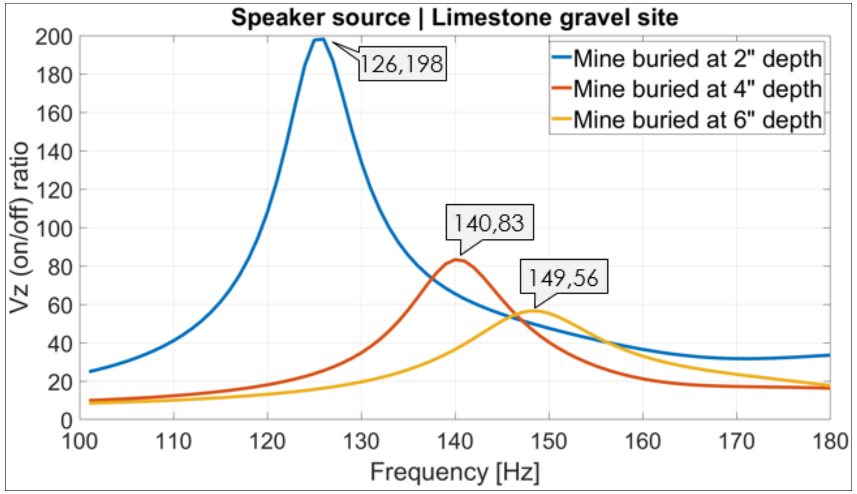
- The off target vibration levels are lower in the hard soil compared to the vibrations in the soft soil.
  - ✓ This is observed above 70Hz in the speaker, and above 110Hz for the shaker.
- The on target vibration levels are higher in the hard soil compared to the vibrations in the soft soil.
- The resonant frequency (RF) in the limestone (hard) soil is higher compared to the RF in the grass (soft) soil.
- The On T /Off T ratios at RF are higher in the limestone.
  - ✓ This is due to the higher on target and lower off target vibration levels in the limestone.

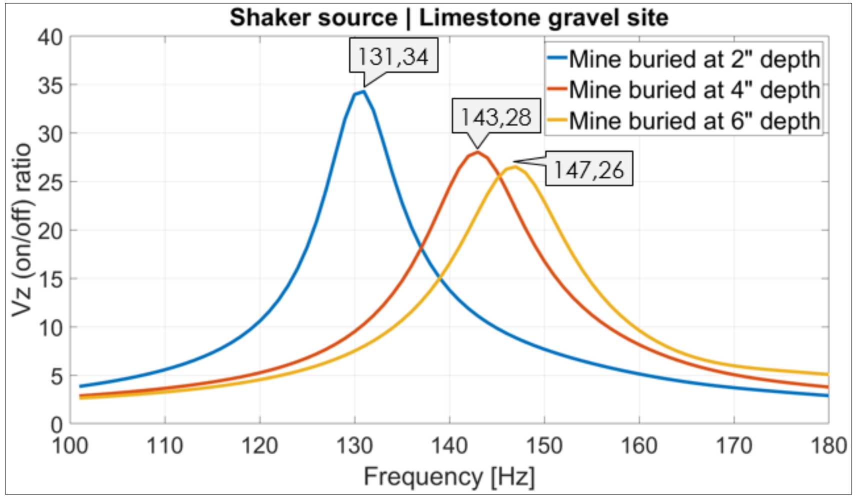
6.3 Results: variation in depth (Limestone site)





COMSOL modeling results





7. Conclusions

Variation in source type

- At 2m spacing, the seismic source generates higher on and off-target vibration levels for both soil types.
  - ✓ *As the source offset increases, the seismic source will generate less vibration at the mine due to attenuation.*
- Although the seismic source generated more vibration, for both soil types, the speaker source has higher On T/Off T ratio.
  - ✓ *This is due to the low Off T vibration level from the speaker.*

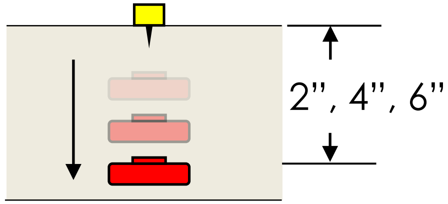
Variation in soil type

Soft

Hard

- Resonant frequency (RF) ⇨ Higher in limestone (hard) soil
- Off target vibration ⇨ Higher in grass (soft) soil
- On target vibration ⇨ Higher in limestone (hard) soil

Variation in depth



- Regardless of source or soil type and with increase in depth
  - ✓ ground vibration level as well as on T/Off T ratio decreases,
  - ✓ resonant frequency increases with depth.

Acknowledgment

This research is sponsored by the Department of the Navy, Office of Naval Research under ONR award number N00014-18-2489. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the Office of Naval Research.

Thank you!

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