

Department of Civil, Chemical, Environmental, and Materials Engineering (DICAM)

Yearly Assessment Presentation

STRUCTURAL AND ENVIRONMENTAL HEALTH MONITORING AND MANAGEMENT (SEHM2) – XXXIII CYCLE

“Metamaterials for seismic waves control”

Candidate: **Farhad Zeighami**

Advisor: **Prof. Alessandro Marzani**

Co-Advisor: **Dott. Ing. Antonio Palermo**

October 22nd, 2019

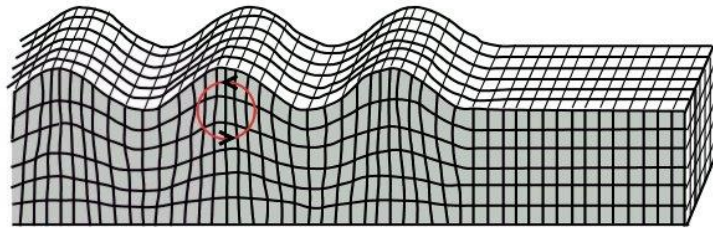
Outline

1. Introduction
2. Main Research Activities:
 - 2.2. Surface elastic waves in bulk metamaterials.
 - 2.3. Resonant metamaterial-based earthquake risk mitigation of large-scale structures and infrastructure systems ([ReWarD Project](#)).
3. Research Outcomes
4. Research Outlook

Elastic surface waves

Vertical polarization

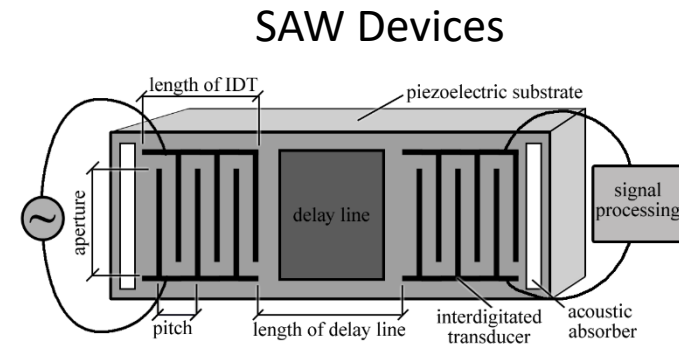
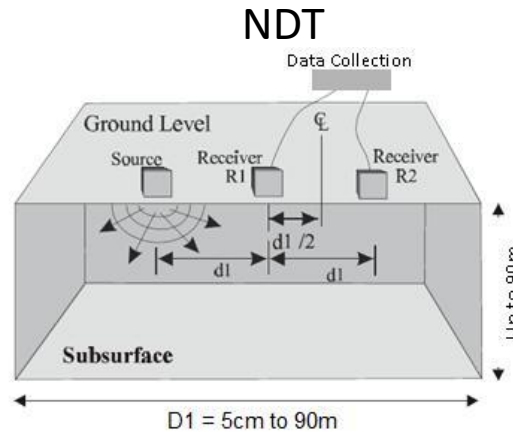
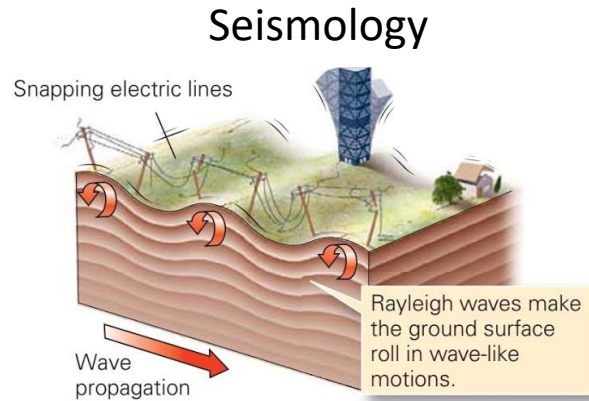
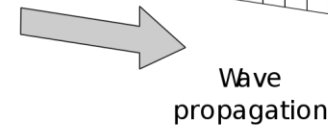
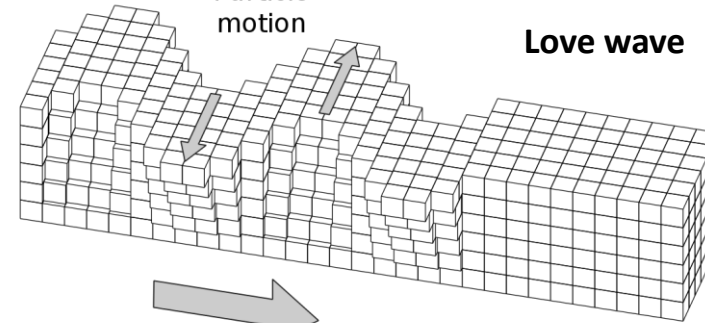
Rayleigh Wave



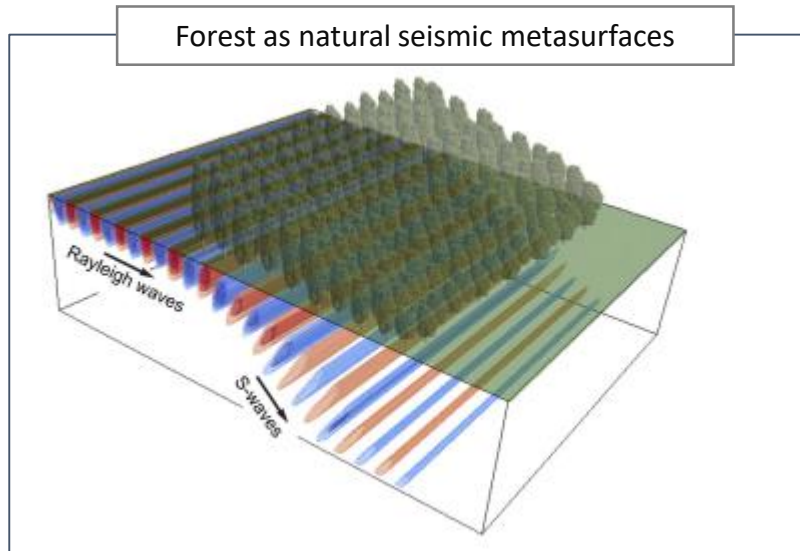
Horizontal polarization

Particle motion

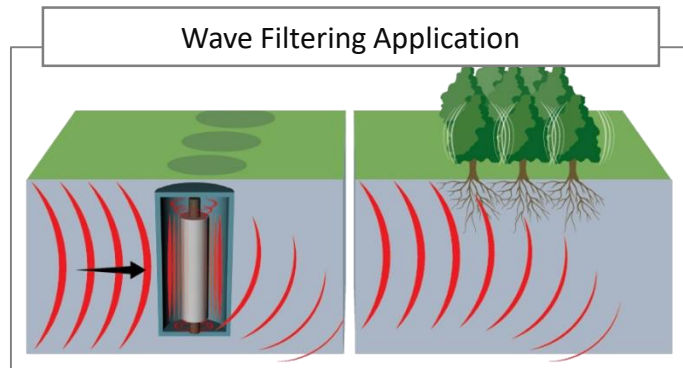
Love wave



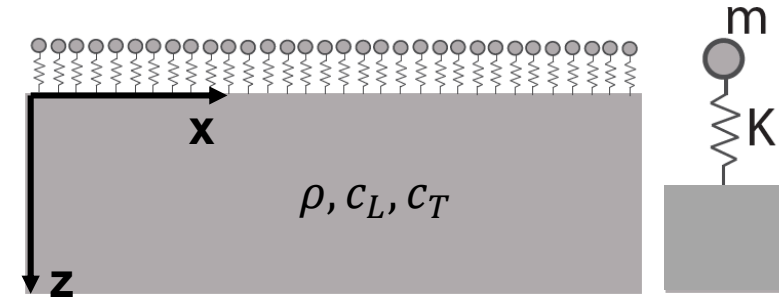
Natural/Engineered metamaterials for the control of seismic waves



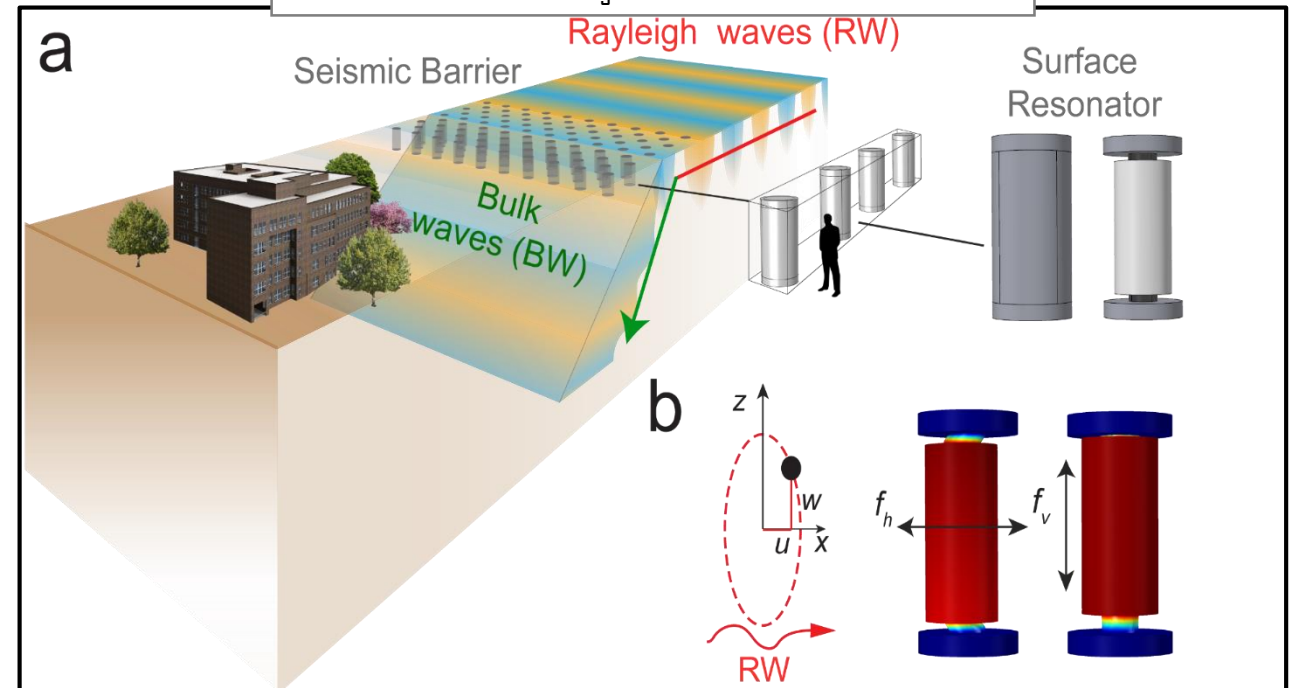
Colombi et al., Sci. Rep. (2016)



K. Ravilius, New Sci. (2016).



Metabarrier for seismic wave-ground borne vibrations



Palermo et al., Sci. Rep. (2016)

Metamaterials for Seismic waves: Limits

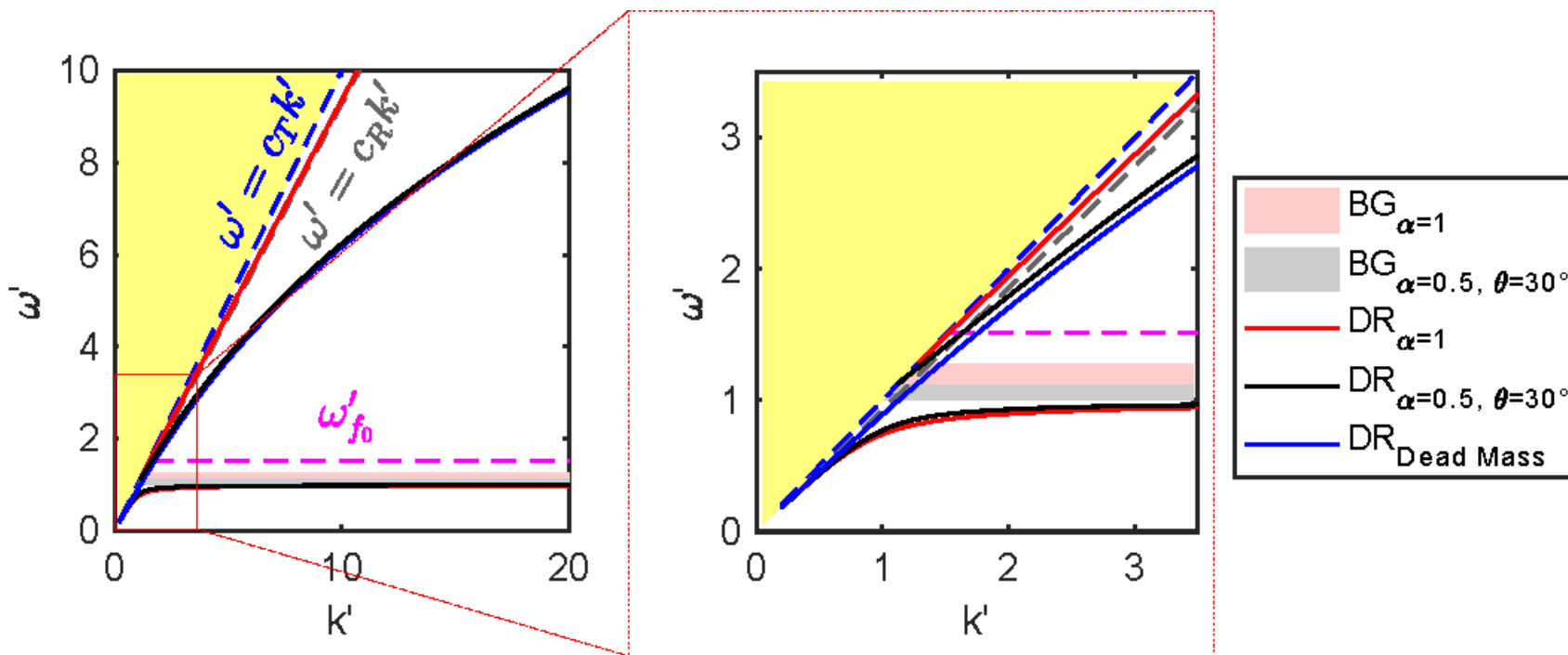
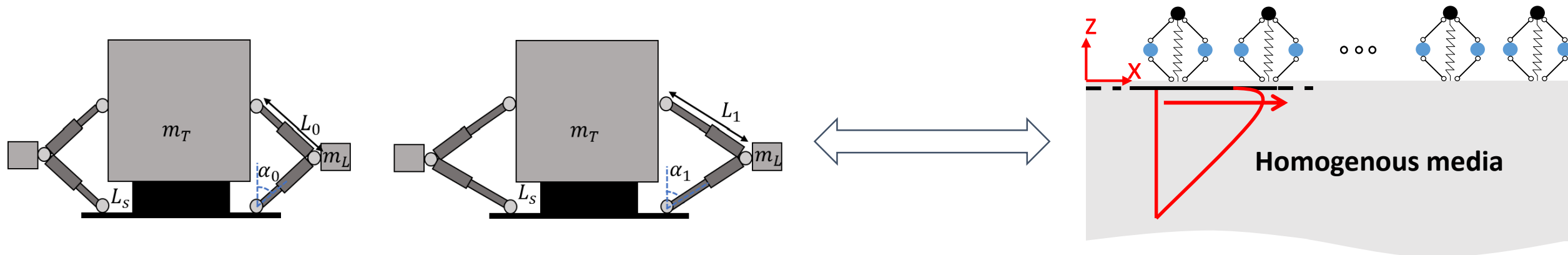
Physics and engineering problems

Challenges:

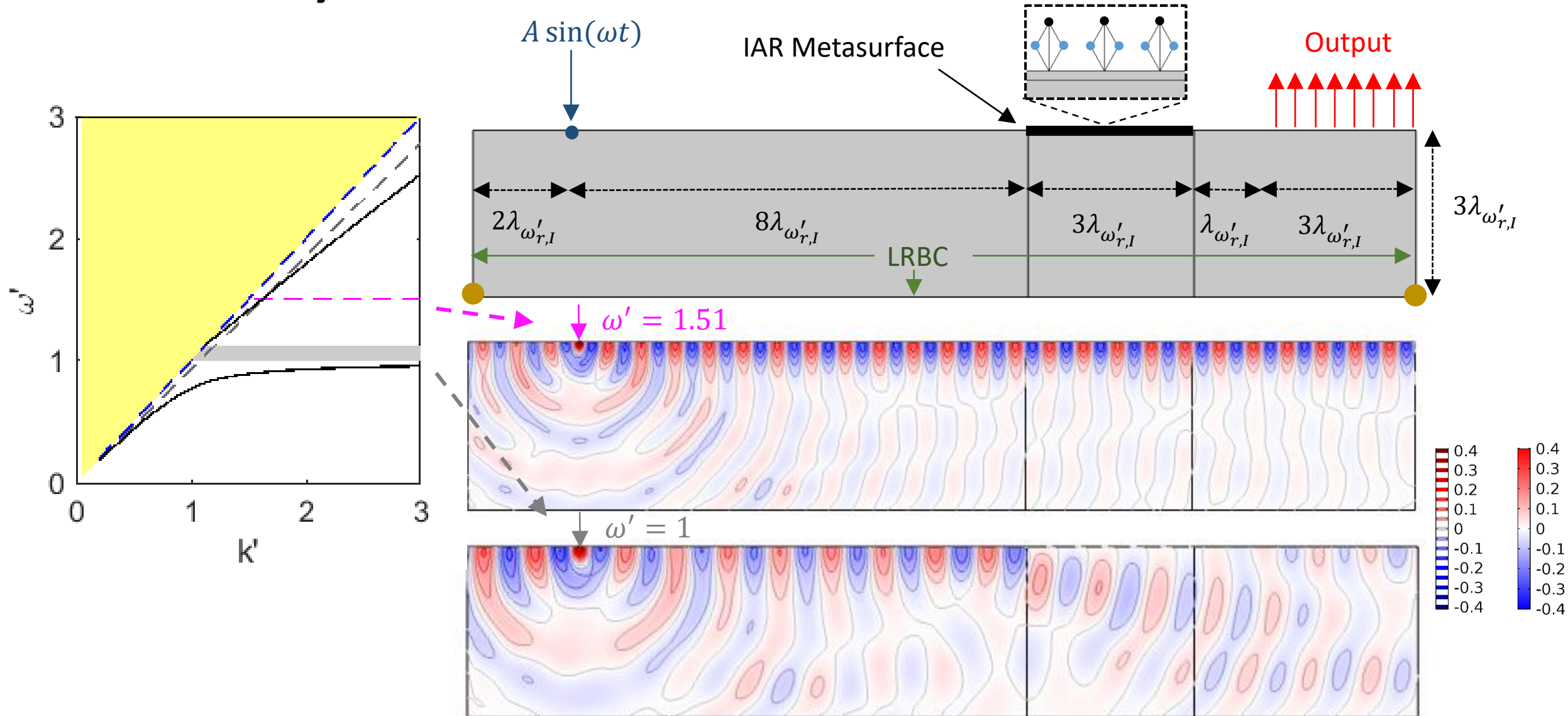
1. Advanced Resonator design:
 - Tunability
 - Optimal Geometry: minimal mass - minimal dimensions
 - Material: ultimate strength and non-linearity

→ IAR metasurface
2. Effect of the metabarrier thickness
→ Bulk metamaterials
3. Effects of material inhomogeneity (soil stratigraphy, topography, etc.)
→ ReWarD Project
4. Experiments (tabletop, medium-scaled and seismic scale tests)
→ ReWarD Project

Inertial Amplified Resonator (IAR) as a tunable metasurface

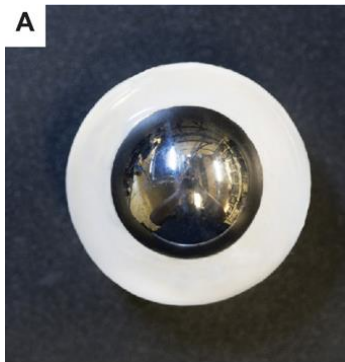


Harmonic Analysis of IAR metasurface



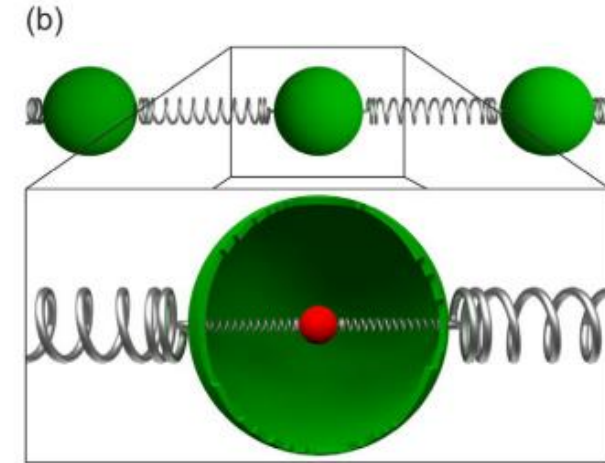
Engineered metamaterials for wave manipulation

Locally resonant materials

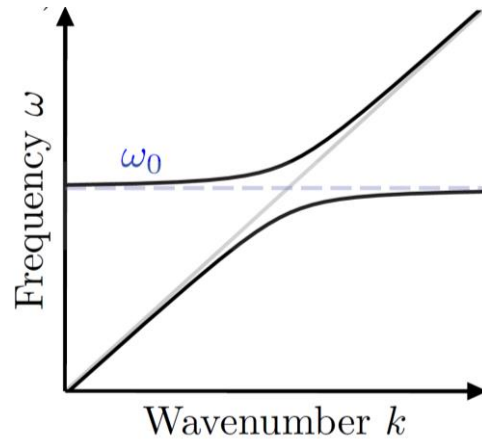


Liu, Science (2000)

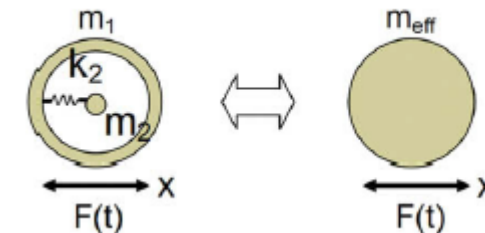
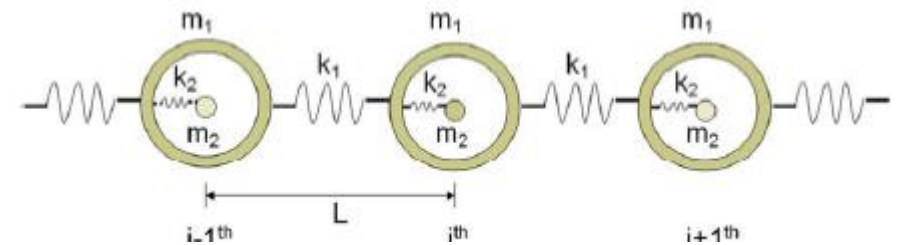
Mass-in-mass chain



Muamer Kadic et al Rep. Prog. Phys. (2013)

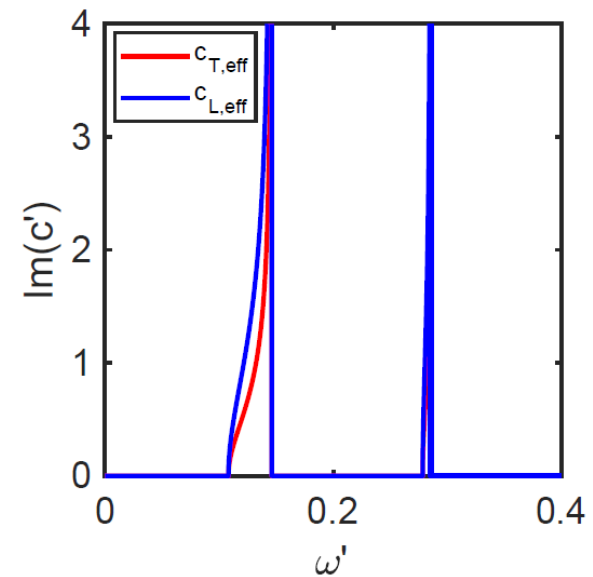
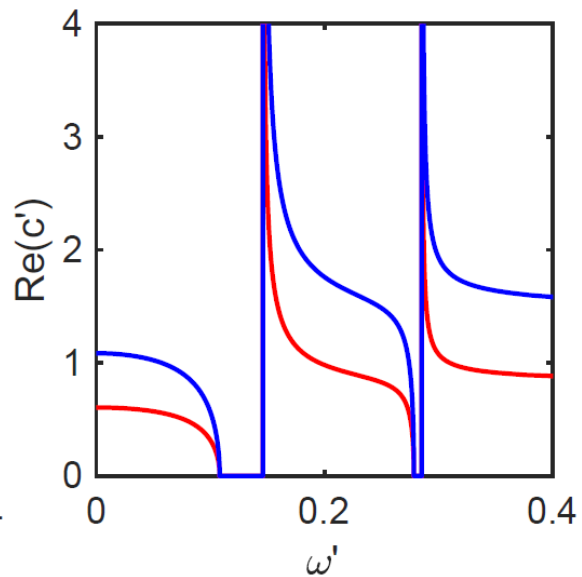
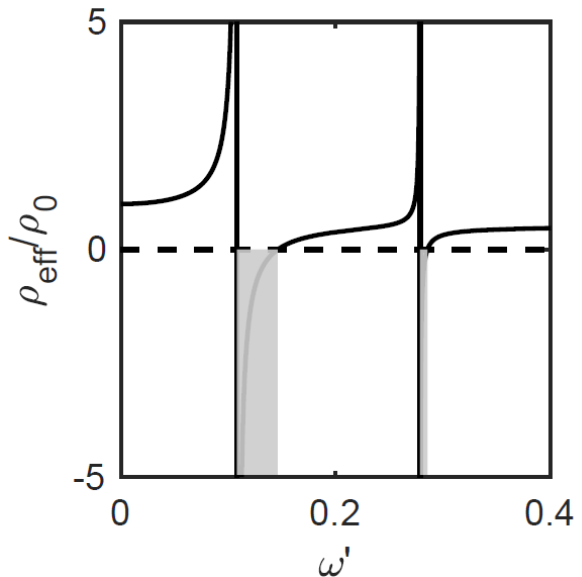
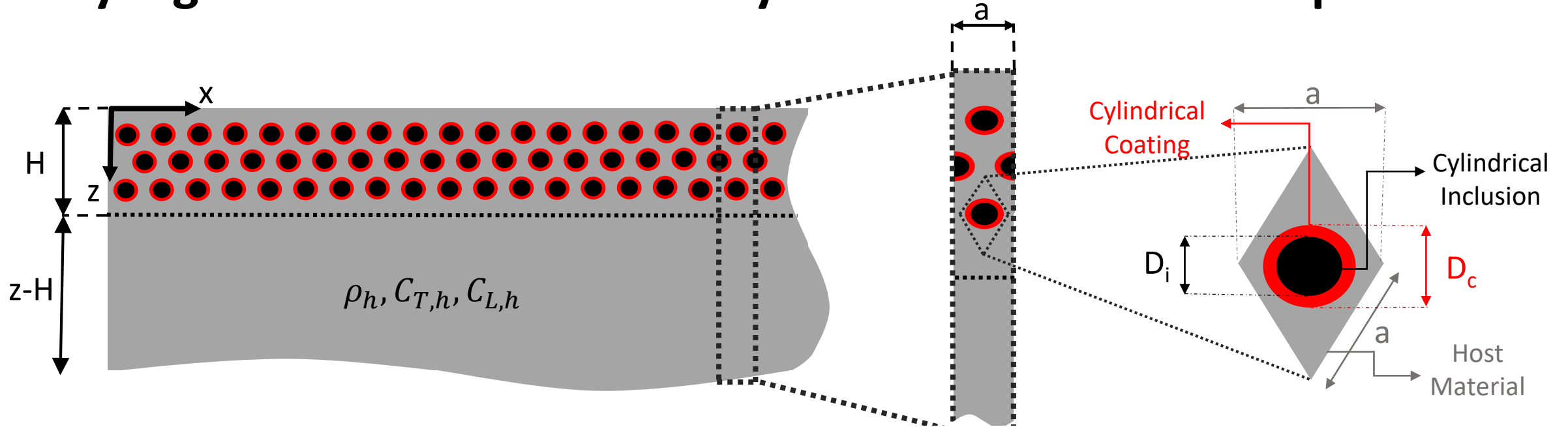


S. Huber, Lectures on Metamaterials (2018)

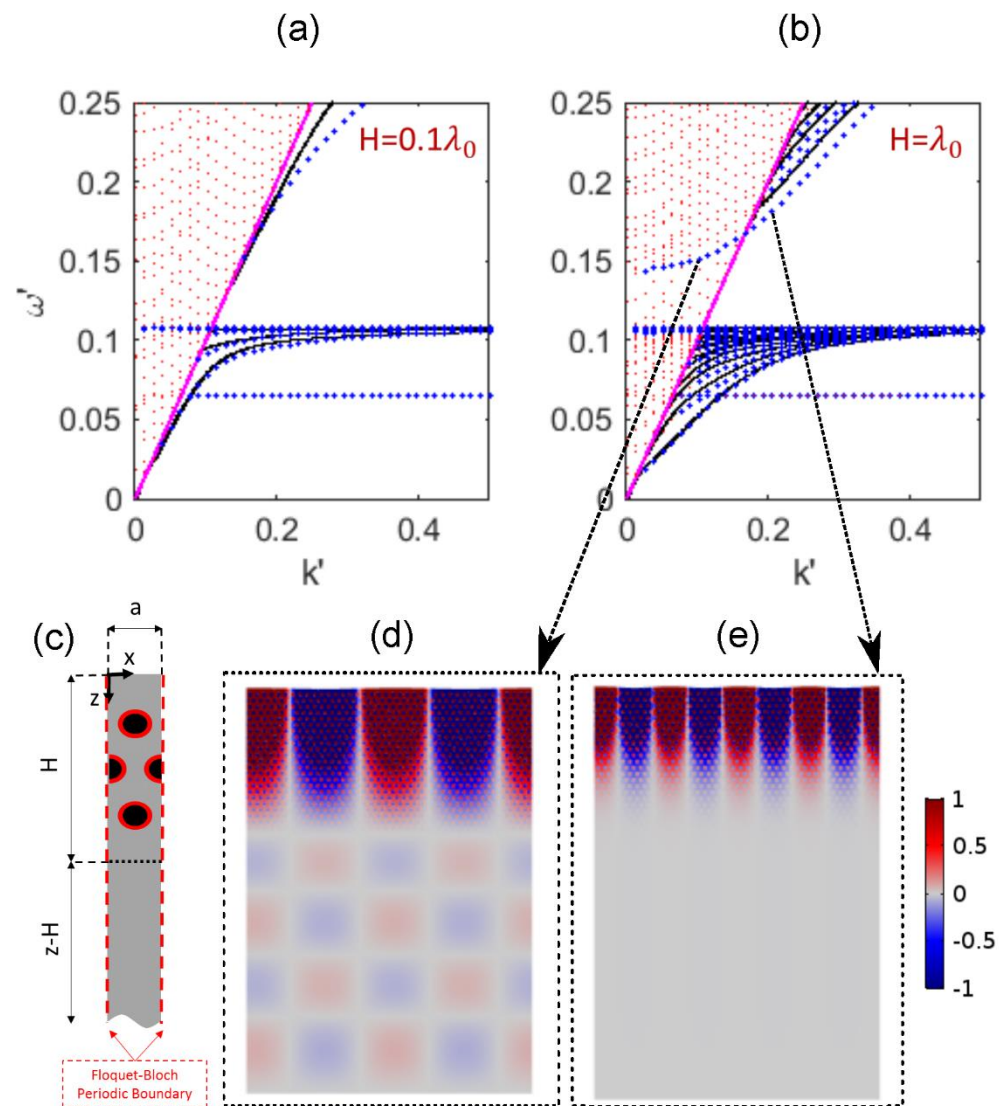
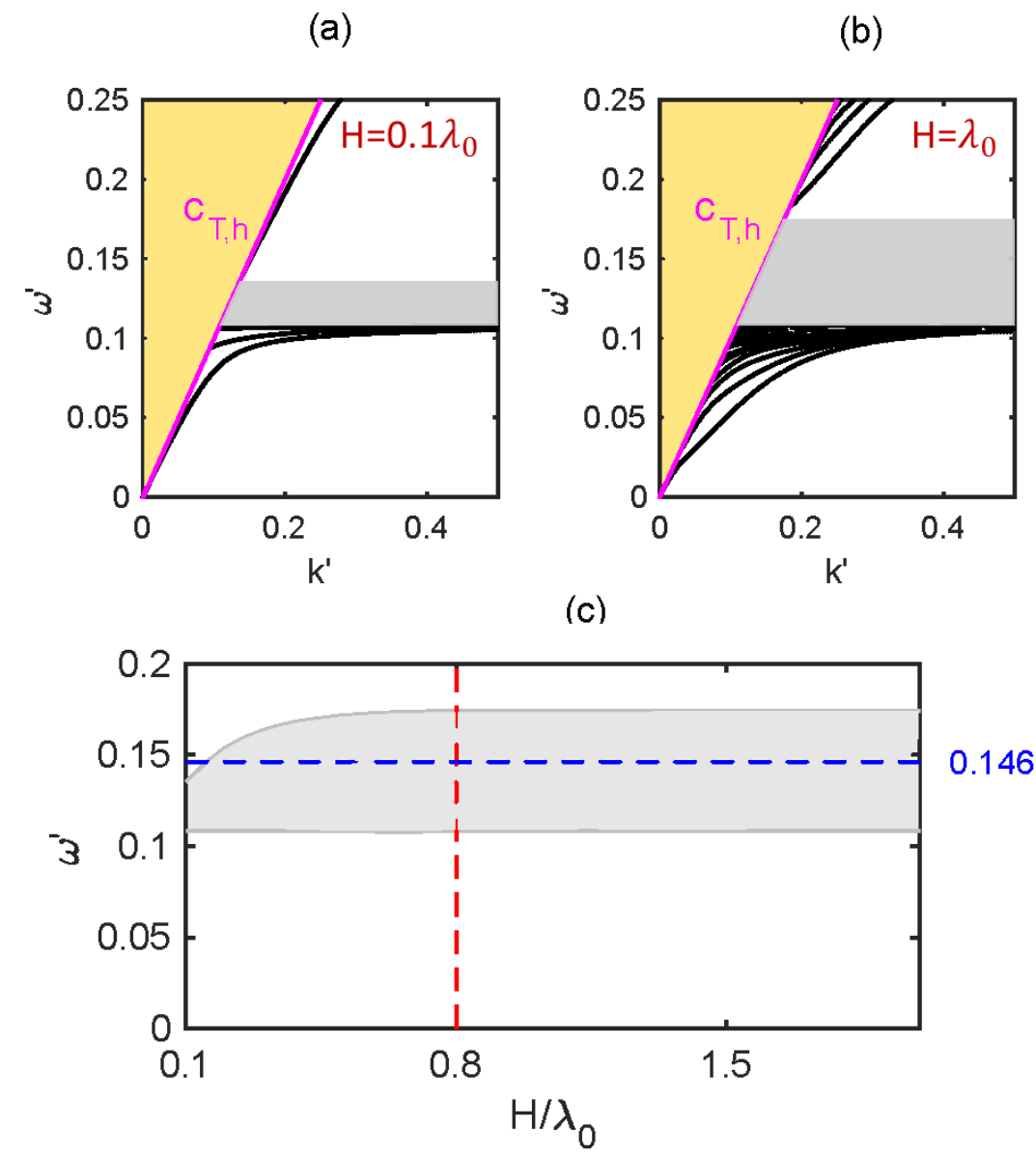


Huang et al Int. Journal of Engineering Science. (2013)

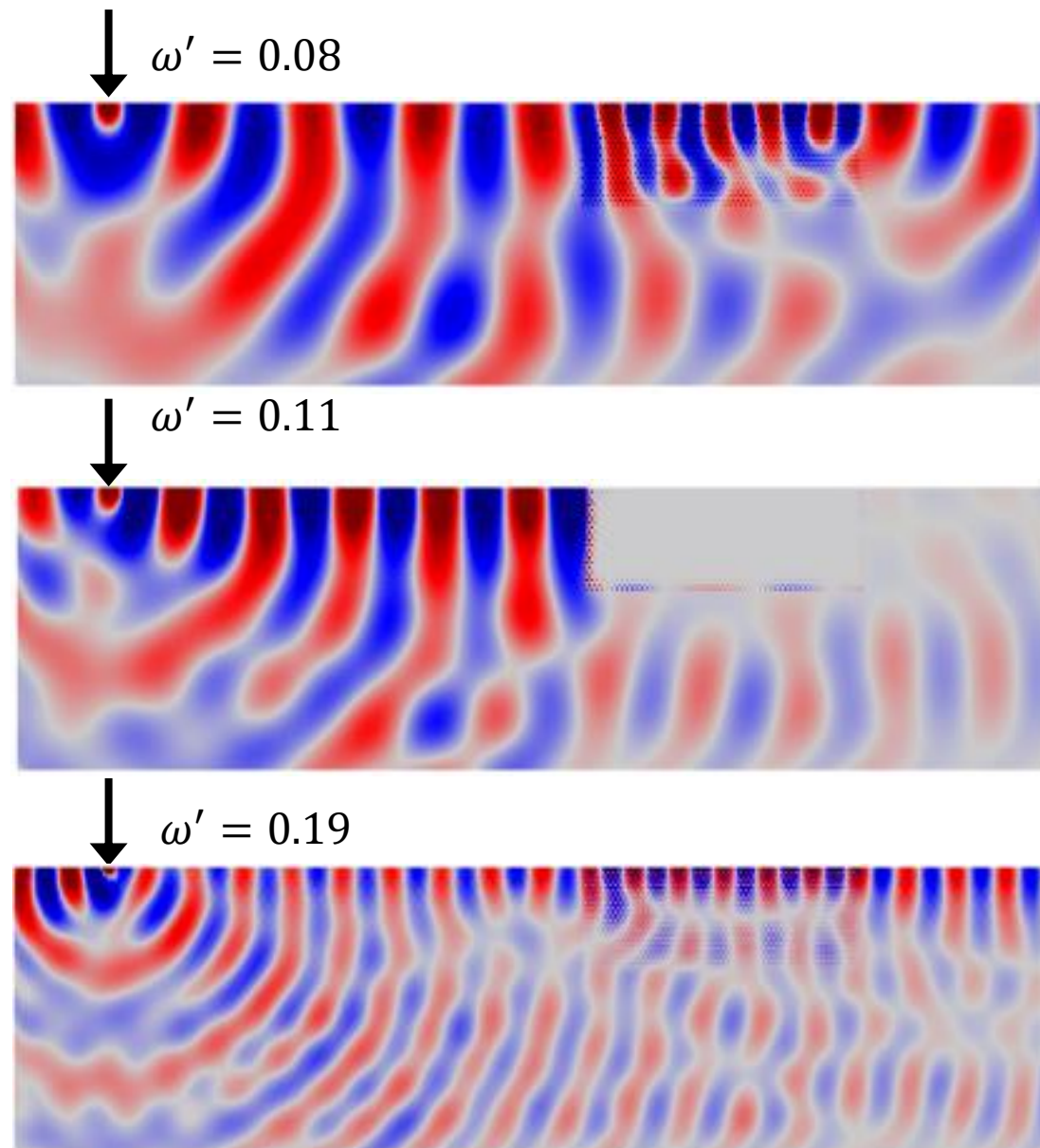
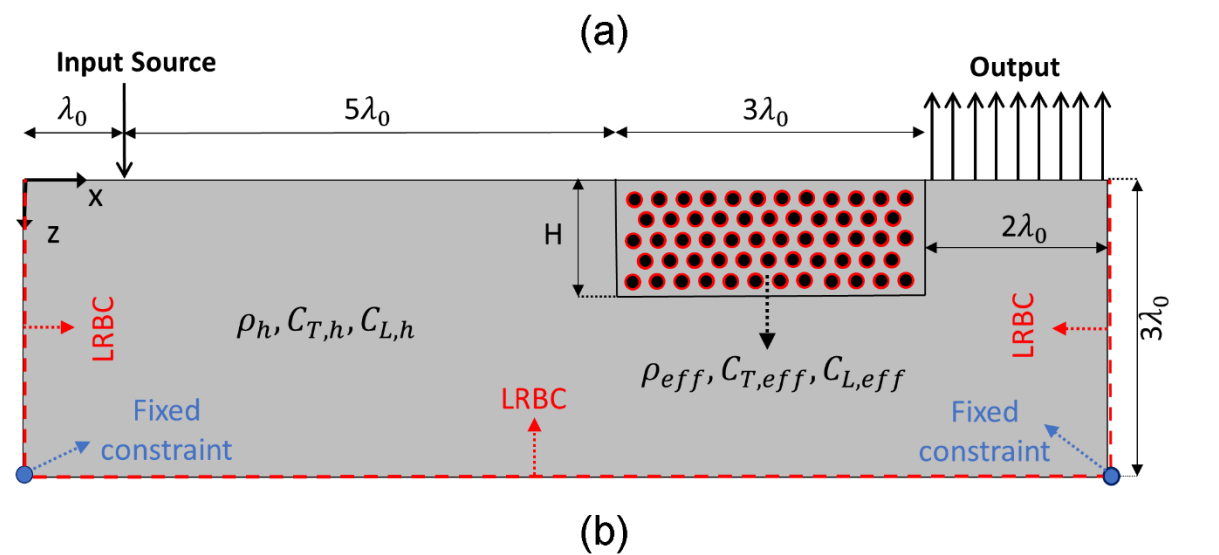
Rayleigh waves in a resonant layer over an elastic half-space



Dispersion relation of a resonant layer over elastic half-space

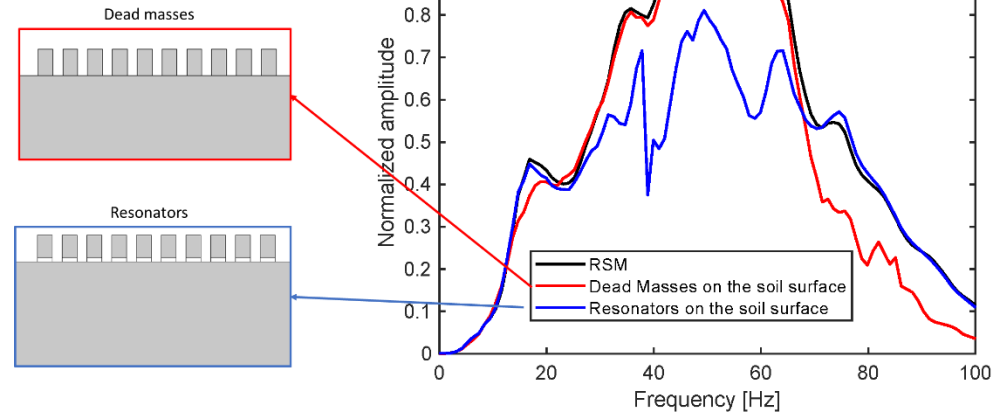
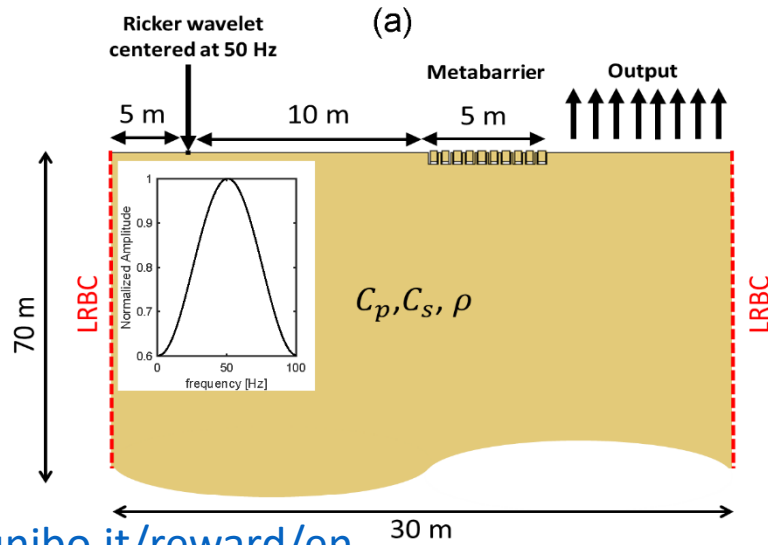
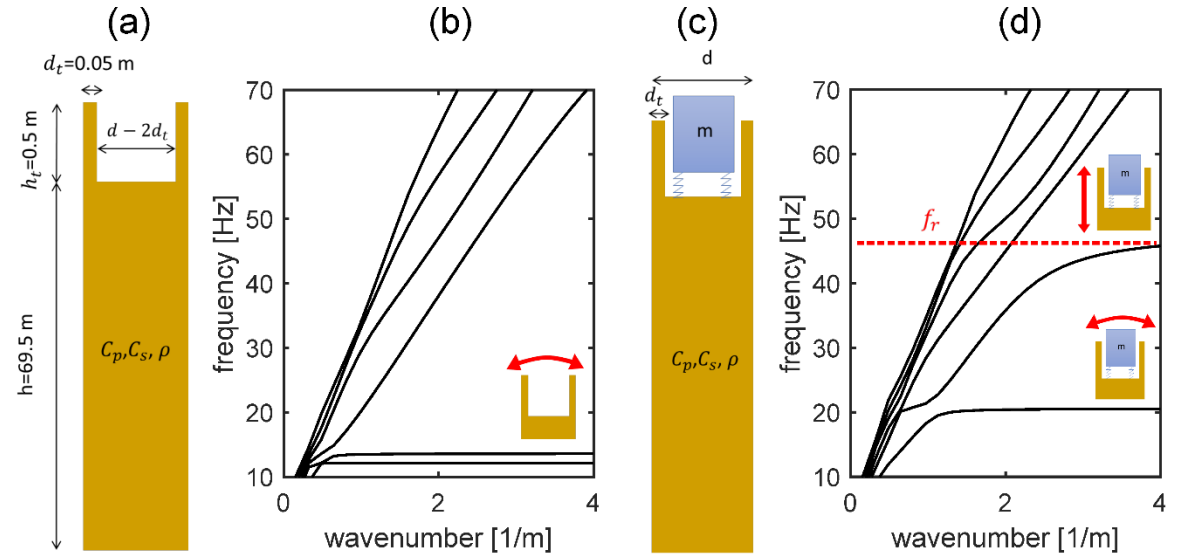
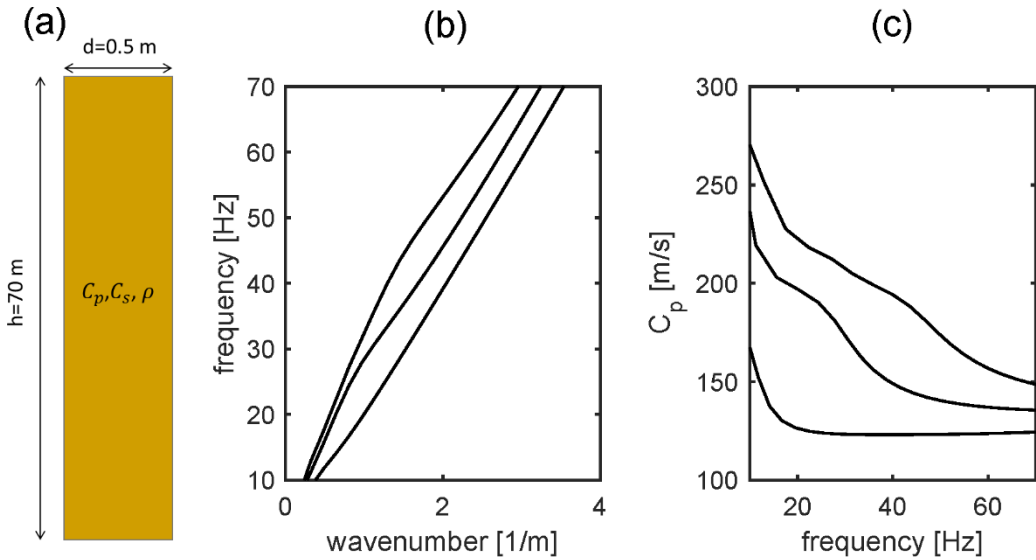


Transmission Coefficient



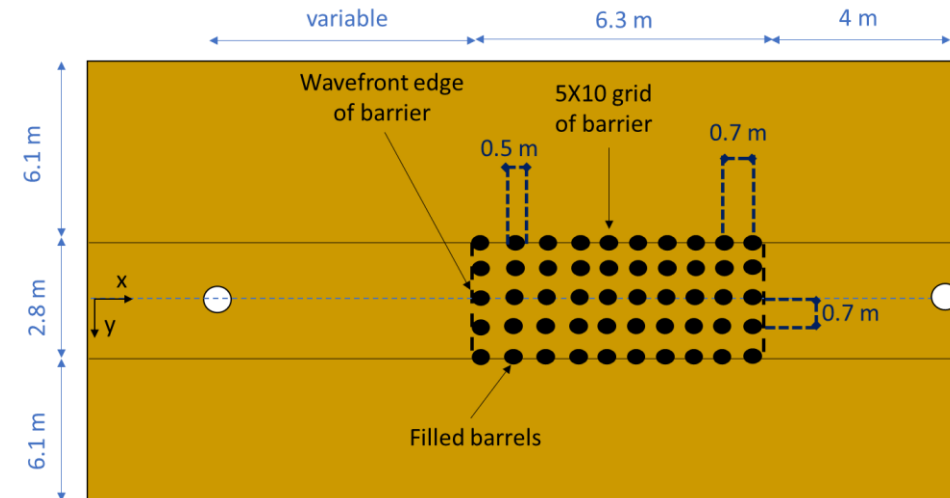
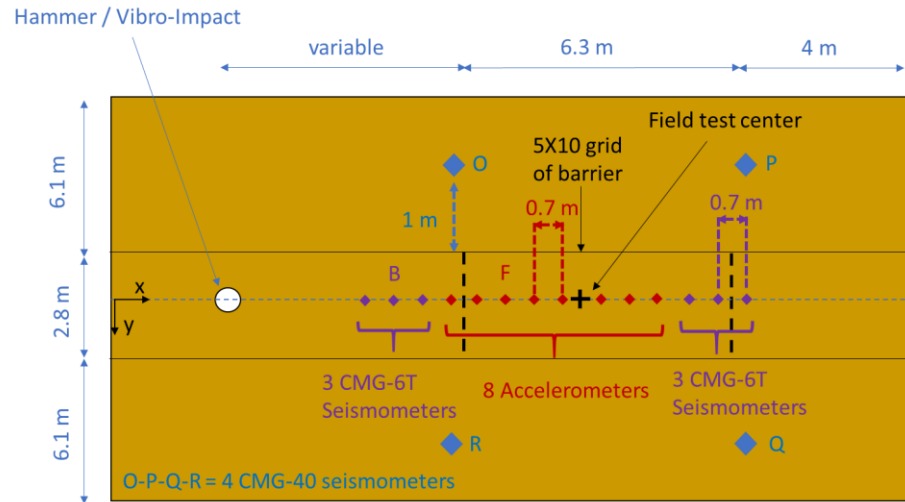


ReWarD Project: Numerical Analysis





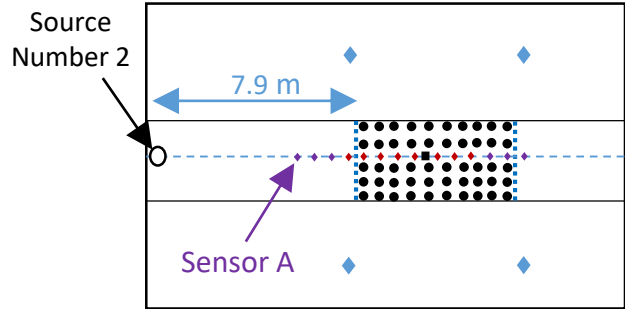
ReWarD Project: Experimental test setup



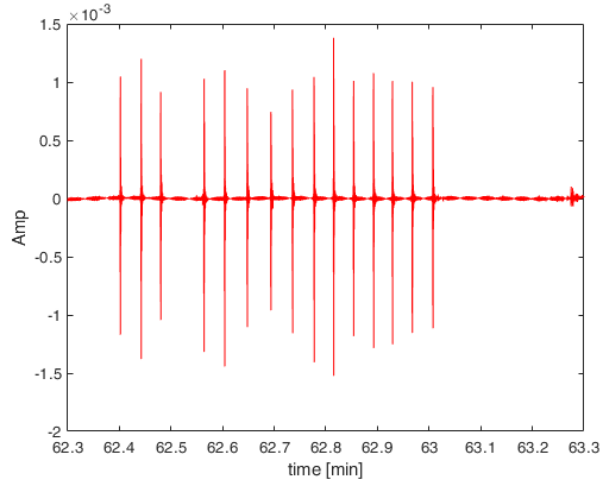


ReWarD Project: Hammer strike (seismometer A)

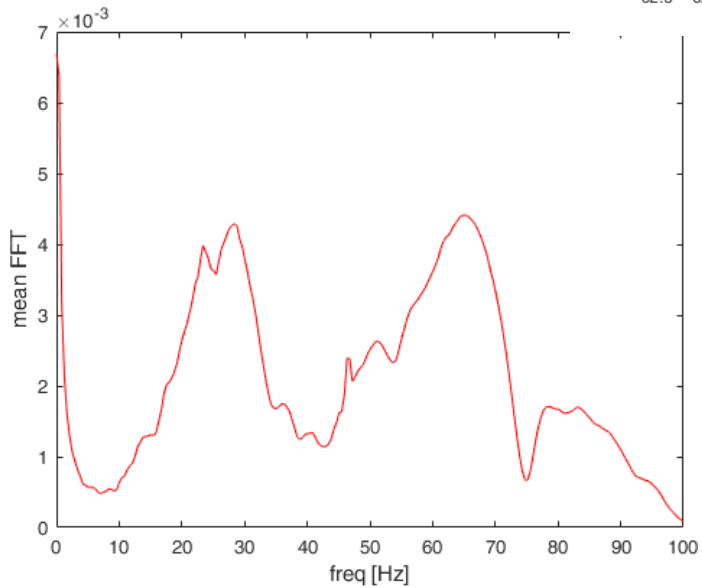
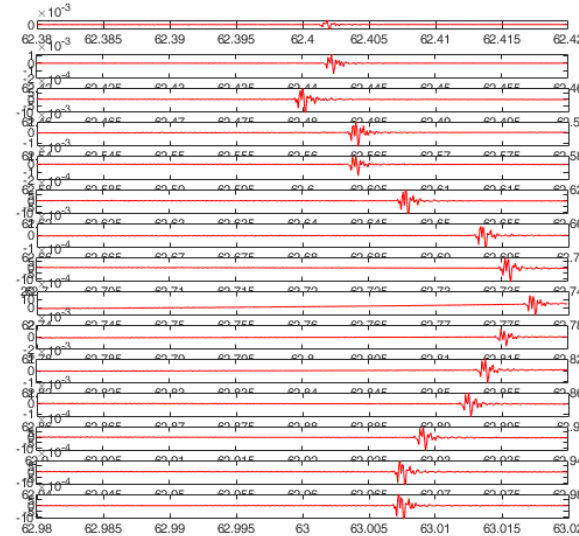
Source and sensor location



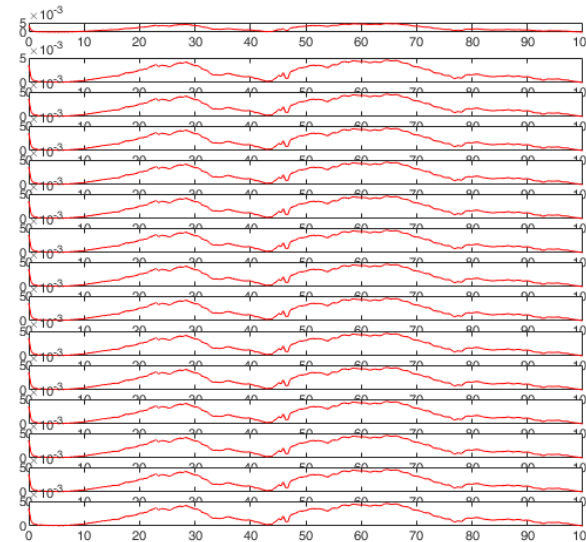
Signal time trace



Chopped time traces for each strike



Mean FFT



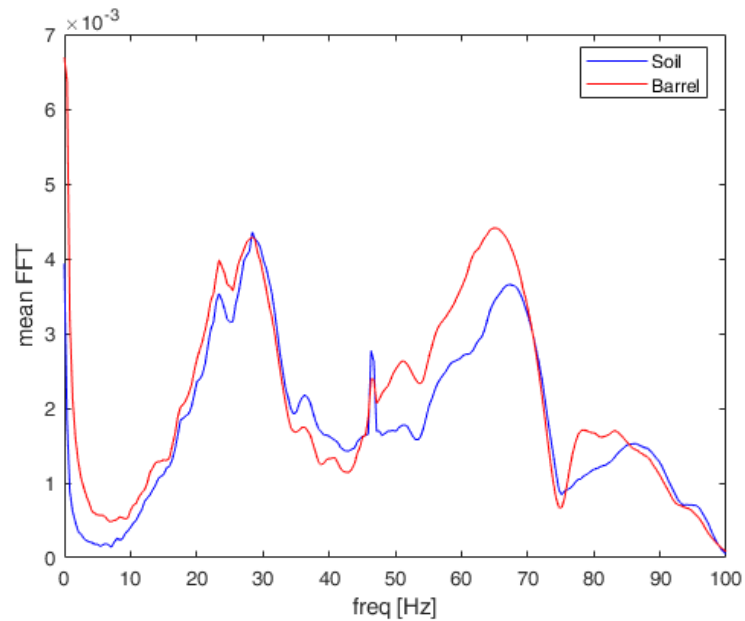
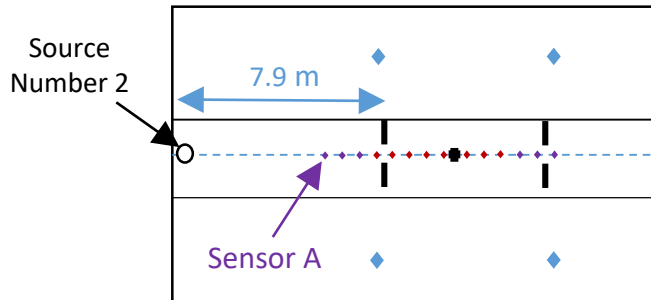
FFT of each strike



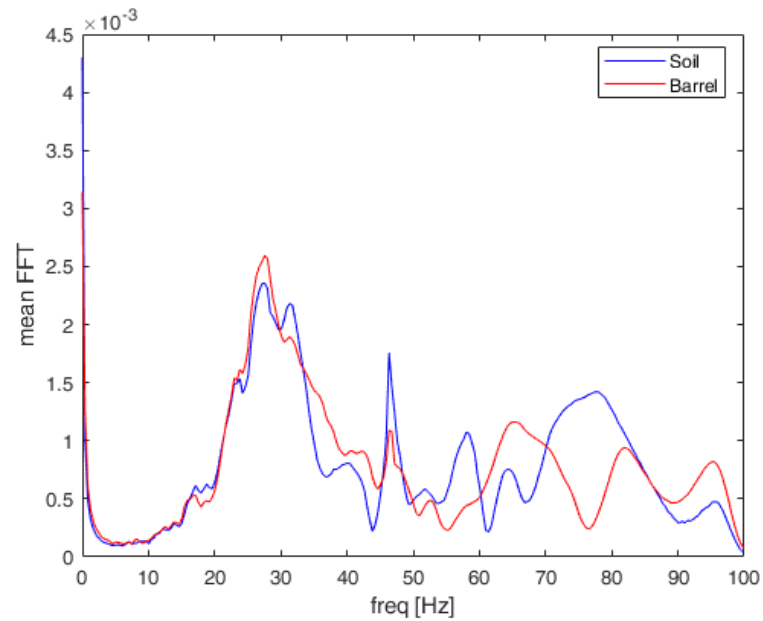
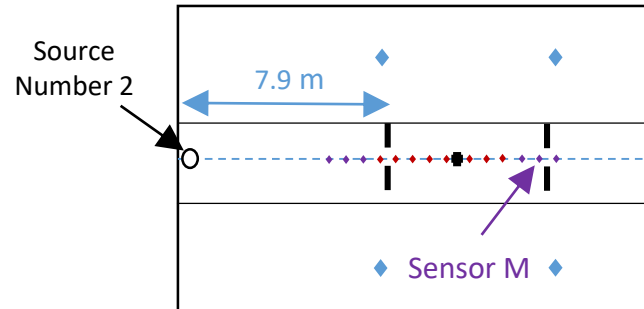


ReWarD Project: Soil vs. Barrel

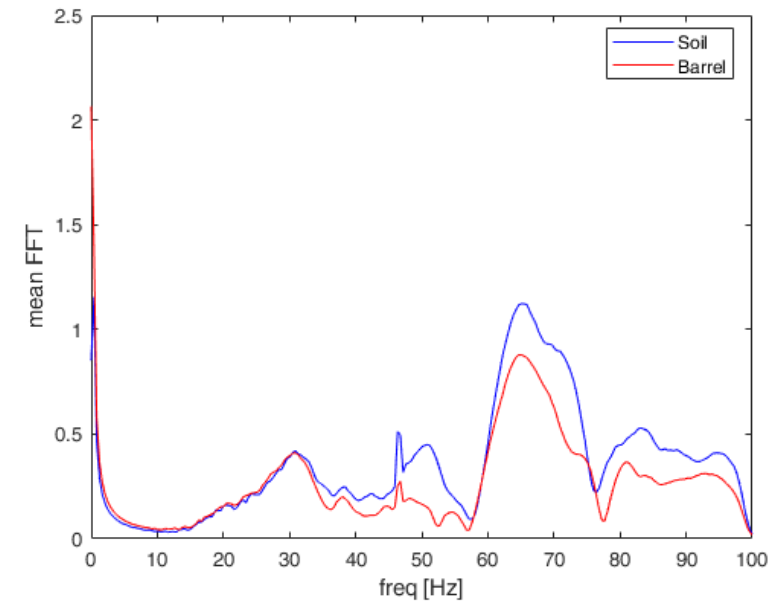
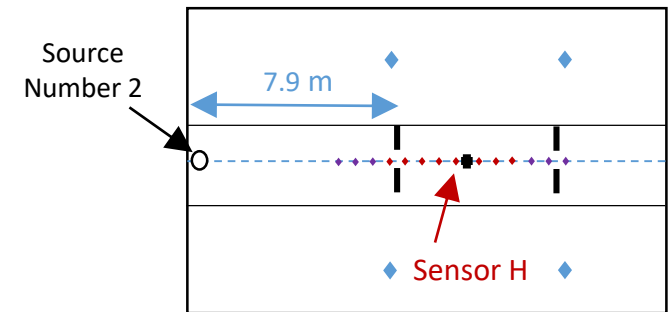
a) Sensor A



b) Sensor M



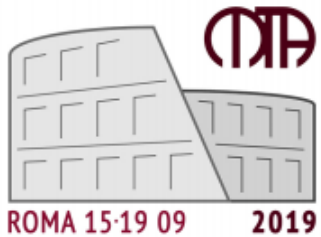
c) Sensor H



Contributions to the conferences



Zeighami, F., Palermo, A., and Marzani, A. (2019). “**Rayleigh waves bandgap tuning via inertial amplified metasurfaces.**” SAM2019 – Symposium on Acoustic Metamaterials at Ischia, Italy. [Abstract]



Palermo, A., Zeighami, F., and Marzani, A. (2019). “**A resonant metasurface for Love waves.**” AIMETA2019 - Italian Association of Theoretical and Applied Mechanics in Rome, Italy. [Abstract]

15th INTERNATIONAL CONFERENCE
Dynamical Systems — Theory and Applications
 December 2-5, 2019. Lodz, POLAND.



Palermo, A., Zeighami, F., Vratsikidis, A., Cheng, Z., Pitilakis, D., and Marzani, A. (2019). “**Design of a medium-scale test for the assessment of a resonant seismic barrier within the ReWarD Project,**” DSTA2019 - 15th INTERNATIONAL CONFERENCE of Dynamical Systems — Theory and Applications, Lodz, Poland. [Conference Paper]

Research Outlook

- **Analytical and numerical study of horizontally polarized surface waves (i.e., Love waves) in resonant bilayer media made of bulk metamaterials.**
- **Analytical and numerical study of Rayleigh waves in a resonant system consists of an elastic metasurface layer placed at the free waveguide surface of a resonant half-space layer.**
- **Analytical and numerical topological optimization of different periodic patterns to replicate the physics of polaritons with elastic surface waves. Performing table-top scale experiments to validate the analytical findings during the mobility period abroad.**