Collaborative Research: Development of Realistic Seismic Input Motions for Improving the Resilience of Infrastructures to Earthquakes

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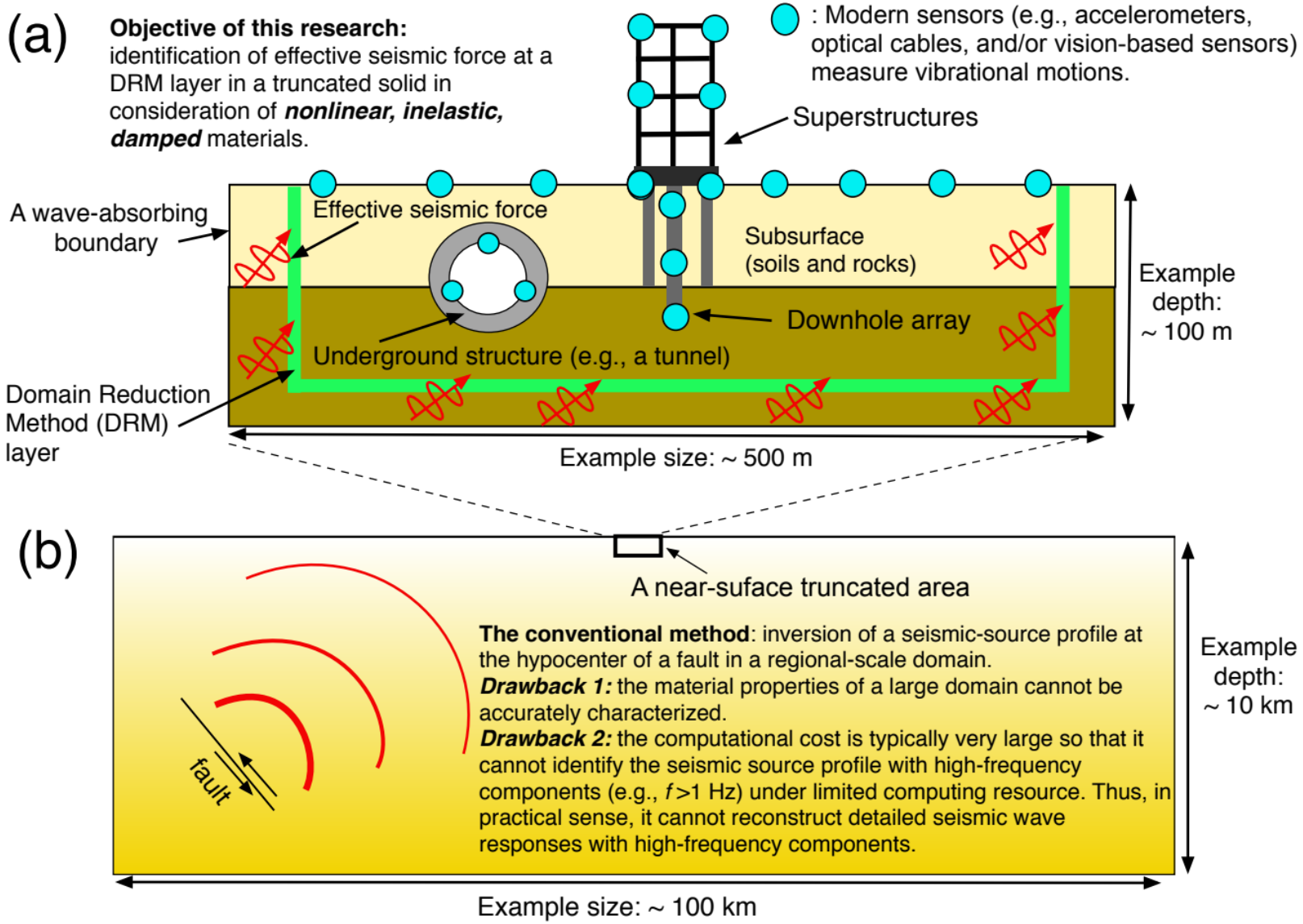
Objective

Investigate a new method for accurate reconstruction of **three component (3C) of incoming seismic wave field** in a 3D, truncated near-surface domain by using sparse seismic data in consideration of mildly nonlinear, inelastic materials.



Motivation for this work

- Estimating incident seismic wavefields in a soil-structure system from seismic measurement allows engineers to pinpoint where large amplitudes of stress waves occur (or structural failures occur) in built environments during seismic events.
- It helps decision-makers to plan the budget and schedule of upgrades, *Improving the Resilience of Infrastructure to Earthquakes.*

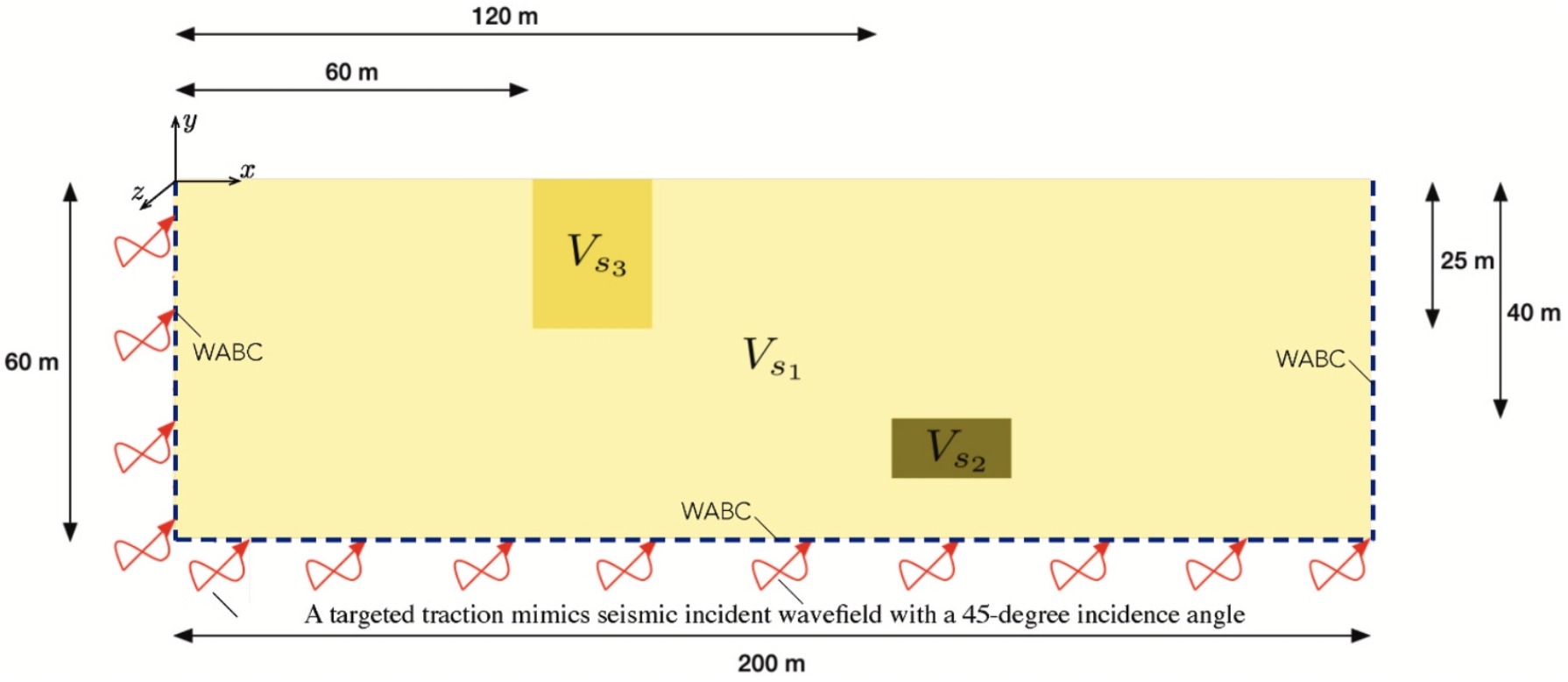
Research Plan

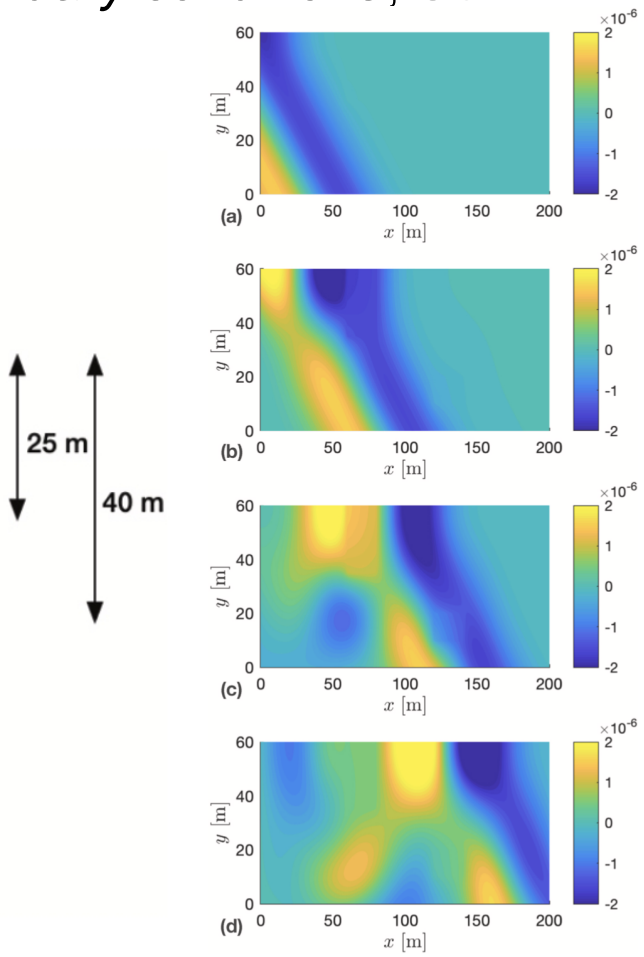
- Task 1: Implementation of the Novel Inverse Modeling Coupled with the Domain Reduction Method (DRM) in Consideration of Various Measurement Types.
- Task 2: Verification of the Task 1.
- Task 3: Parametric Studies.

Task Name	Project Year 1				Year 2			
Task 1: Developing novel inverse modeling								
Task 2: Verification								
Task 3: Parametric studies								

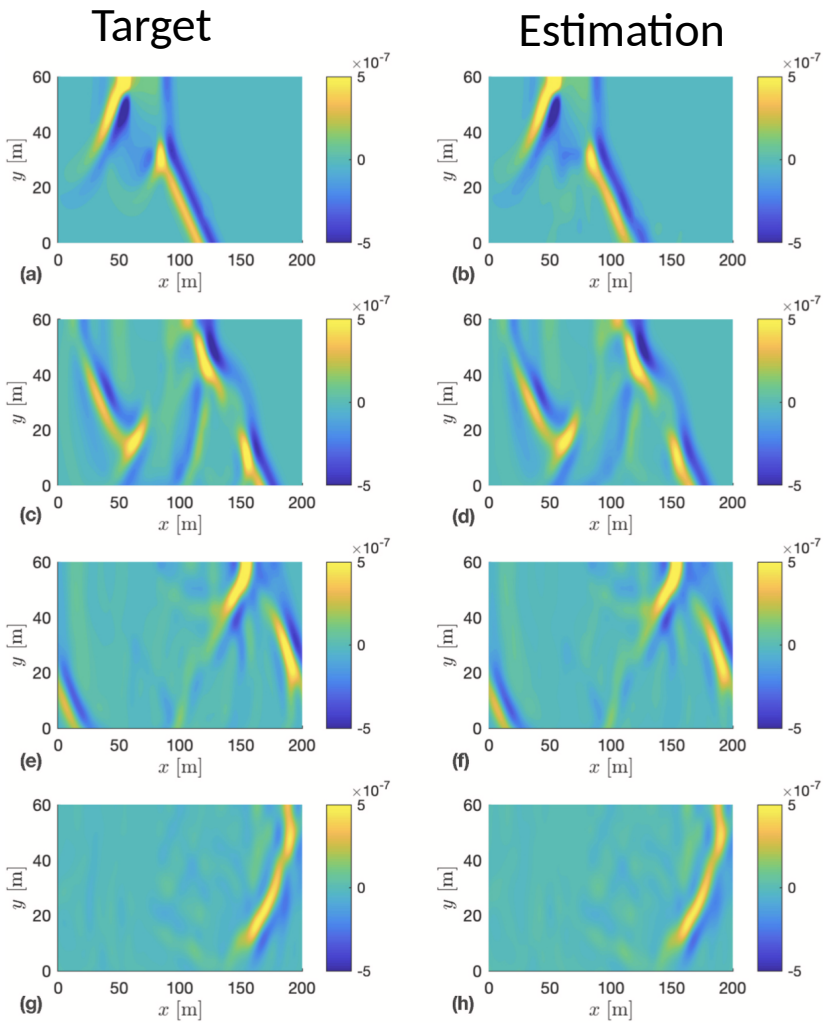
Research Results

(2022) B. Guidio, B. Jeremic, L. Guidio, and C. Jeong, *Passive-seismic inversion of SH-wave input motions in a domain truncated by wave-absorbing boundary conditions*, **Soil Dynamics and Earthquake Engineering**, Vol. 158, Elsevier.

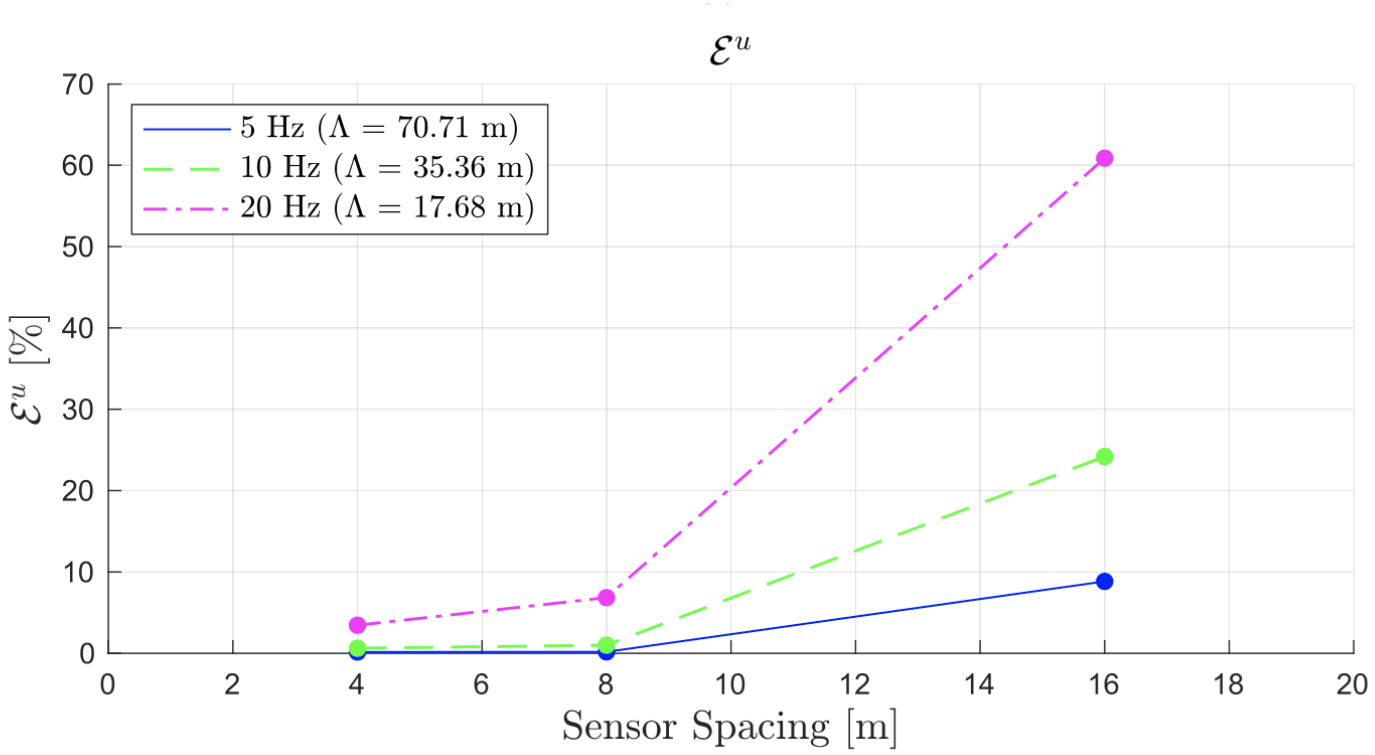




Research Results



Waves of a dominant frequency of 20 Hz are considered with a sensor spacing of 8 m.



To increase the accuracy of the presented algorithm, **the number of sensors per unit length should rise as the frequency content of an incident wave increases.**

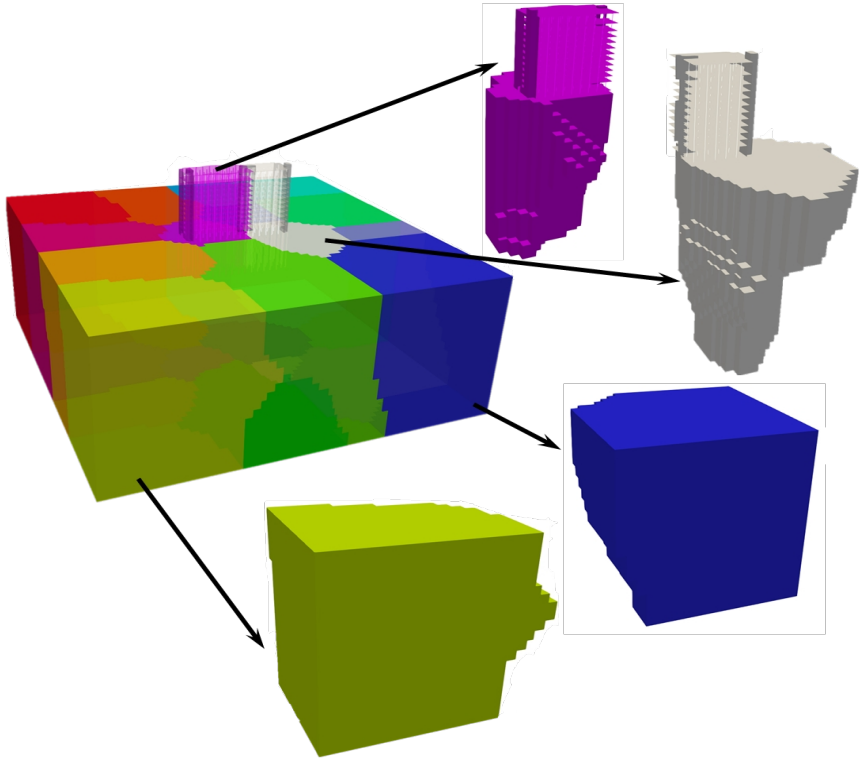
Simulation Program

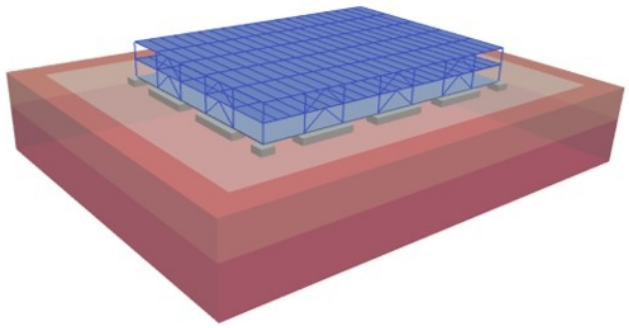
- Implementation of the Inverse Modeling Method in the **Real-ESSI Simulator**
  - **Real**istic Modeling and Simulation of **E**arthquakes, **S**oils, **S**tructures, and their **I**nteraction
  - Goal – Achieve accurate and efficient reconstruction of **full three component (3C) seismic wave field** in a **three dimensional (3D)** domain
  - Accuracy → High fidelity finite element method (FEM) modeling techniques
  - Efficiency → High performance parallel computing techniques
  - Verification and Validation
- Take advantage of the existing functionality in Real-ESSI
  - Modeling of elastic/inelastic materials, soil/structure/interface elements
  - Domain reduction method (DRM) for seismic wave input
  - Plastic domain decomposition technique for parallel computing
  - Post-Processing and Visualization

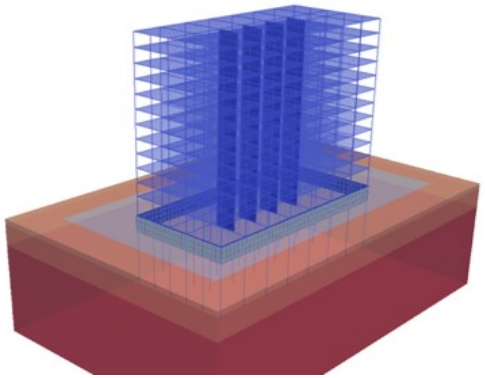
Real-ESSI Website: http://real-essi.info/

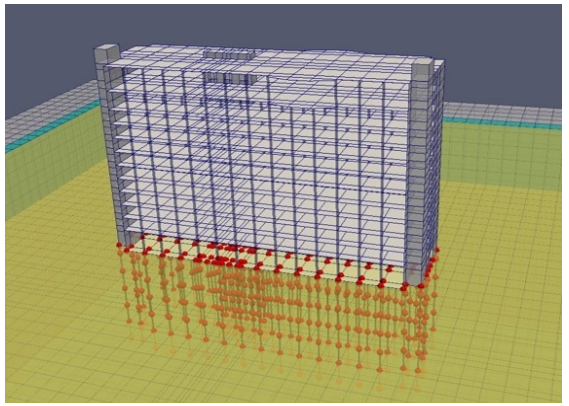
Parallel Computing

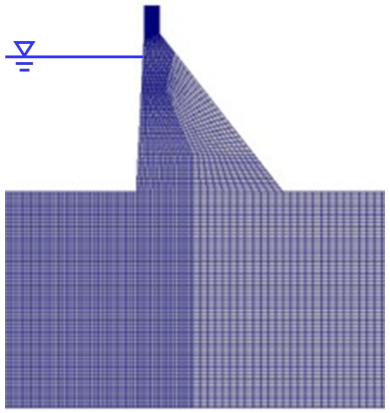
- Implementation in Real-ESSI – Parallel Computing in progress…
  - Necessary for large realistic models
  - Plastic domain decomposition method
- Ongoing work
  - Parallelization of time-integration schemes, solvers, output module, etc.
  - Verification and validation
  - Post-processing and visualization





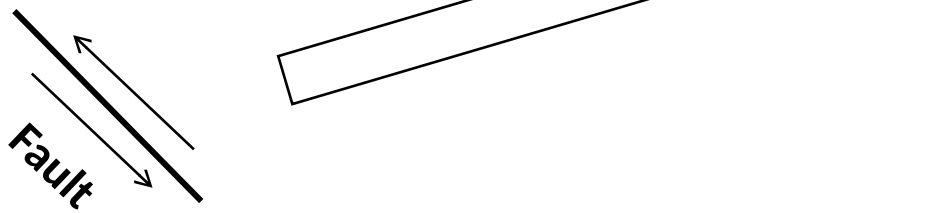


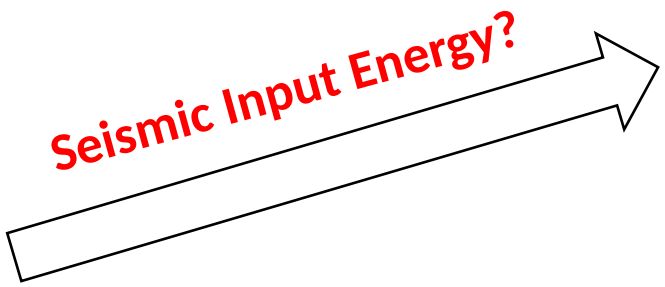


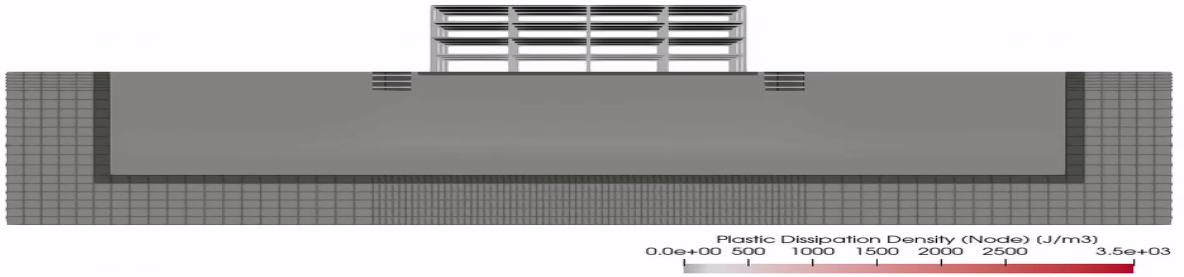


Use: Energy-Based Design

- Follow Energy Flow in Soil-Structure Systems
  - Proposed inverse modeling method can be used to accurately calculate seismic energy input into a realistic infrastructure object under realistic seismic excitations.

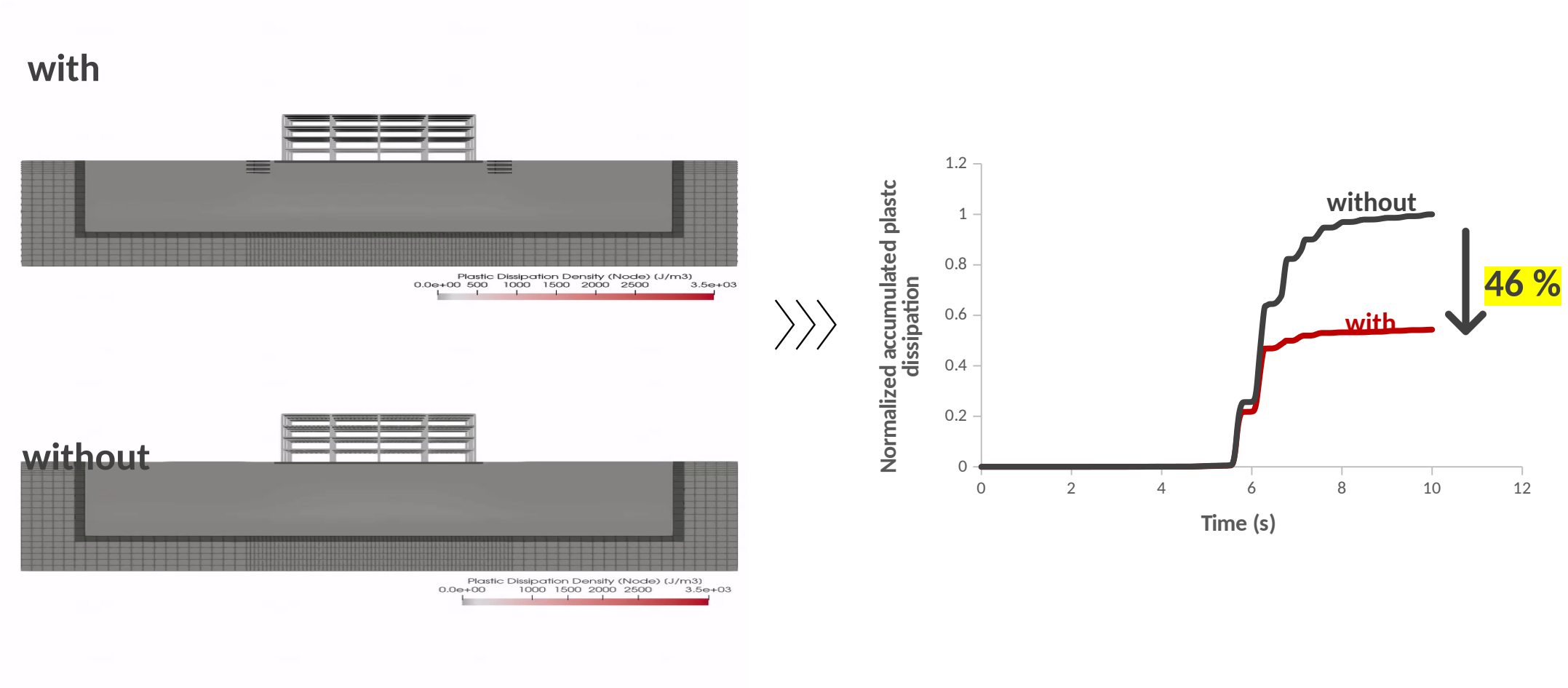






Improved Infrastructure

- Control Energy Dissipation in Soil-Structure Systems



Summary

- We will be investigating a method for accurate reconstruction of 3C incoming seismic wave in a 3D, truncated near-surface domain by using seismic data in consideration of nonlinear, inelastic materials using Real-ESSI Simulator.
- Proposed inverse modeling method can be used to accurately calculate seismic energy input into a realistic infrastructure object under realistic seismic excitations for energy-based design.
- Acknowledgement: This material is based upon work supported by the National Science Foundation under Awards CMMI-2053694.