

Multi-physics RTHS framework

Claudia Reis, PhD PE



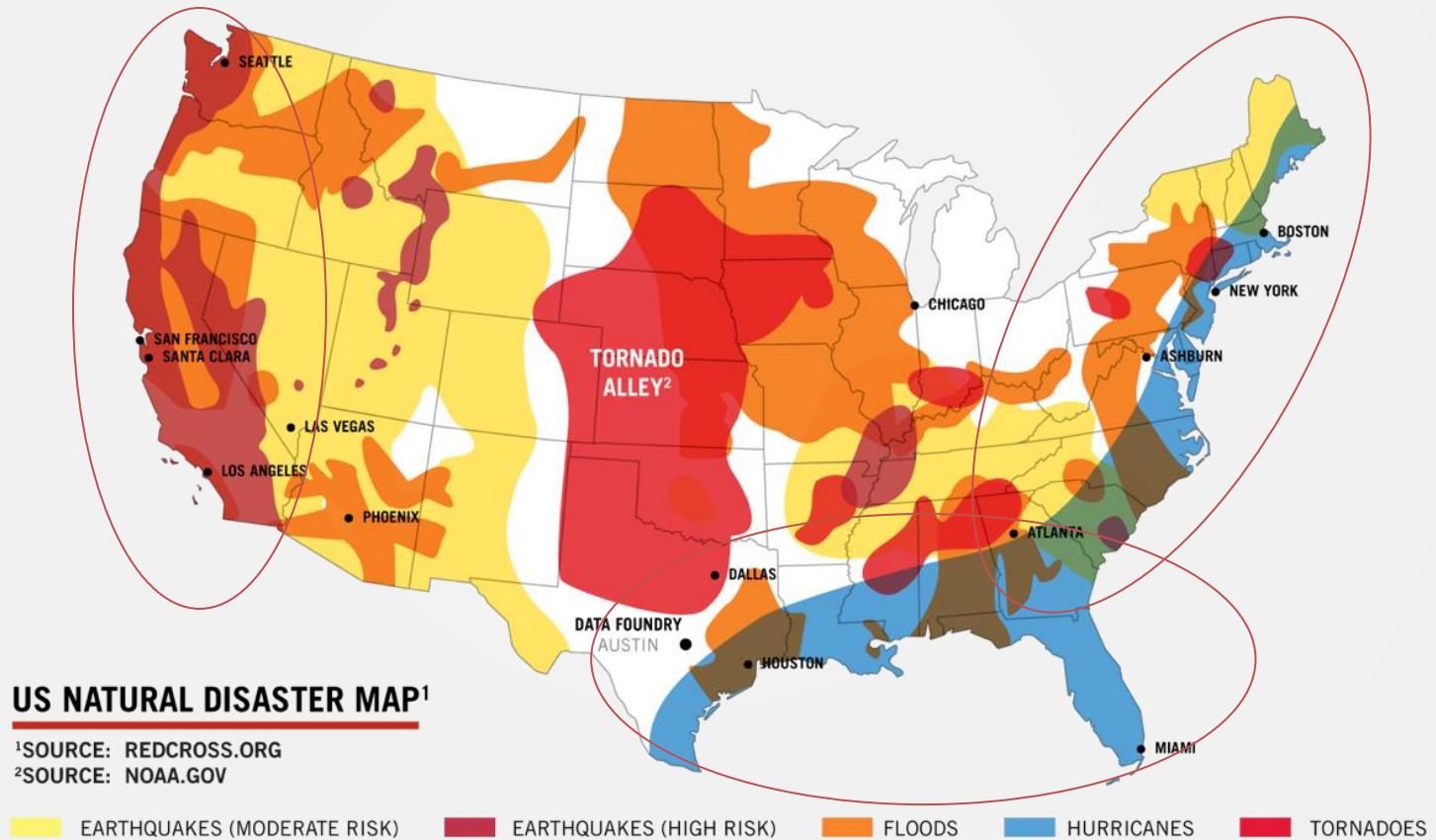
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CYBER-PHYSICAL SIMULATION

1. Introduction

- Natural Hazard Engineering Research Infrastructure



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- Natural Hazard Engineering Research Infrastructure

'Ninety percent of natural disasters within the United States involve flooding. Consequently, floods inflict more economic damage and loss of life and property than any other natural hazard.'

- U.S. Department of Homeland Security



Tsunami

2011, Tohoku-Oki Earthquake and Tsunami



Hurricane

2022, Hurricane Ian



Floods (rain)

2024, Rio Grande do Sul Floods

1. Introduction

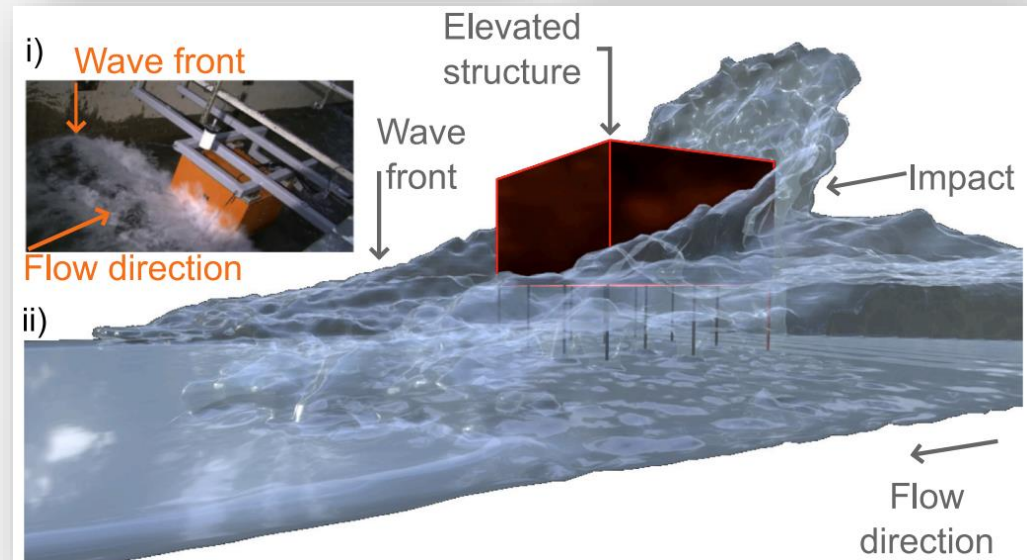
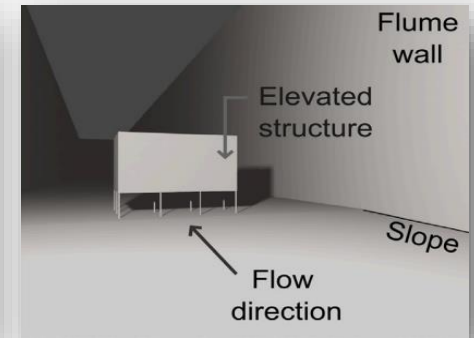
- Challenges
 - Extreme events
 - Infrequent nature
 - Lack of data
 - Multiphysics
 - Solids
 - Fluids
 - Multi-scale
 - Space
 - Time
 - Dynamic loading patterns
 - Independent
 - Interdependent

Complex phenomena involving
Natural hazard
Natural and built environment



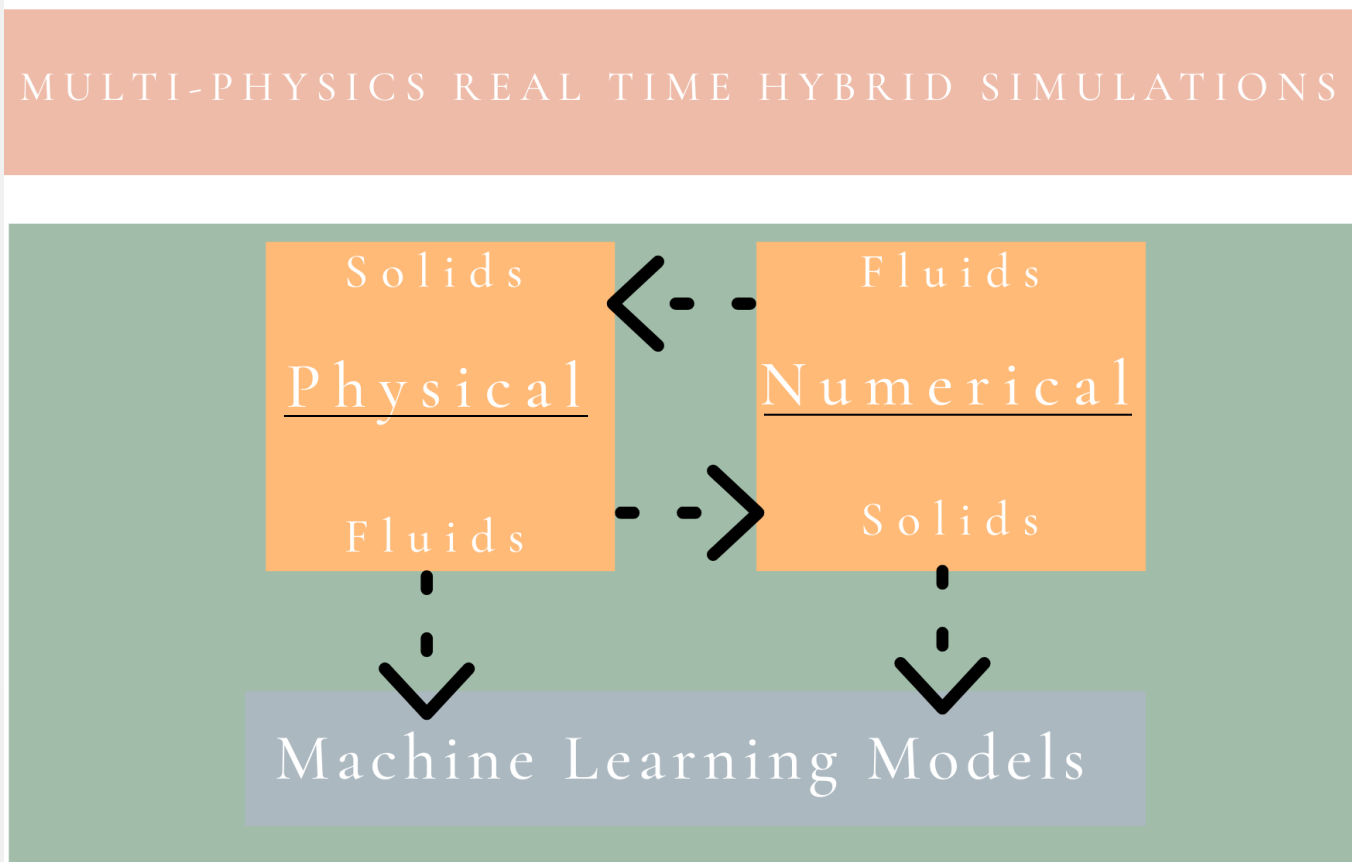
1. Introduction

- Simulations challenges
 - Physical simulations
 - Large scale
 - Similitude
 - Numerical simulations
 - Coupled num. schemes
 - Computational cost
 - Data (cal. & val.)
 - Hybrid simulations
 - Best of both worlds
 - Yet...
 - Real-time



2. NHERI Lehigh Multi-RTHS

- Combinations in Cyber-Physical simulations



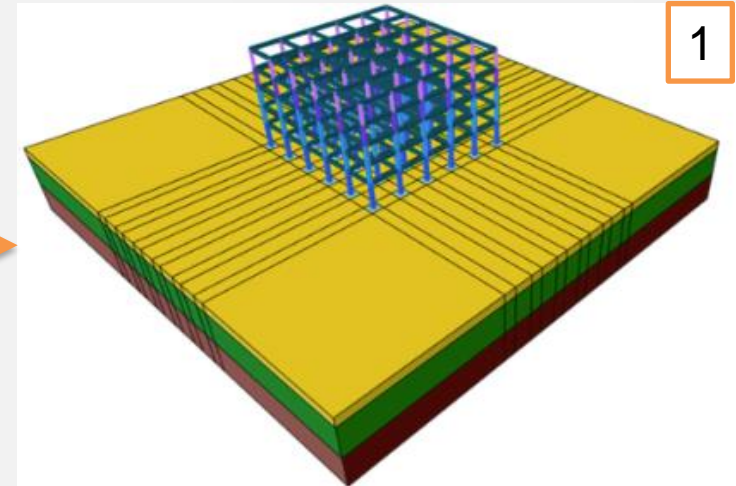
2. NHERI Lehigh Multi-RTHS

- Implementation of the framework
 - Example: Cascading Earthquake and Tsunami



2. NHERI Lehigh Multi-RTHS

- Implementation of the framework
 - Physical fluids & Numerical solids



Physical simulation (geographical distribute, in site)
Response of fluid-soil-structure system to dynamic tsunami load

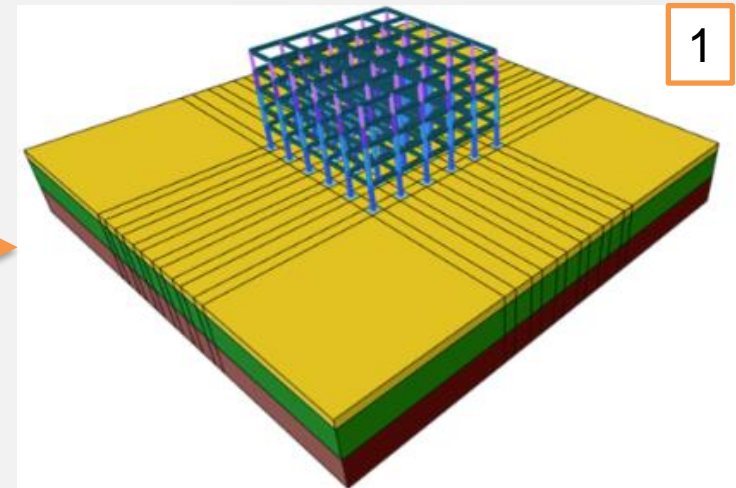
Validated numerical simulation
Response of soil-structure system to dynamic seismic load

FSSI response to cascading ET

Residual FSI damage

2. NHERI Lehigh Multi-RTHS

- Implementation of the framework
 - Physical fluids & Numerical solids (future work)



Physical simulation (geographical distribute, in site)
Response of fluid-soil-structure system to dynamic tsunami load

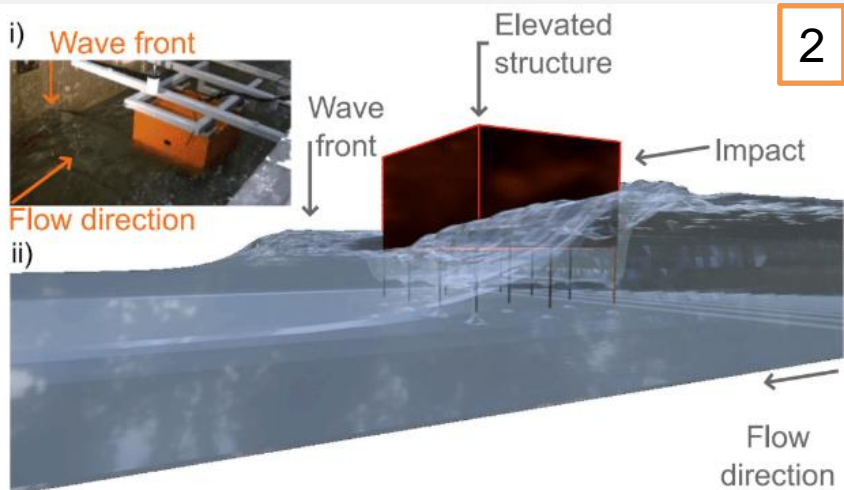
Validated numerical simulation
Response of soil-structure system to dynamic seismic load

FSSI response to cascading ET

Residual FSI damage

2. NHERI Lehigh Multi-RTHS

- Implementation of the framework
 - Numerical fluids & Physical solids (ongoing work)



Validated Numerical simulation
 Characterization of hydrodynamic pressures due to tsunami load

Coupled to physical specimen again

Multi-scale hybrid simulations
 Response of soil-structure system to dynamic seismic load

Residual FSI damage

FSSI response to cascading ET

2. NHERI Lehigh Multi-RTHS

- Implementation of the framework
 - Numerical fluids & Physical solids (ongoing work)
 - What are the challenges of implementing the fluids into the multi-physics cyber-physical simulations?



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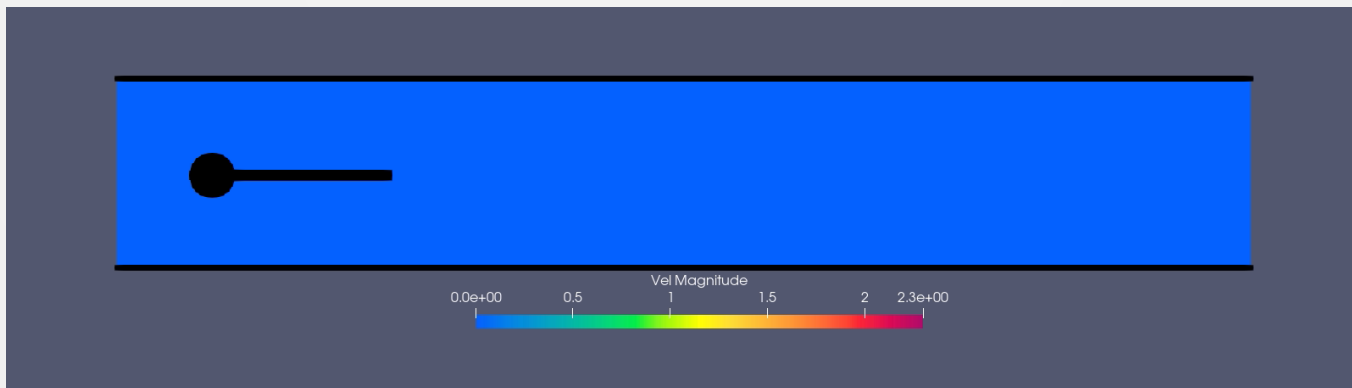
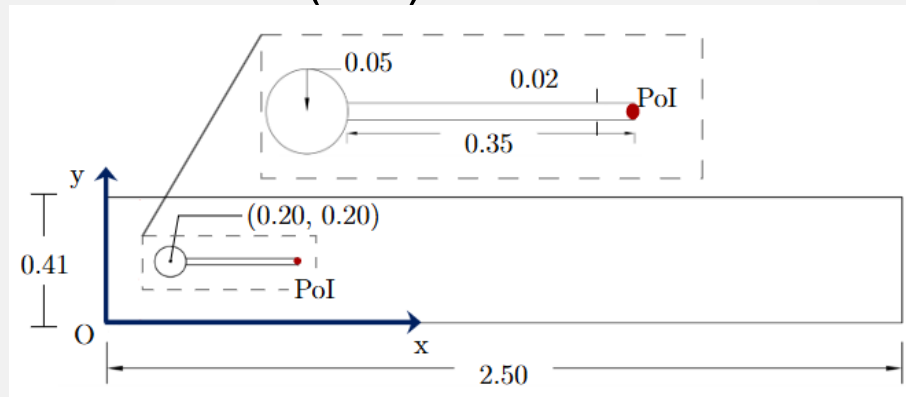
2. NHERI Lehigh Multi-RTHS

- Implementation of the framework
 - Numerical fluids & Physical solids (ongoing work)
 - What are the challenges of implementing the fluids into the multi-physics cyber-physical simulations?
- Available data to calibrate and validate the models
 - Benchmarking process of numerical tool
 - GPU accelerated simulations using Navier Stokes Lagrangian Smoothed Particle Hydrodynamics method
 - Navier Stokes solved using SSM – ALE (skeleton-based structural models with an Arbitrary Lagrangian-Eulerian)



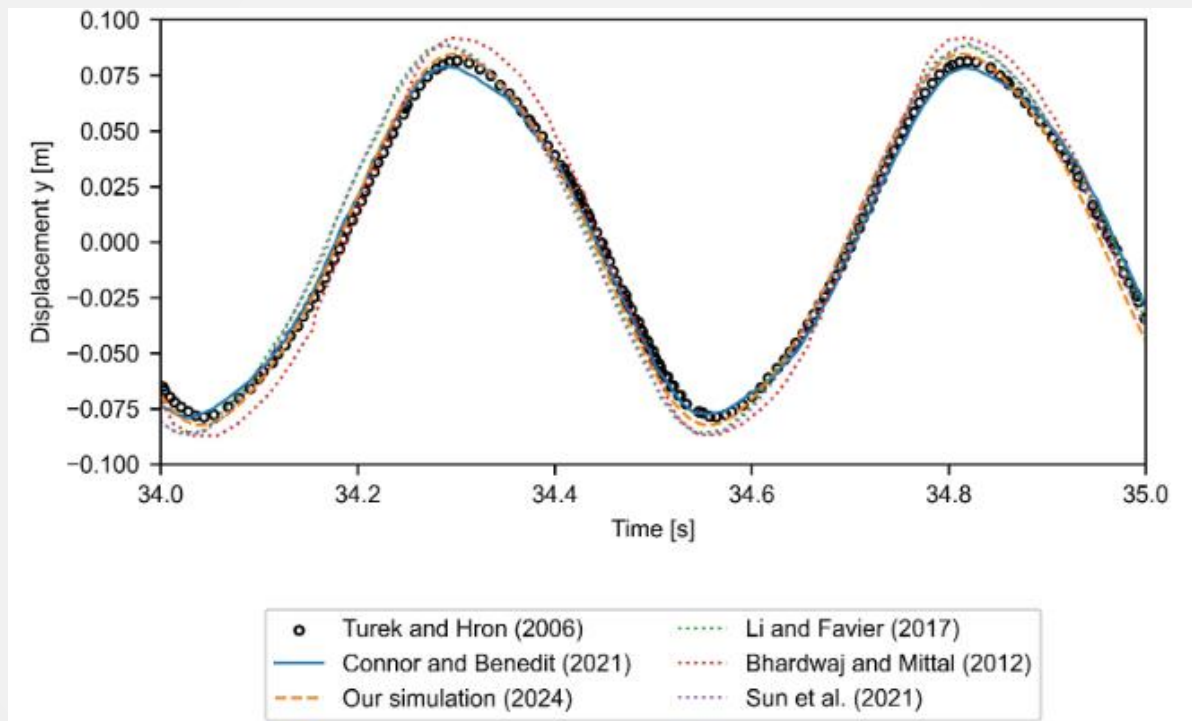
2. NHERI Lehigh Multi-RTHS

- Implementation of the framework
 - Analytical Benchmark (FSI)



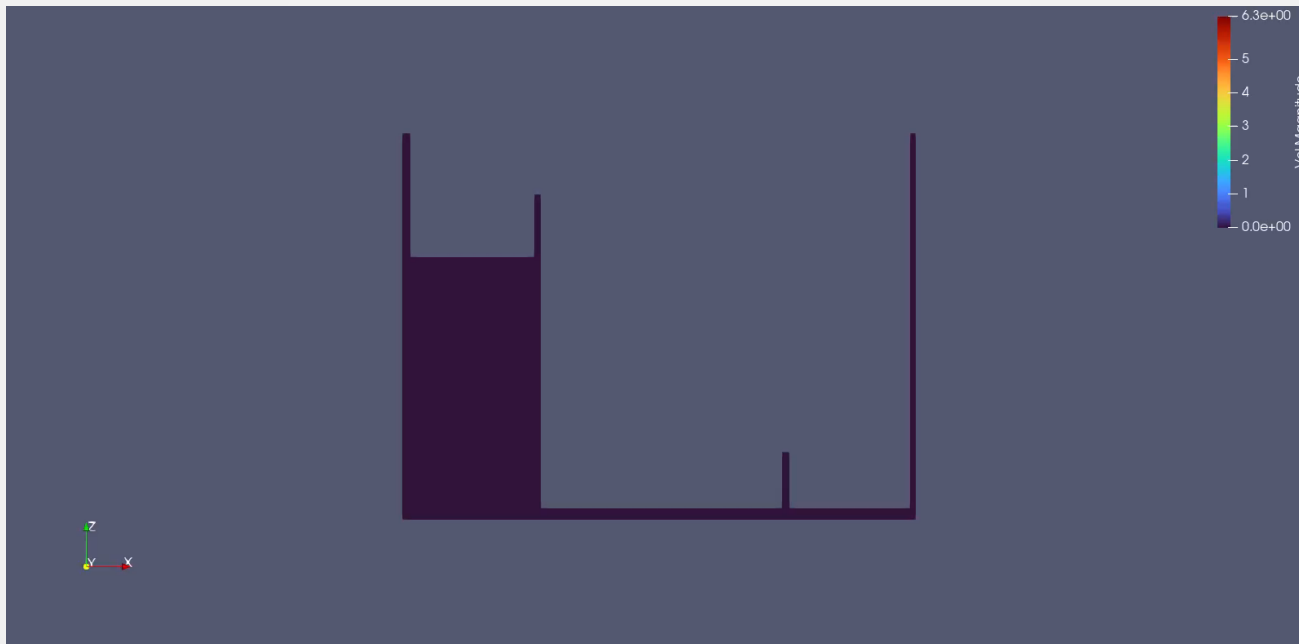
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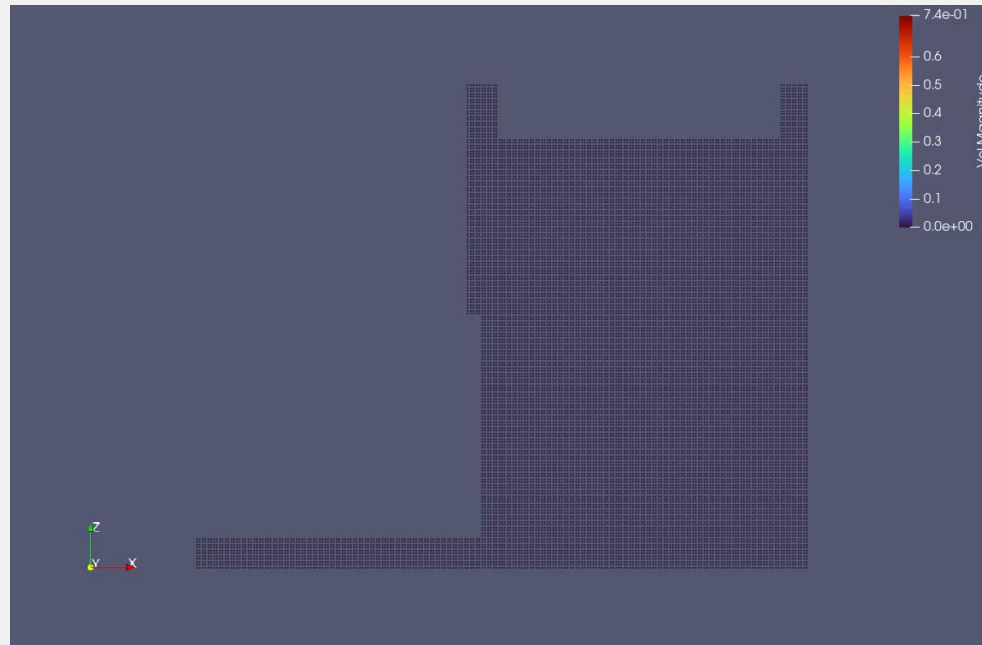
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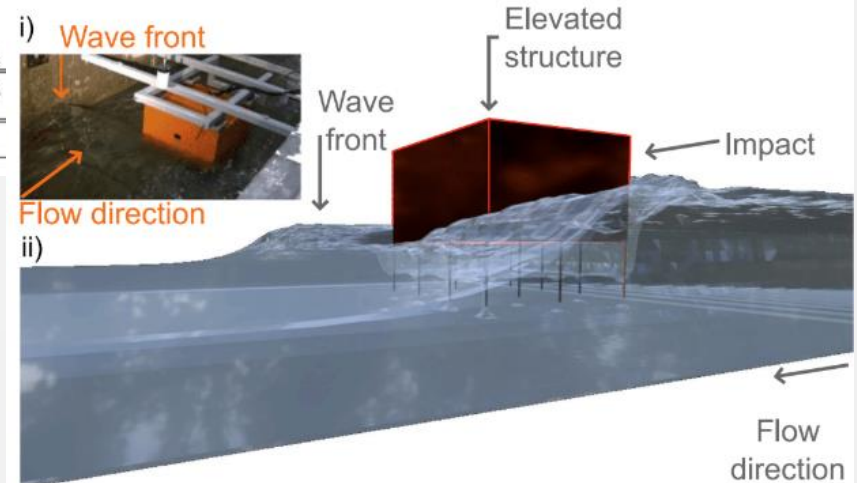
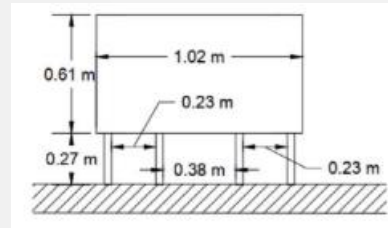
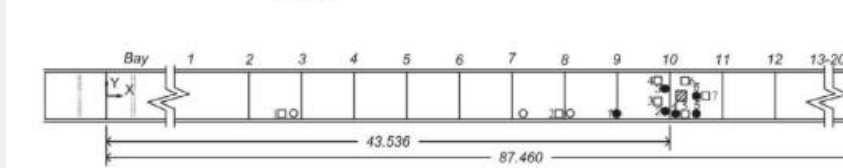
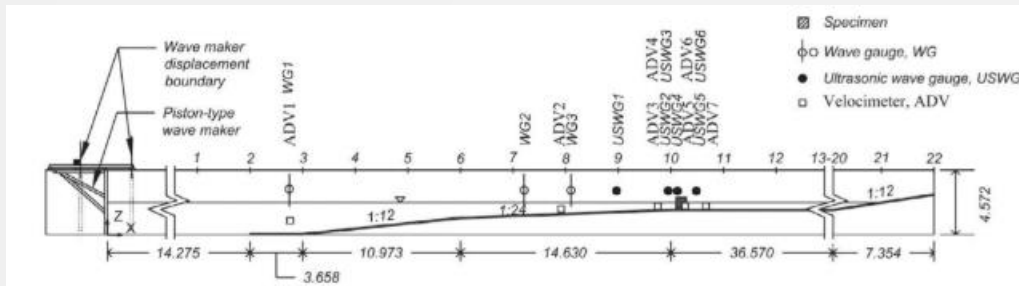
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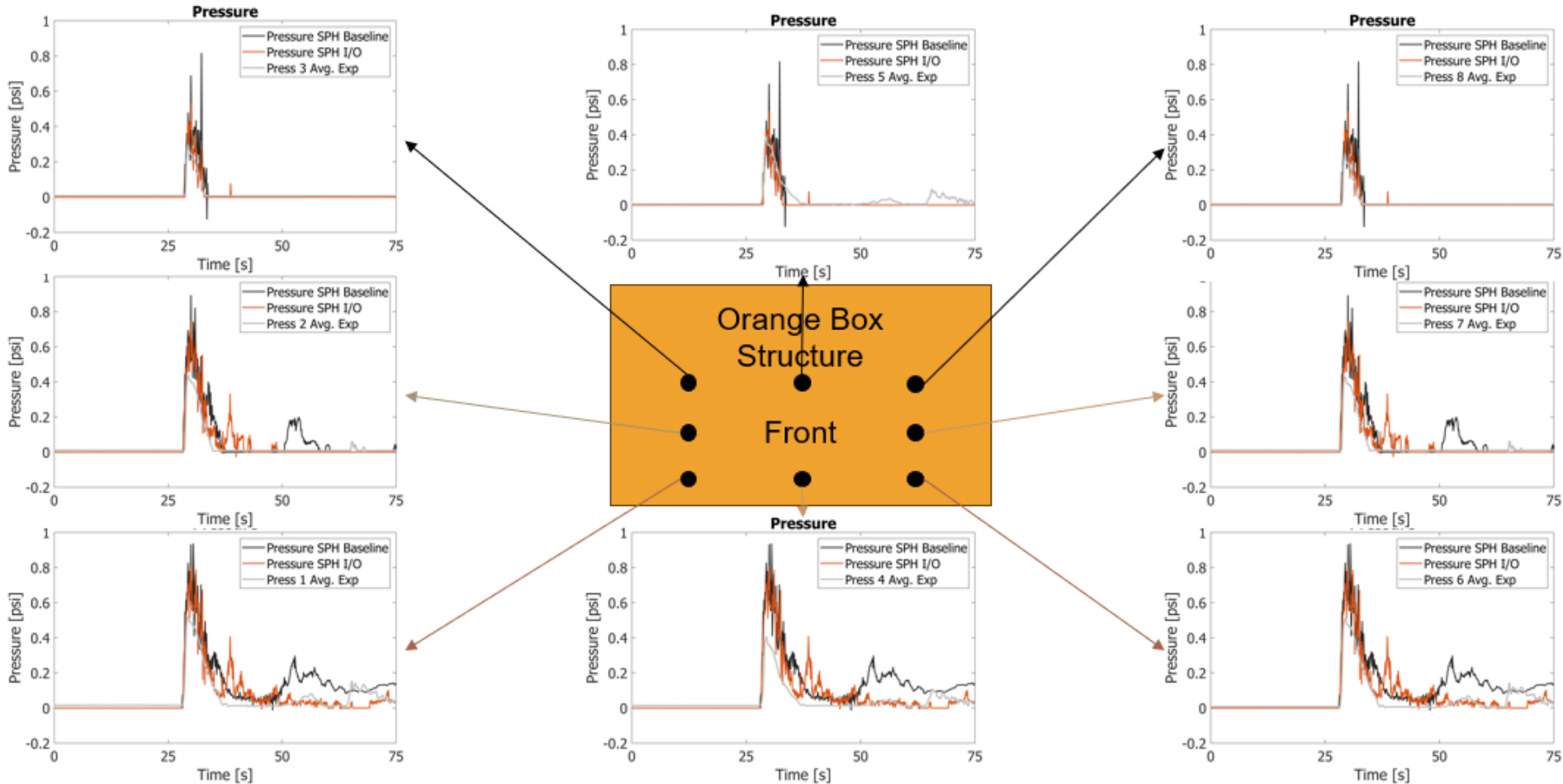


2. NHERI Lehigh Multi-RTHS

- Implementation of the framework
 - Physical Benchmark – Larger scales, multi-directional

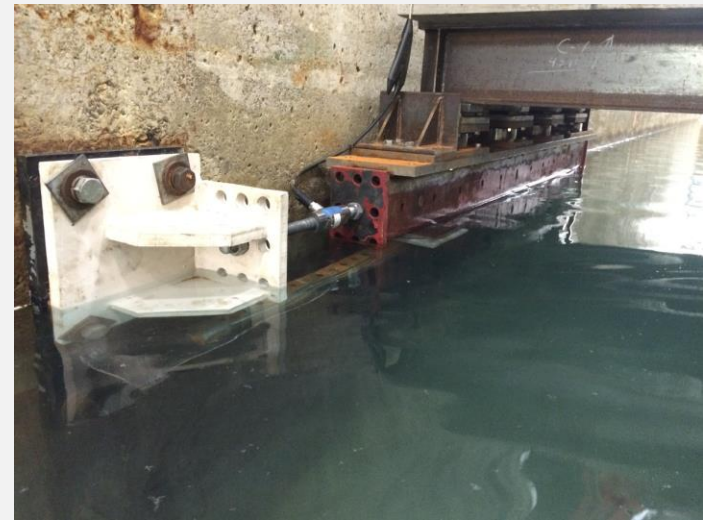


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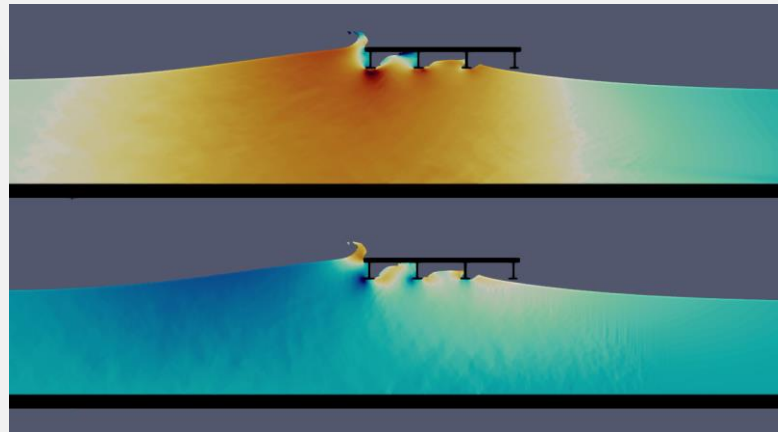
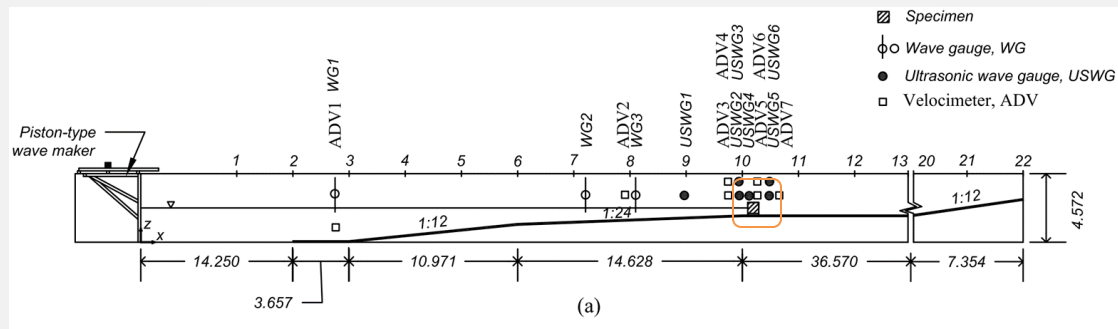
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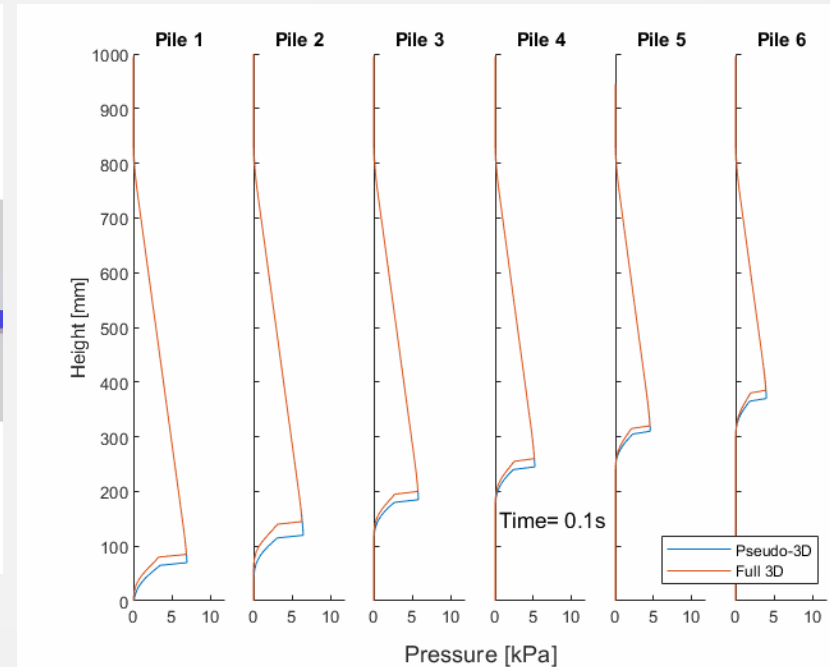
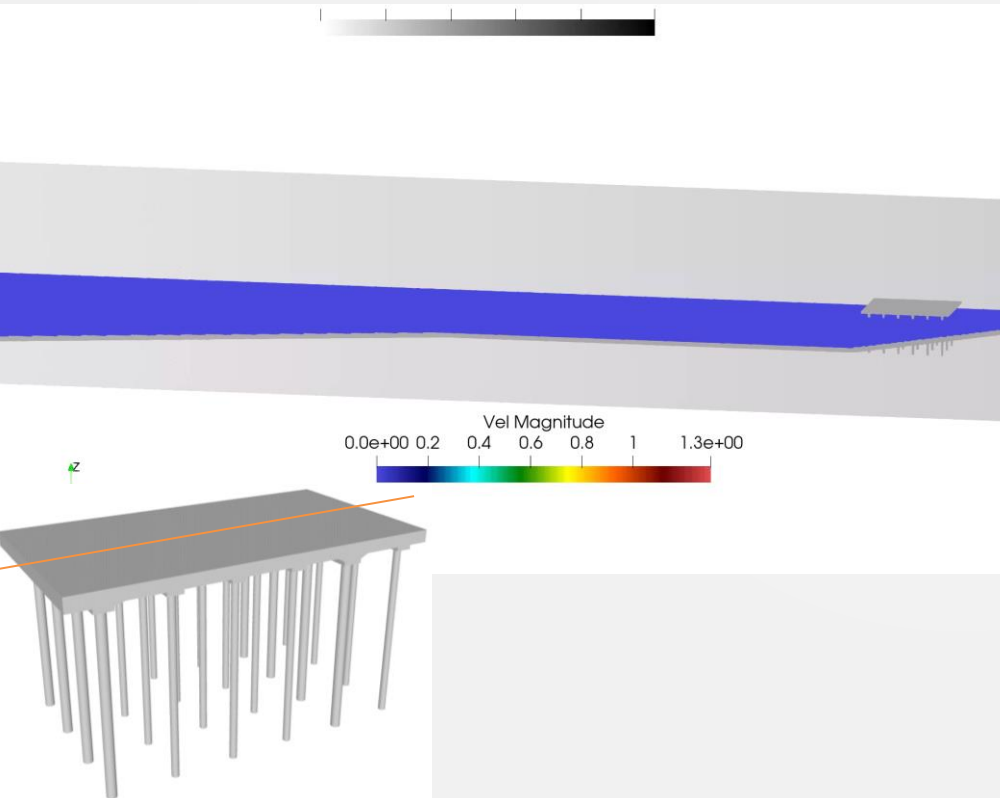
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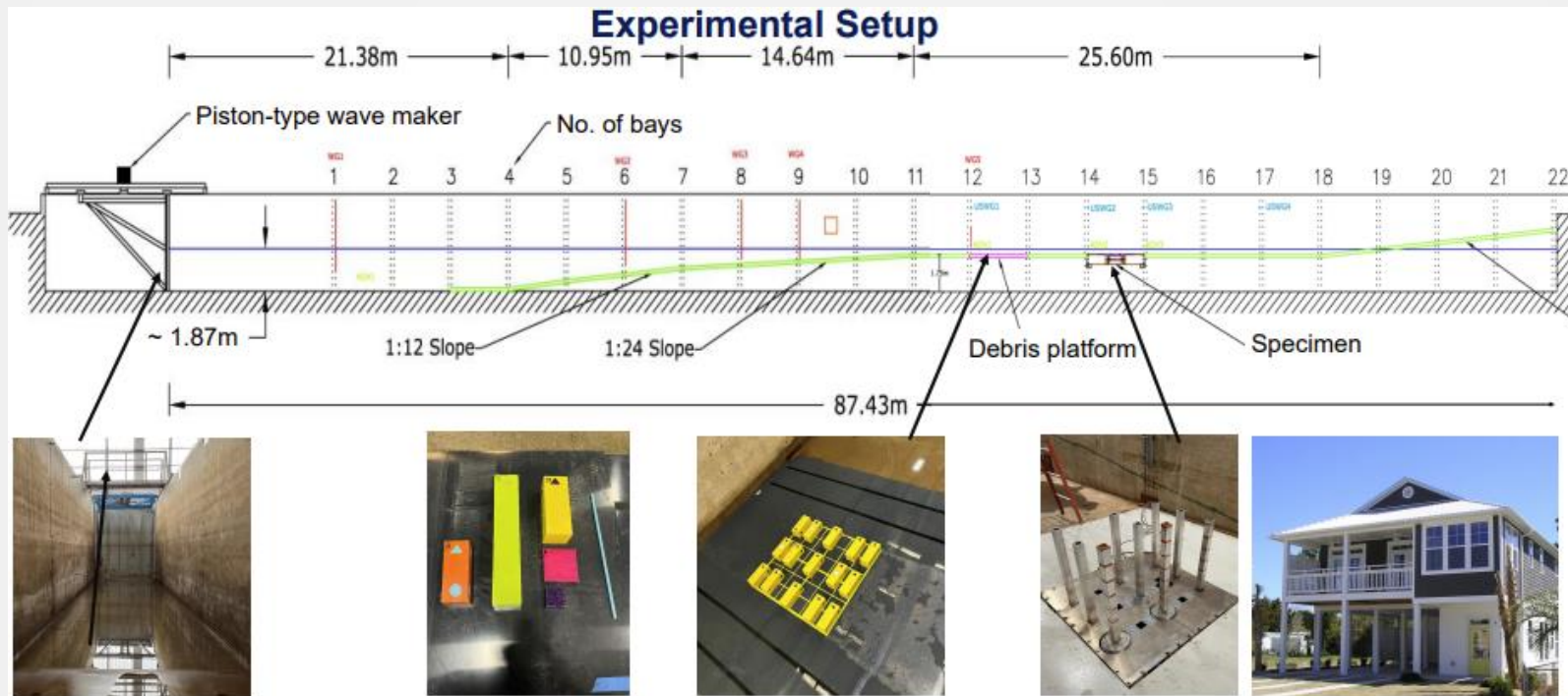
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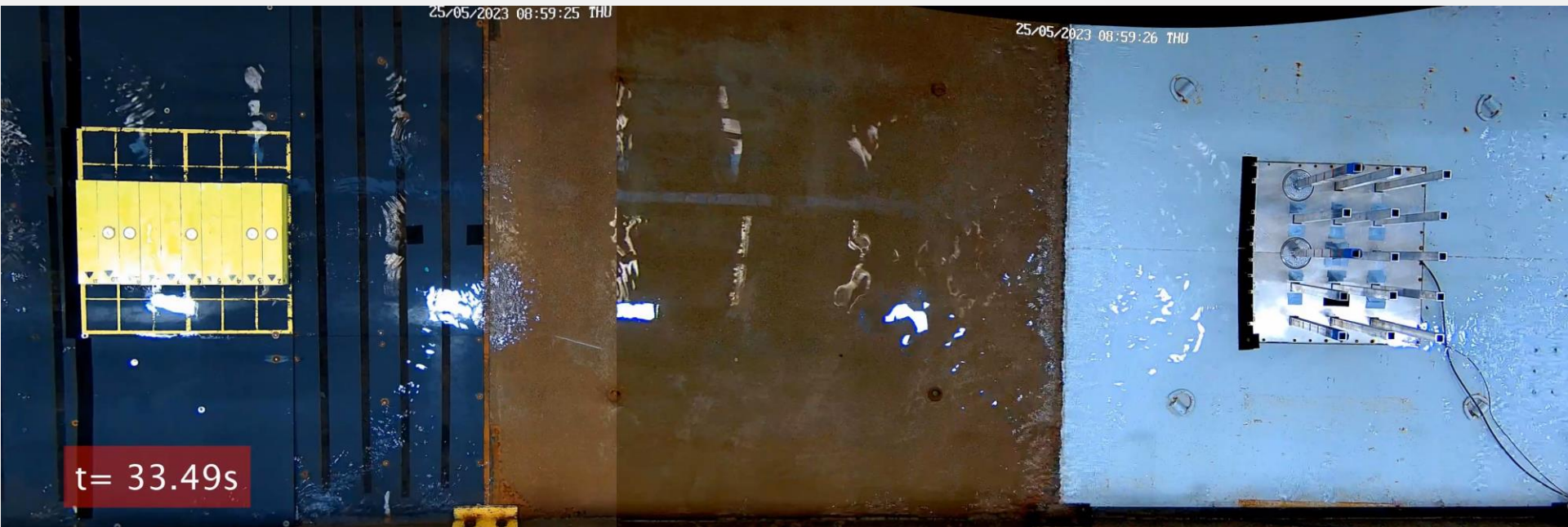
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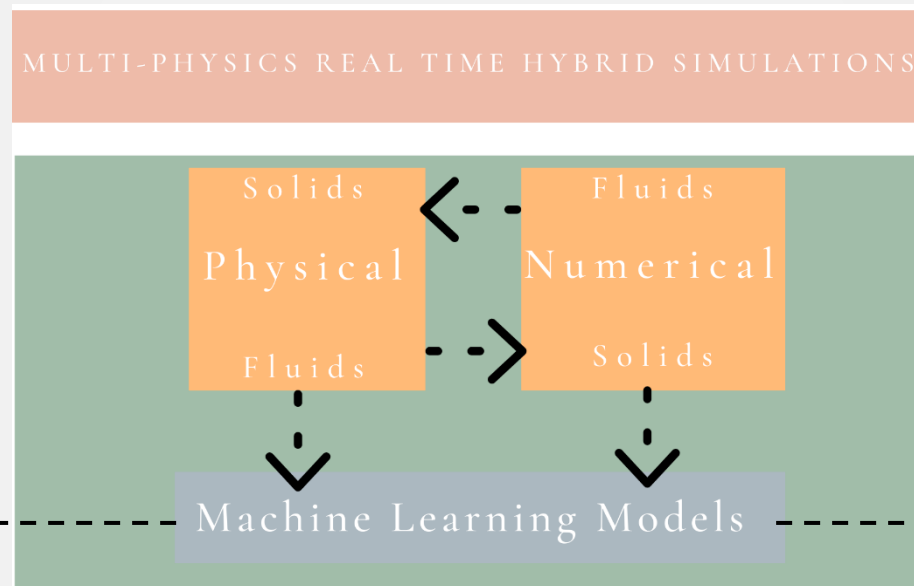
2. NHERI Lehigh Multi-RTHS

- Implementation of the framework
 - Numerical fluids & Physical solids (ongoing work)
 - What are the challenges of implementing the fluids into the multi-physics cyber-physical simulations?
 - Available data to calibrate and validate the models
 - Benchmarking process of numerical tool
 - Computational costs and real-time requirement
 - Computational costs associated with sophisticated numerical schemes
 - Machine learning models



2. NHERI Lehigh Multi-RTHS

- Implementation of the framework
 - Numerical fluids & Physical solids (ongoing work)



Surrogate models

- artificial neural networks
- polynomial chaos expansion
- auto-regressive

3. Potential Research

- Phenomena on coastal and offshore engineering
 - Fluid-soil interactions
 - Fluid-structure interactions
 - Fluid-soil-structure interactions
 - Fluid(s)-soil-structure interactions
- Scale
 - Synergistic system
 - Non-structural elements
- Loading pattern
 - Individual
 - Compound
- Transfer
 - Physical-Numerical
 - Physical-Physical



Thank you

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