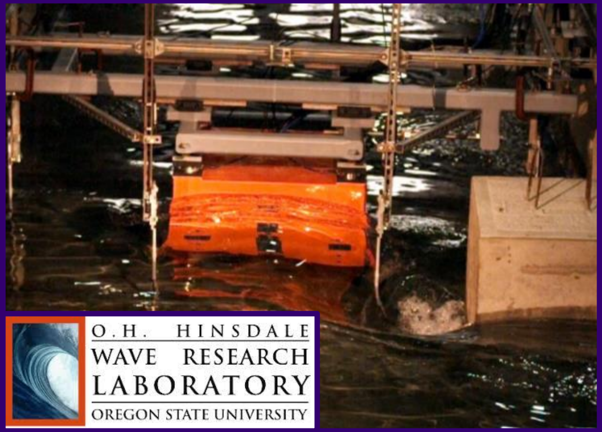
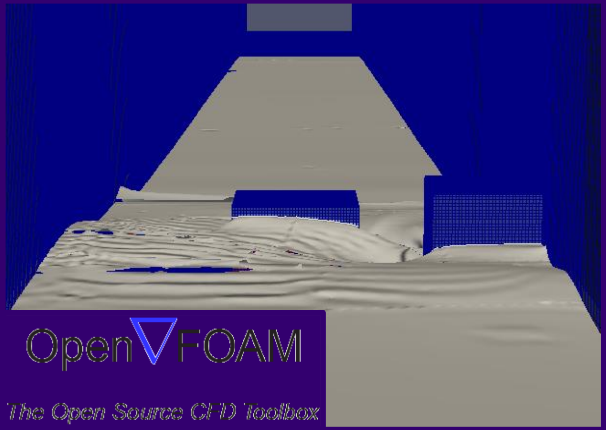
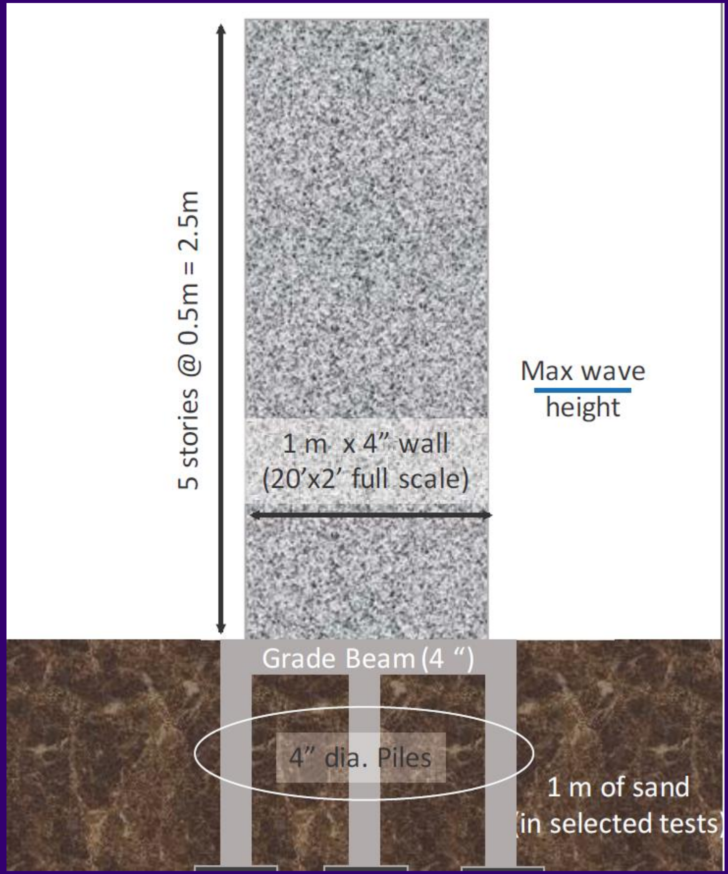
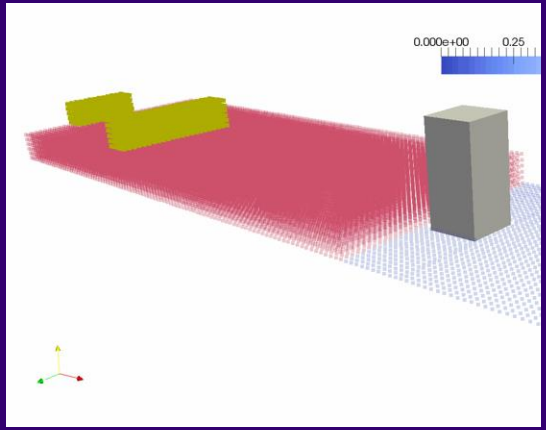
Experimental and Numerical Evaluation of Tsunami Loads on Vertical Evacuation Structures









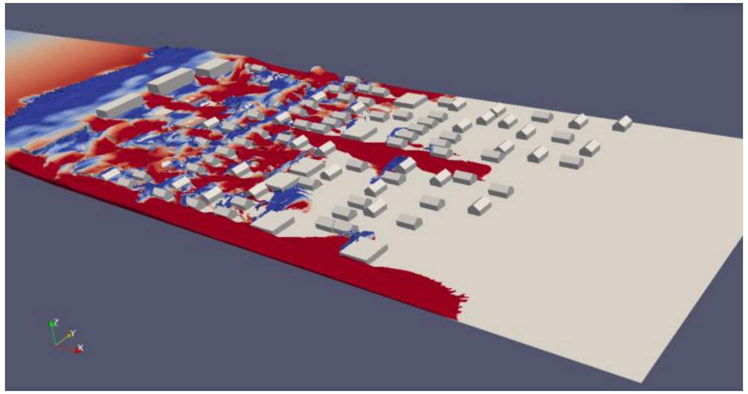
World Bosai Forum

12 November 2019

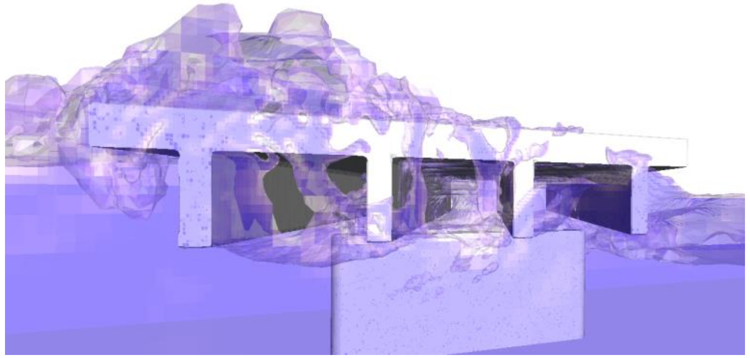
CIVIL & ENVIRONMENTAL ENGINEERING
UNIVERSITY of WASHINGTON

Multi-Scale Modeling of Tsunami Forces

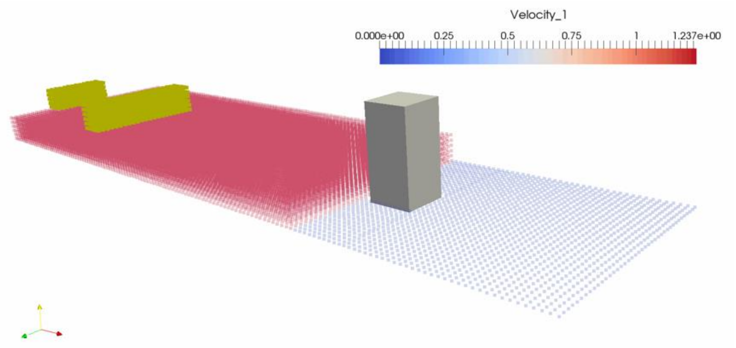
Community-Scale Inundation and Force Prediction



Structure-Scale Force Prediction



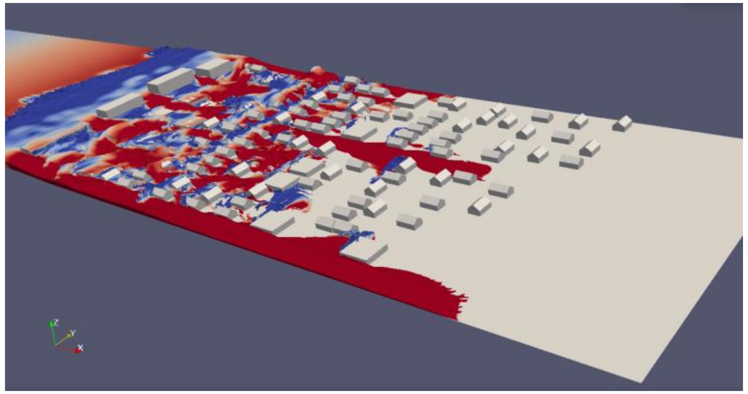
Wave-Induced Debris Impact



Detailed structural models provide insight into the dynamic fluid forces that a vertical evacuation structure may experience to permit capacity analysis

Multi-Scale Modeling of Tsunami Forces

Community-Scale Inundation and Force Prediction



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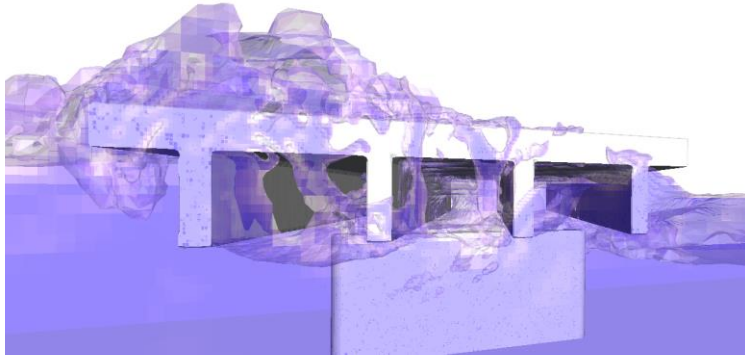
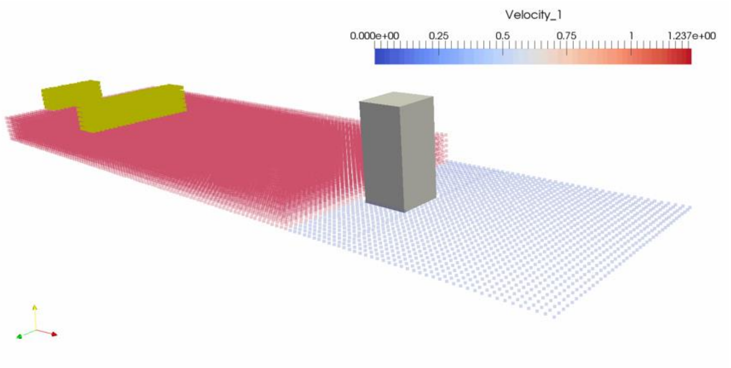


Wave-Induced Debris Impact



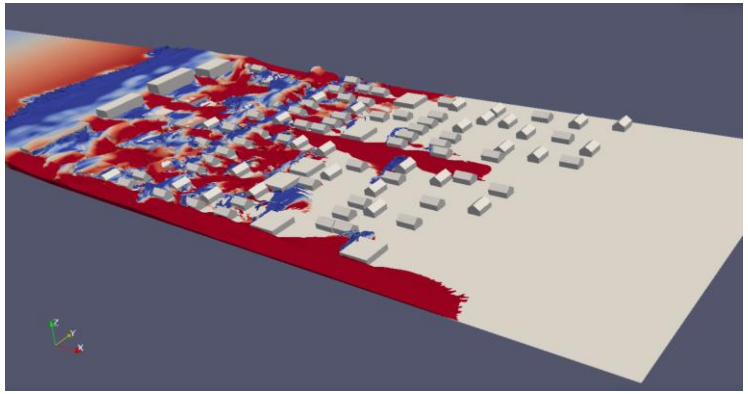
Detailed structural models provide insight into the dynamic fluid forces that a vertical evacuation structure may experience to permit capacity analysis

Models require extensive validation for acceptance in the engineering community but data is often insufficient

Collaboration discussions stressed the need for proper benchmark testing and data sharing

Multi-Scale Modeling of Tsunami Forces

Community-Scale Inundation and Force Prediction



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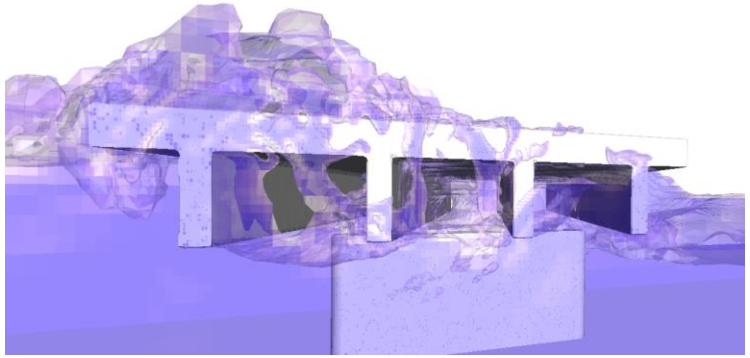

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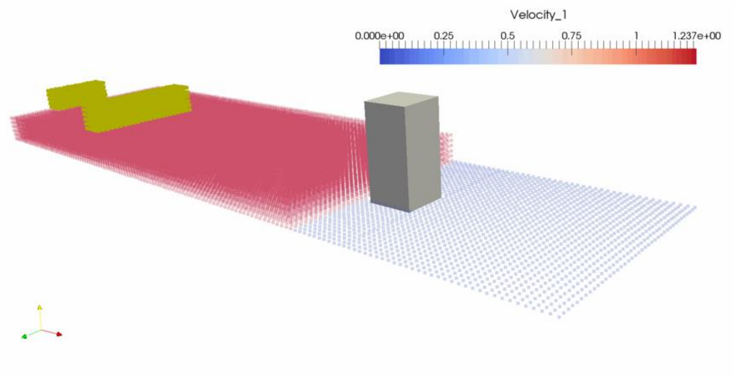


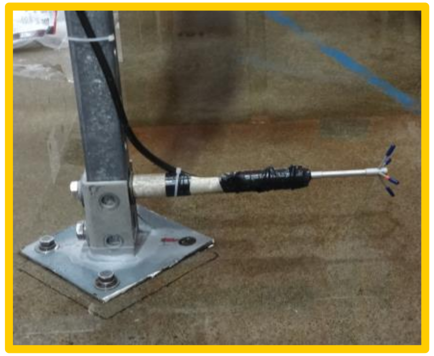
- Since 2017, we have designed three experimental programs
    - January 2017: Uncertainty, repeatability, and correlation between pressure and force measurements
    - October 2019: Loading and response of typical vertical evacuation structures
    - Winter 2020: Comprehensive study of debris and debris field impact forces
- Research questions
    - How well do localized pressure predictions correlate with resultant forces?
    - How reliable are experimental datasets from the large wave flume for model validation?
    - How accurate are numerical force predictions extrapolated where validation studies are based only on experimental flow measurements?
- **All data is to be made publicly available at the NSF DesignSafe Data Depot and archived for ease of access**

NHERI Large Wave Flume

Experiments take place at the NSF NHERI Large Wave Flume at Oregon State University

- **Dimensions:**
  - Length: 104 m
  - Width: 3.7 m
  - Depth: 4.6 m
- **Wavemaker:**
  - Type: Piston-type, Hydraulic Actuator
  - Wave Types: Regular, Irregular, Tsunami
  - Period Range: 0.8 to 12 seconds
  - Max Wave: 1.4 m tsunami in max 2.0 m deep water
  - Max Stroke: 4.0 m at 4.0 m/s
- **Structural scaling ranges from approximately 1:10 to 1:4**

Sample Experimental Setup



ADV

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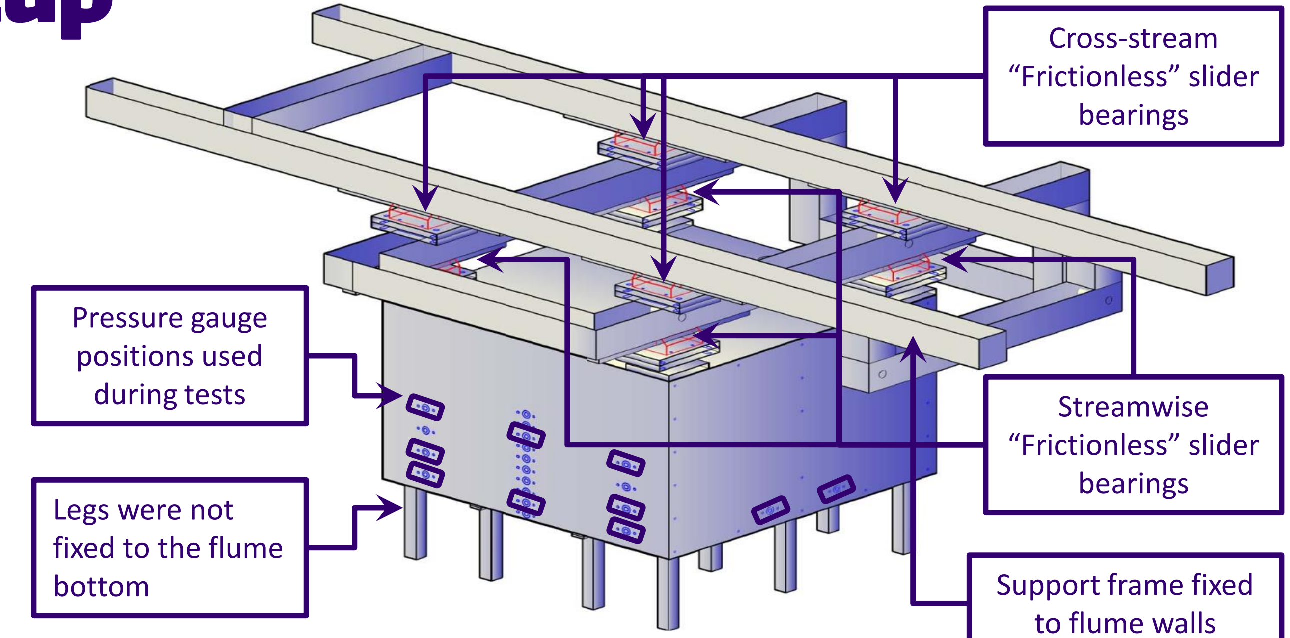
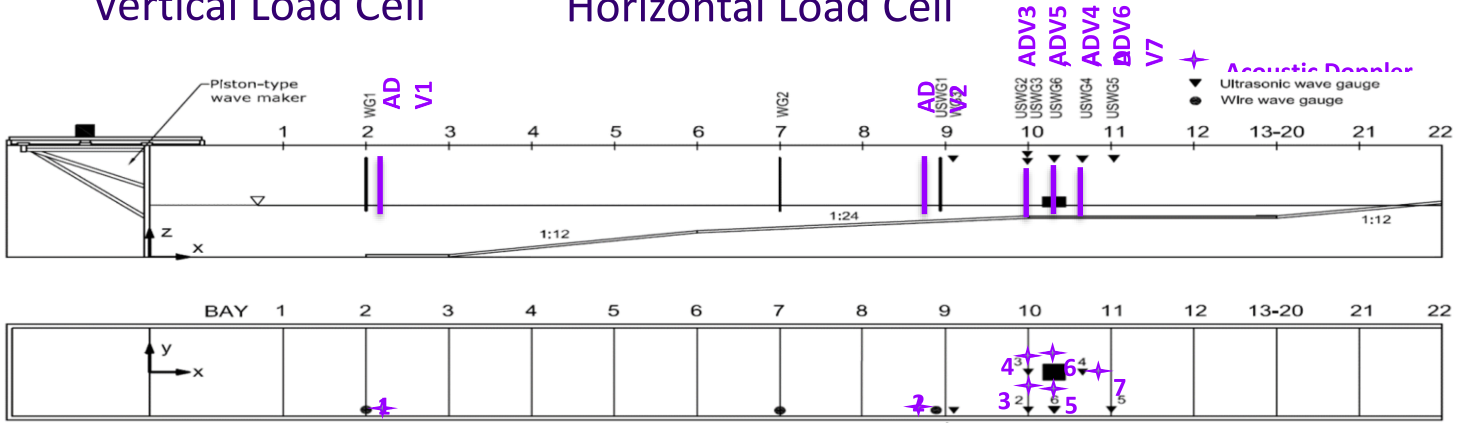
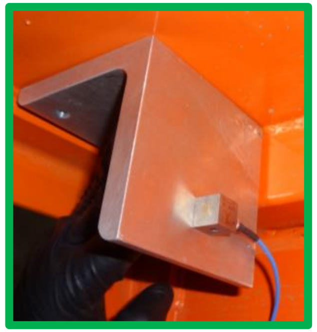
Vertical Load Cell

Horizontal Load Cell



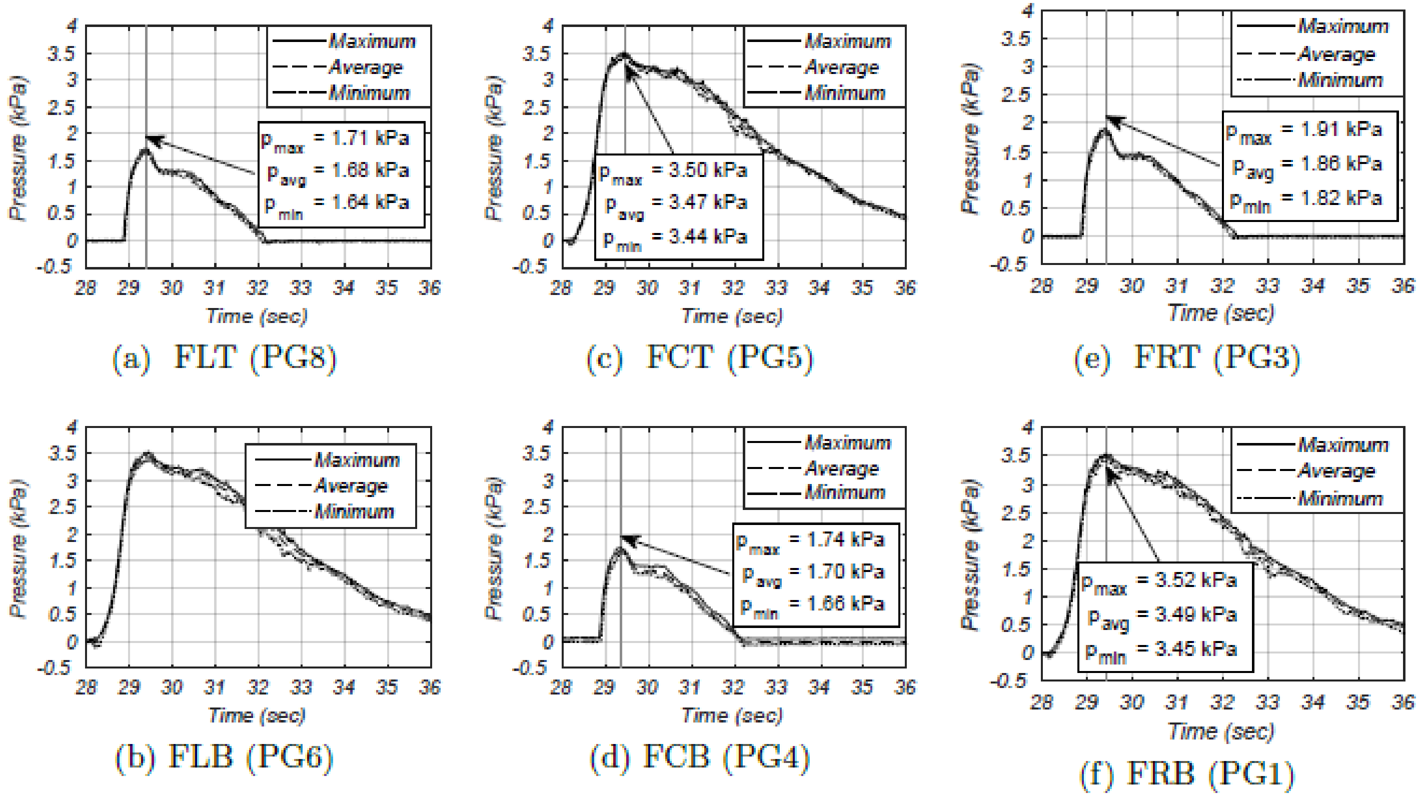


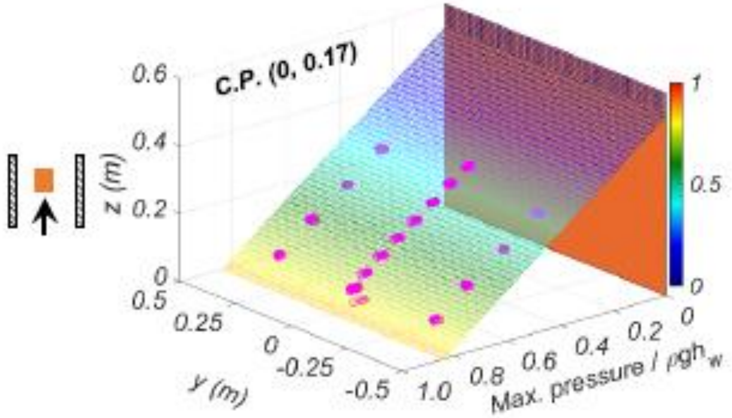
Pressure Gauges



Accelerometer

Uncertainty and Repeatability of Flume Experiments

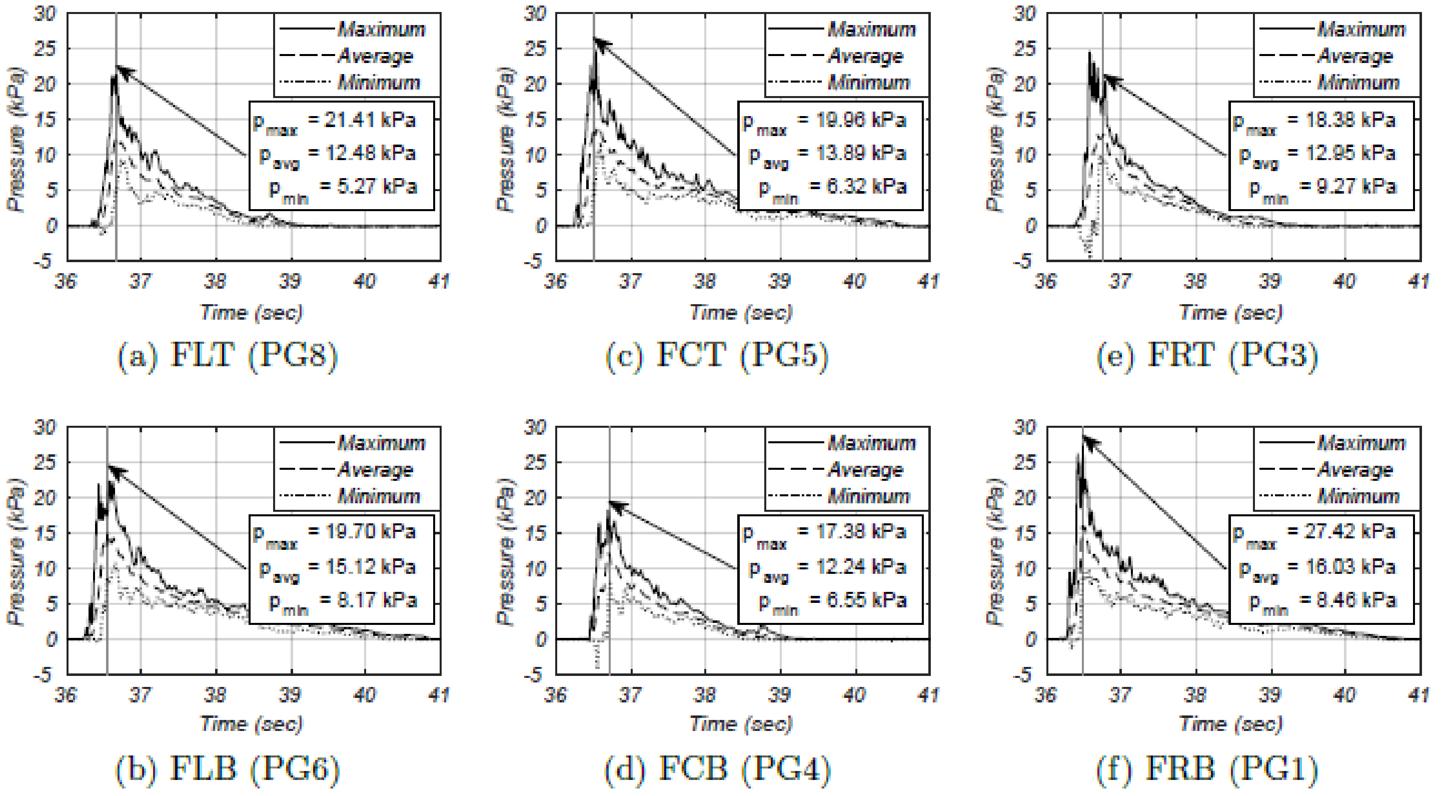




(a)

Alam et al., "Tsunami-like wave-induced lateral and uplift pressure on an elevated coastal structure" Journal of Waterway, Port, Coastal, and Ocean Engineering (2019), In Press

Uncertainty and Repeatability of Flume Experiments



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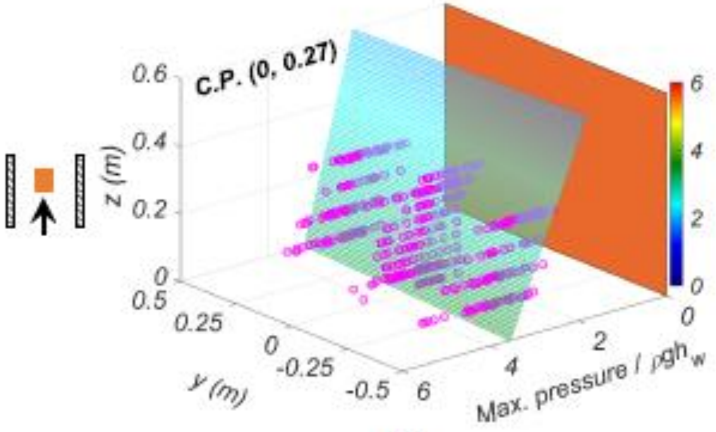
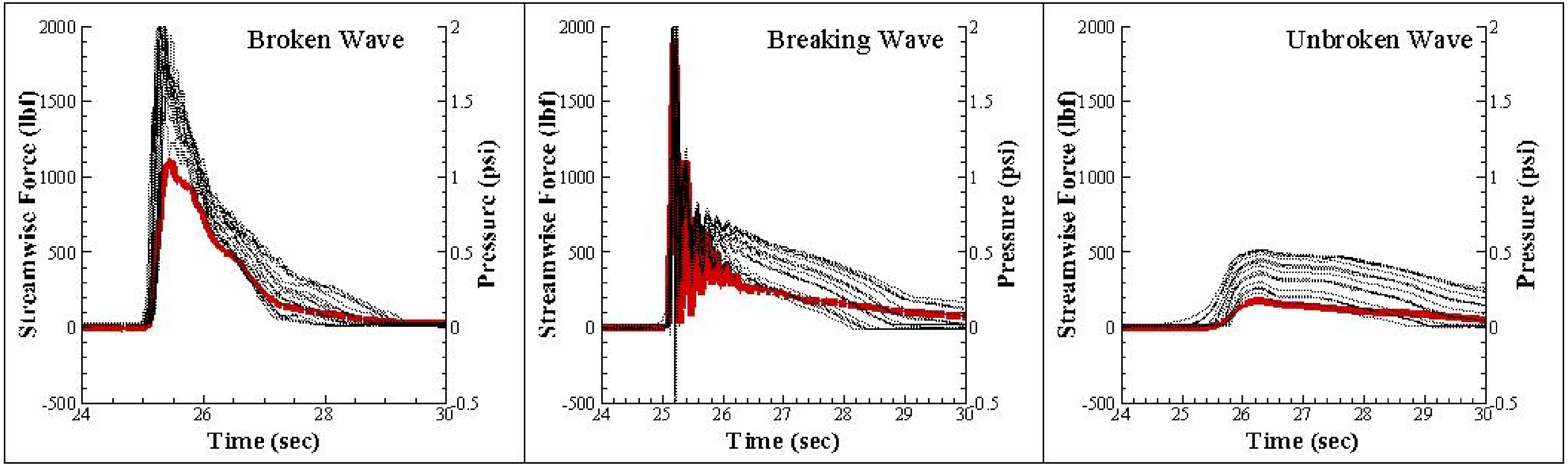
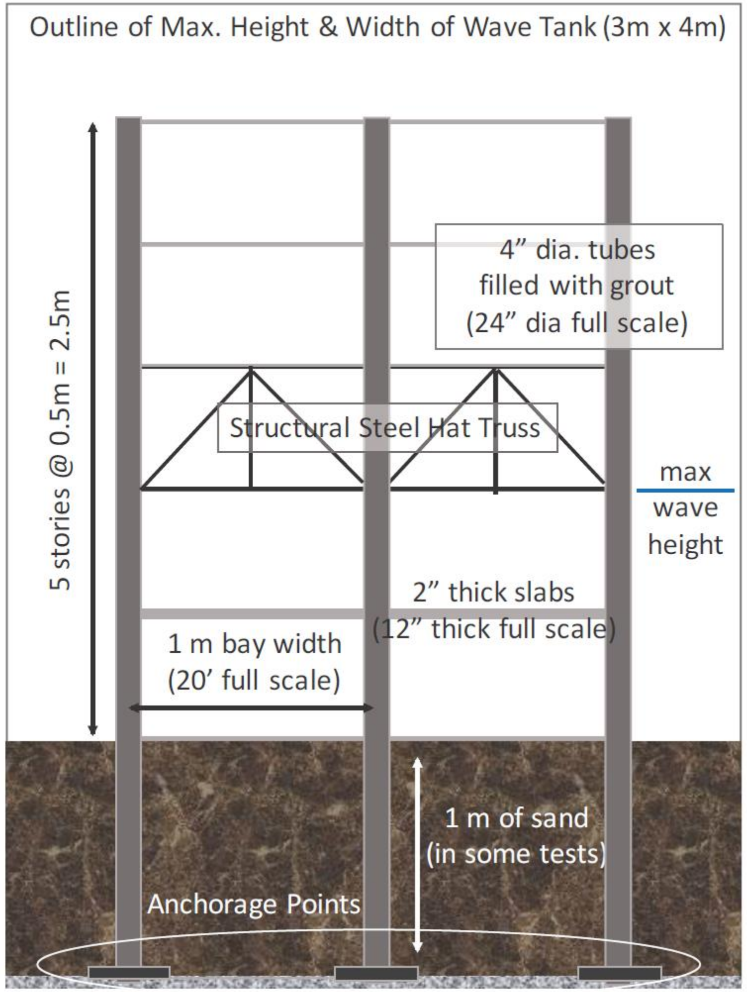


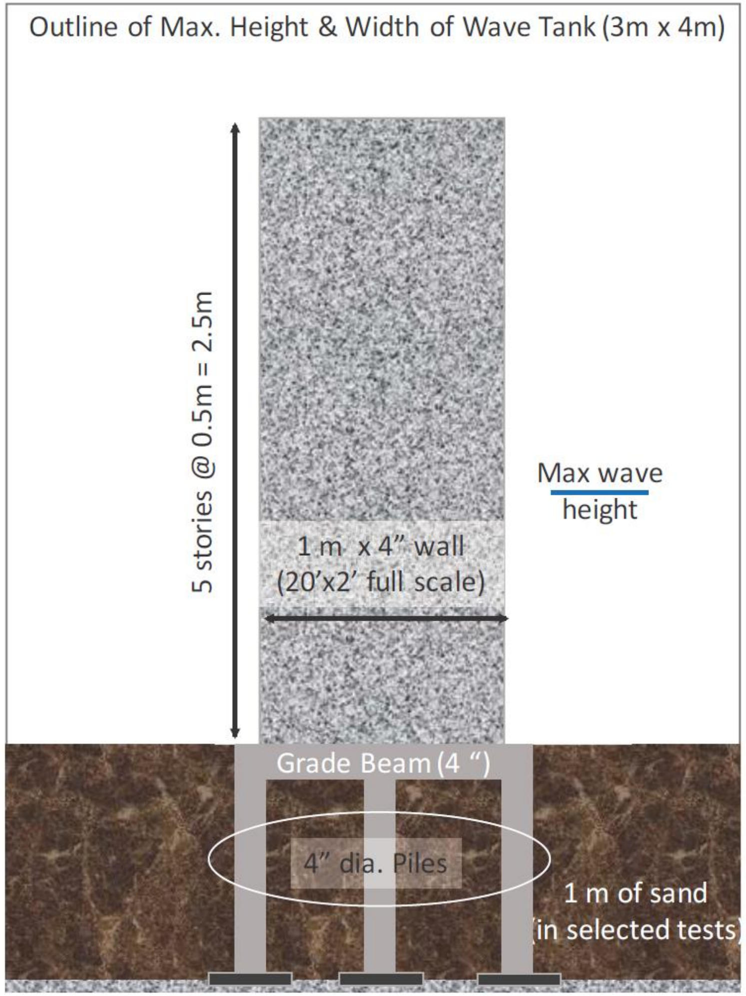
(b)

Uncertainty and Repeatability of Flume Experiments

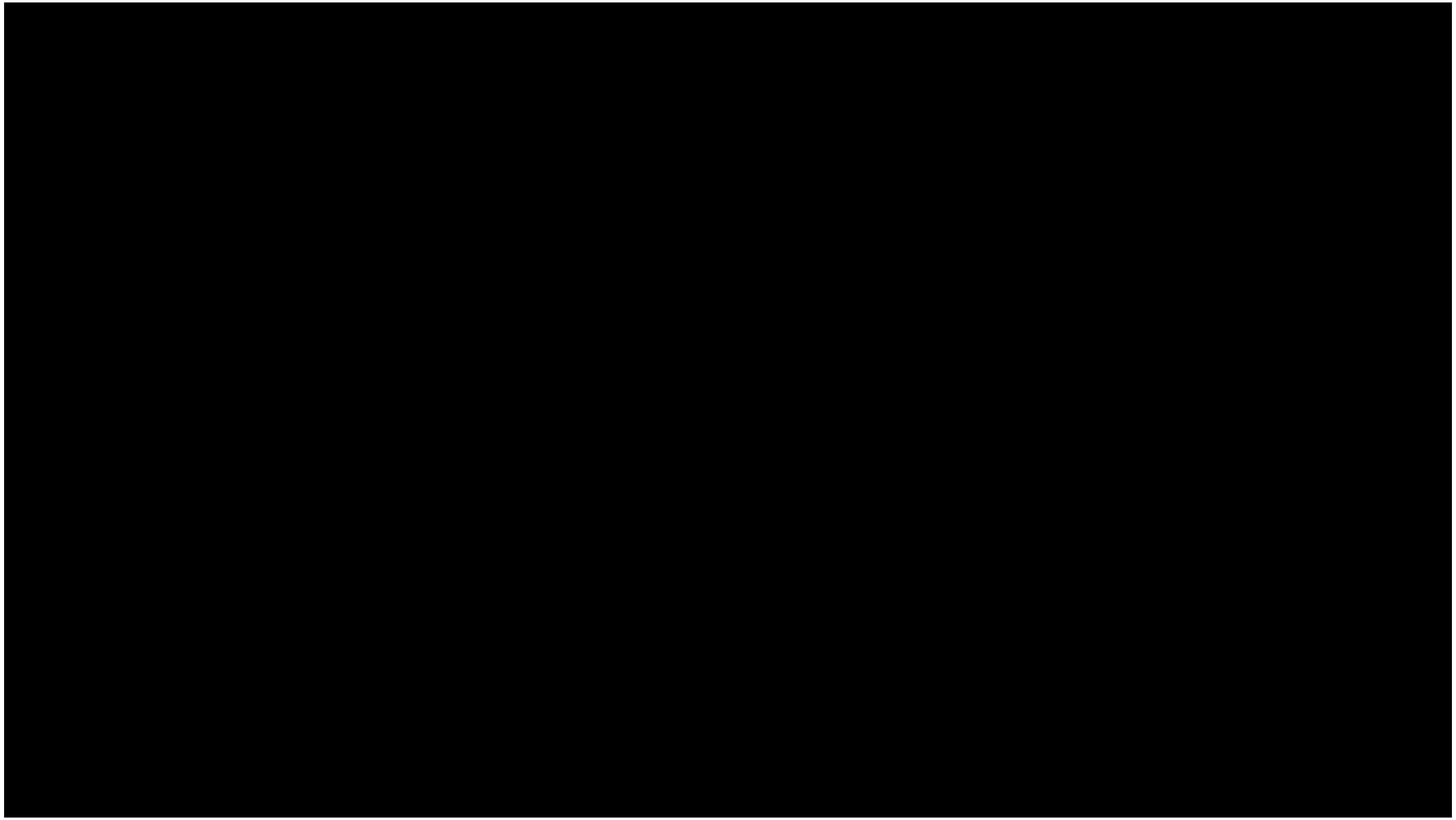


Structural Response of Vertical Evacuation Structures





Structural Response of Vertical Evacuation Structures



Design Safe Data Depot

https://www.designsafe-ci.org/data/browser/public/

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NHERI: A NATURAL HAZARDS ENGINEERING RESEARCH INFRASTRUCTURE

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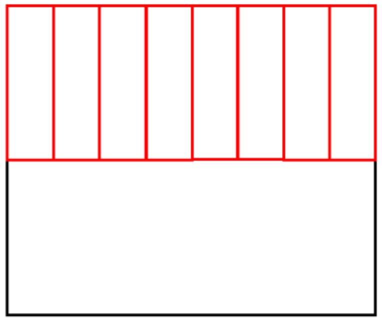
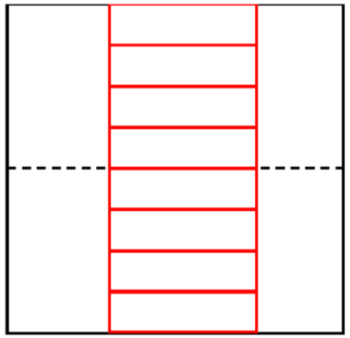
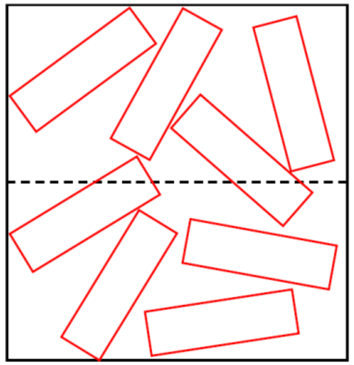
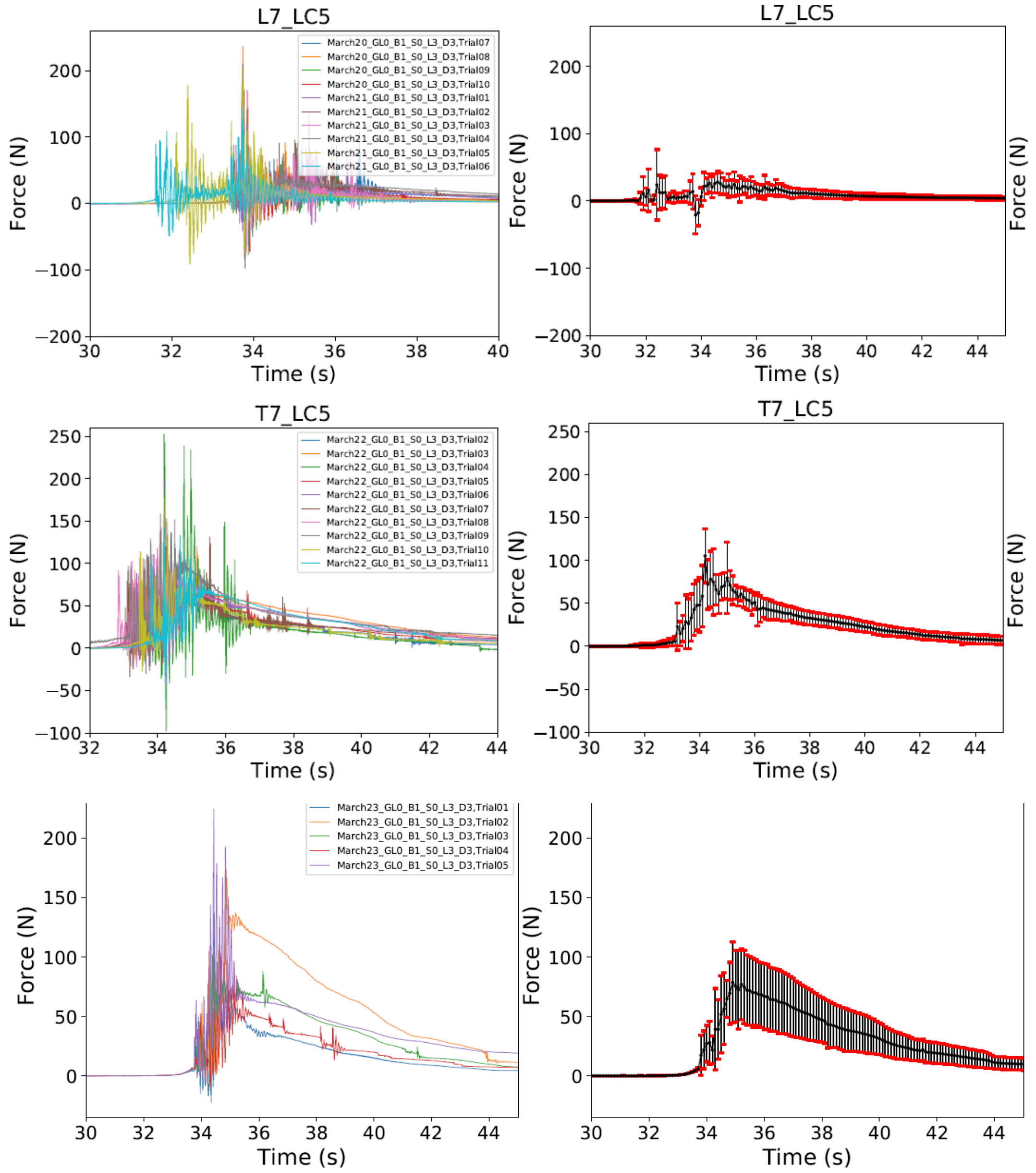
Publication Title	Author	Publication Description	Keywords	Date of Publication
NHERI Debris Impact Experiments (Experimental)	Motley, Michael	View Description	debris, wave, tsunami, impact, force, experiment	2/7/2018
Probabilistic Assessment of Tsunami Forces on Coastal Structures (Experimental)	Motley, Michael	View Description	Debris, tsunami, storm surge, elevated structure, hydrodynamic force	2/23/2019

Debris and Debris Field Impact





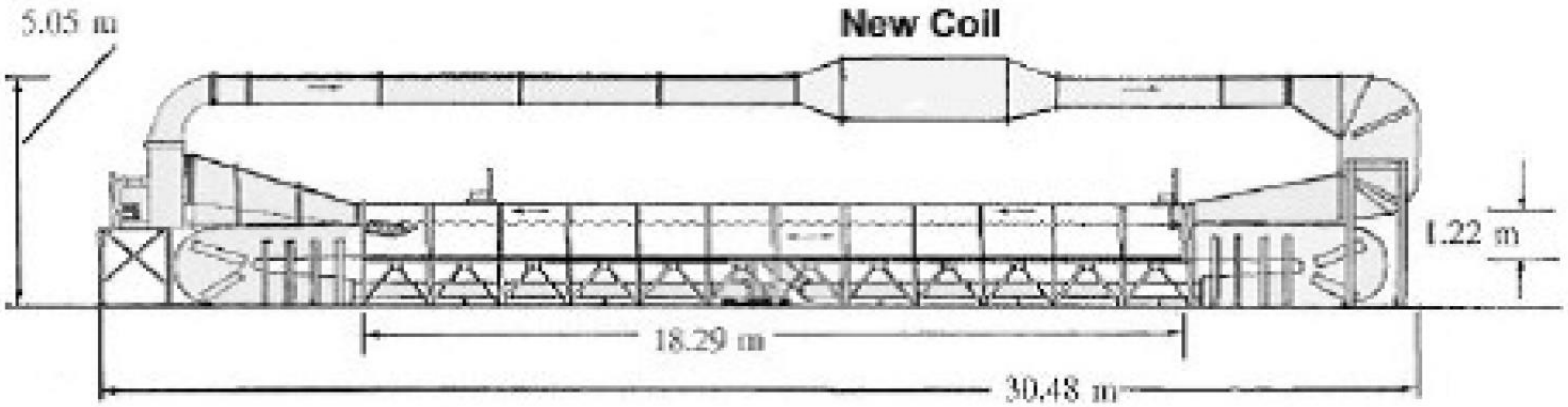




Proof-of-concept tests were conducted as part of the 2017 tests to look into variability in a debris field

Additional tests were funded in Summer 2019 and will be conducted in late 2020

Debris and Debris Field Impact



An additional set of tests will be conducted in the constant flow wind-wave flume at the University of Washington to better model the physical tsunami process of quasi-steady flow. Data will be made available in by 2022.

Debris and Debris Field Impact

Task 3b: Blind Prediction Workshop

As both a success metric and to broaden the impact of this work, the team will coordinate and participate in an international blind prediction workshop based on the experimental results developed in Tasks 1 and 3. In collaboration with the Pacific Earthquake Engineering Center (PEER), the team will invite interested researchers from across the U.S. and abroad for a two-day workshop at UW designed to highlight the unique experimental data developed herein and present the various modeling approaches being applied for debris-fluid-structure interaction modeling problems. The PIs participated in a March 2019 UW workshop with tsunami researchers from Japan (IRIDeS) and Chile (CIDIGEN) to formally initiate collaborative research efforts, and this work would provide an natural opportunity to extend those international collaborations. PEER has been sponsoring various workshops related to earthquake engineering topics, including a December 2014 tsunami engineering workshop in collaboration with the Public Works Research Institute of Japan (in which Profs. Motley and Arduino were participants), and PEER will support, sponsor, and advertise the proposed blind prediction workshop (see attached letter of collaboration).

Contributors

- Tsunami Forces on Structures
  - Andrew Winter, UW
  - Shafiq Alam, OSU
  - Pedro Arduino, UW
  - Andre Barbosa, OSU
  - Dan Cox, OSU
  - Marc Eberhard, UW
  - Dawn Lehman, UW
  - Pedro Lomonaco, NSF
  - Dakota Mascarenas, UW
  - Greg Miller, UW
  - Chris Pyke, UW
  - Charles Roeder, UW
  - Andrew Sen, UW
  - Krish Shekhar, UW
  - Ken Sullivan, UW
- M9:
  - Xinsheng Qin, UW
  - Randy LeVeque, UW
  - Frank Gonzalez, UW
- This work has been supported through the National Science Foundation.

Thank you