OpenFOAM Modeling of Tsunami Forces on Coastal Structures

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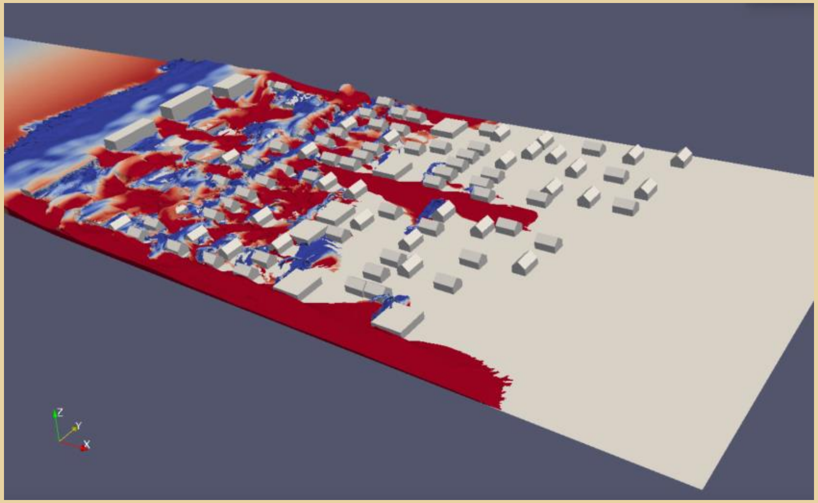
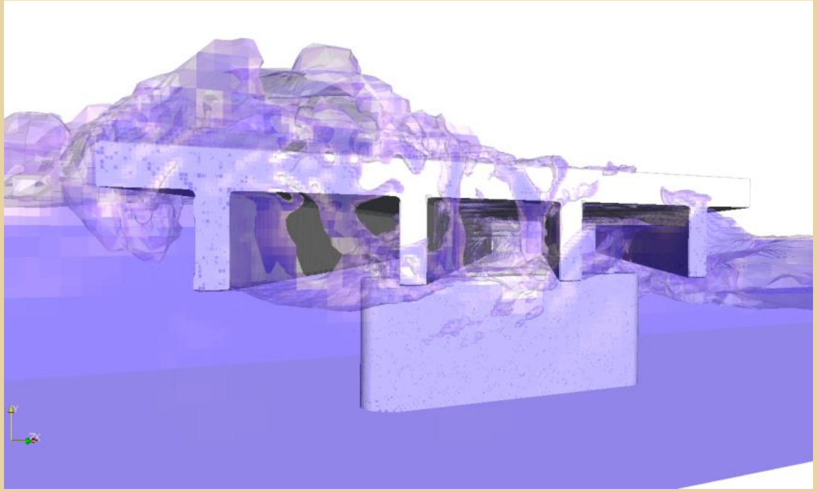
CIVIL & ENVIRONMENTAL ENGINEERING
UNIVERSITY of WASHINGTON

Multi-Scale Modeling of Tsunami Forces

Community-Scale Inundation and Force



Structure-Scale Force Prediction



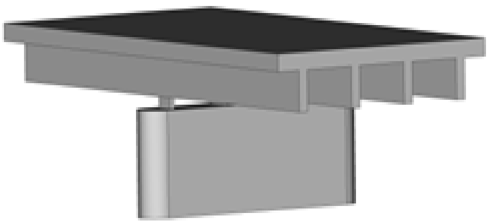
Detailed structural models provide insight into the dynamic fluid forces that a structure may experience to permit capacity analysis

Computational Fluid Dynamics Modeling

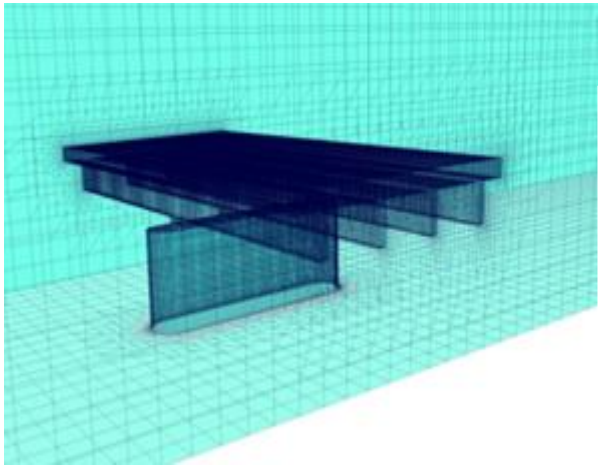
- **OpenFOAM: O**pen **F**ield **O**peration **a**nd **M**anipulation
- Purposely developed for solving a wide range of fluid problems
  - Incompressible flows, multiphase flows, buoyancy-driven flows, and more
- Complete CFD software package
  - Comes with 80+ solvers and 170+ utilities
  - Mesh Generations and Refinements
  - Data loaders for converting CAD geometries to meshes
  - Parallelization of fluid problem solutions
    - In this work, 64-256 processors were commonly used
    - Other researchers have used up to ~1000 processors
  - Will be available for use on NHERI Cyberinfrastructure in the coming months

Computational Fluid Dynamics Modeling

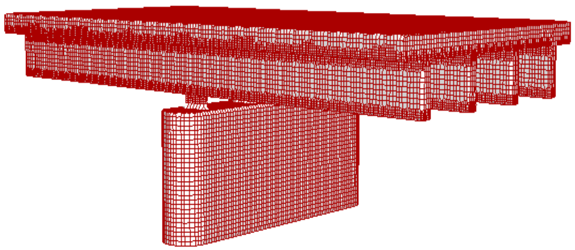
We convert CAD *.stl files into OpenFOAM 3D Meshes



CAD Rendering



OpenFOAM Internal Mesh



OpenFOAM Boundary Faces

Computational Fluid Dynamics Modeling

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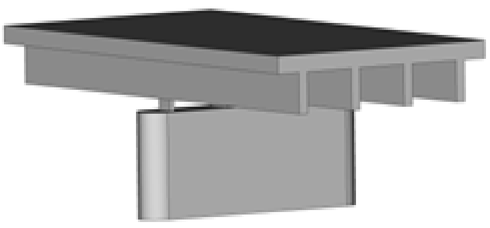

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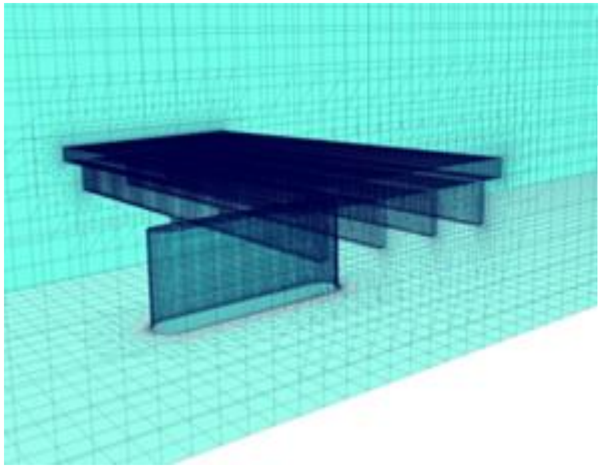

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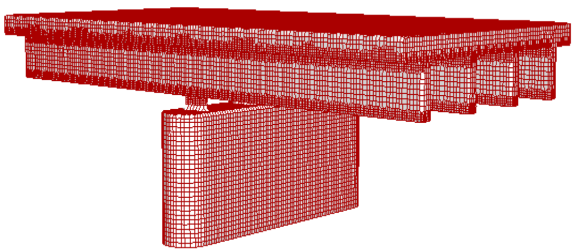

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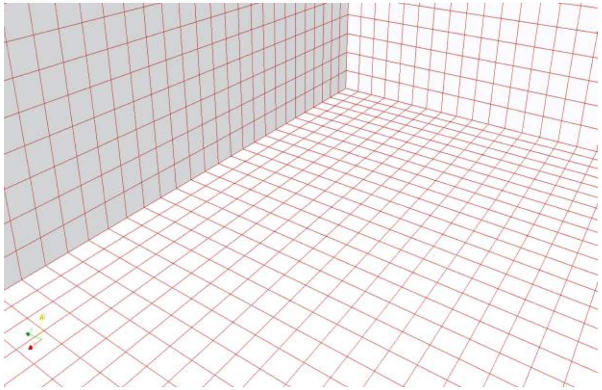

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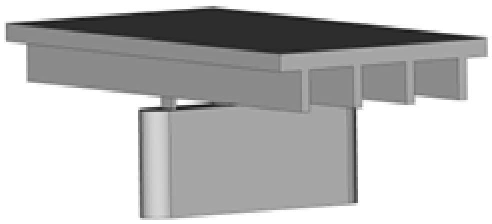

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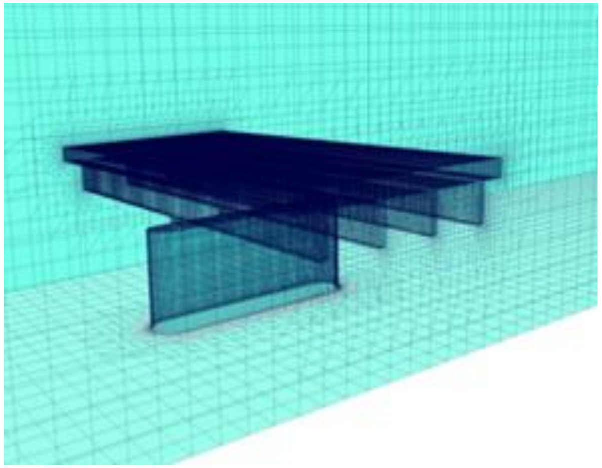

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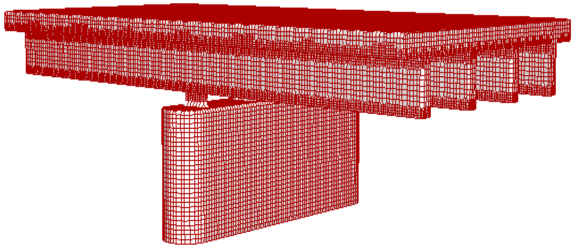
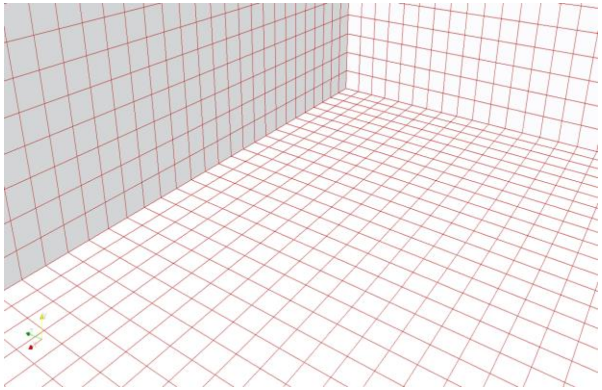
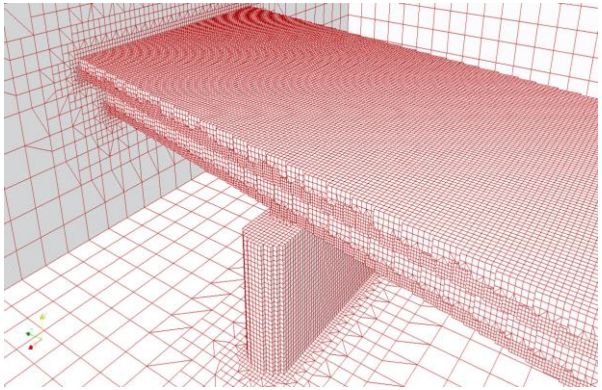


OpenFOAM Boundary Faces





Computational Fluid Dynamics Modeling

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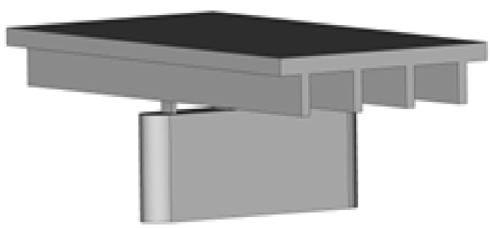

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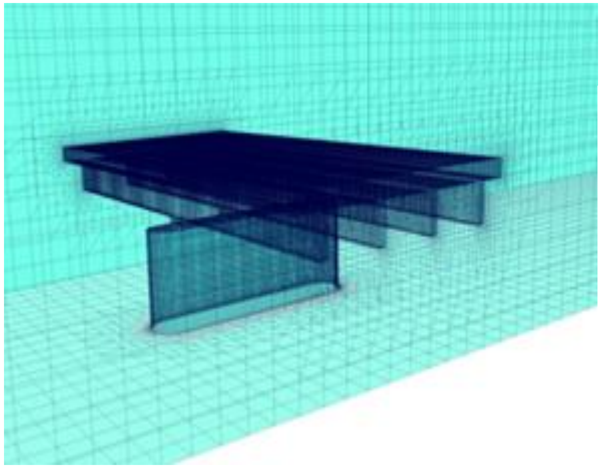
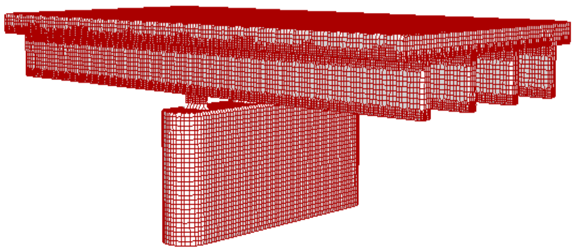


OpenFOAM Internal Mesh



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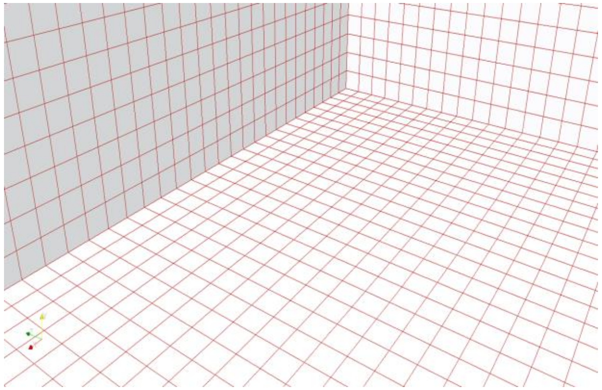
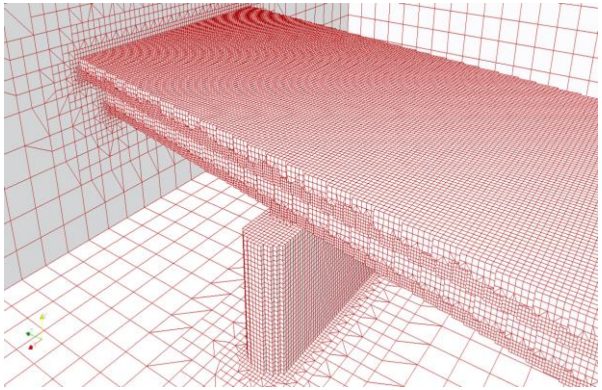
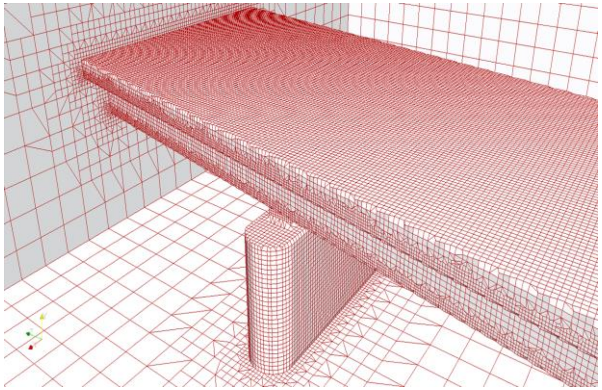
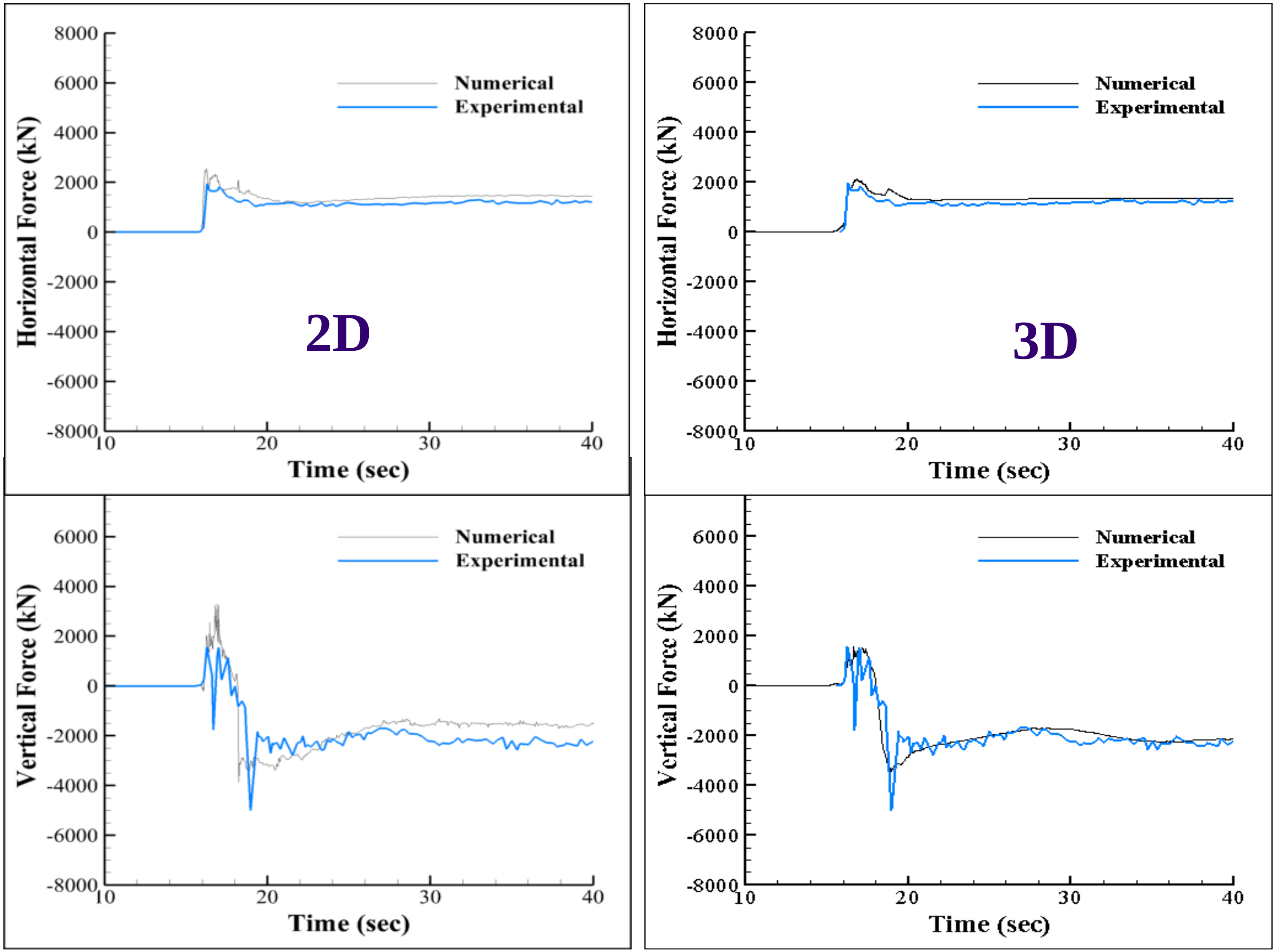






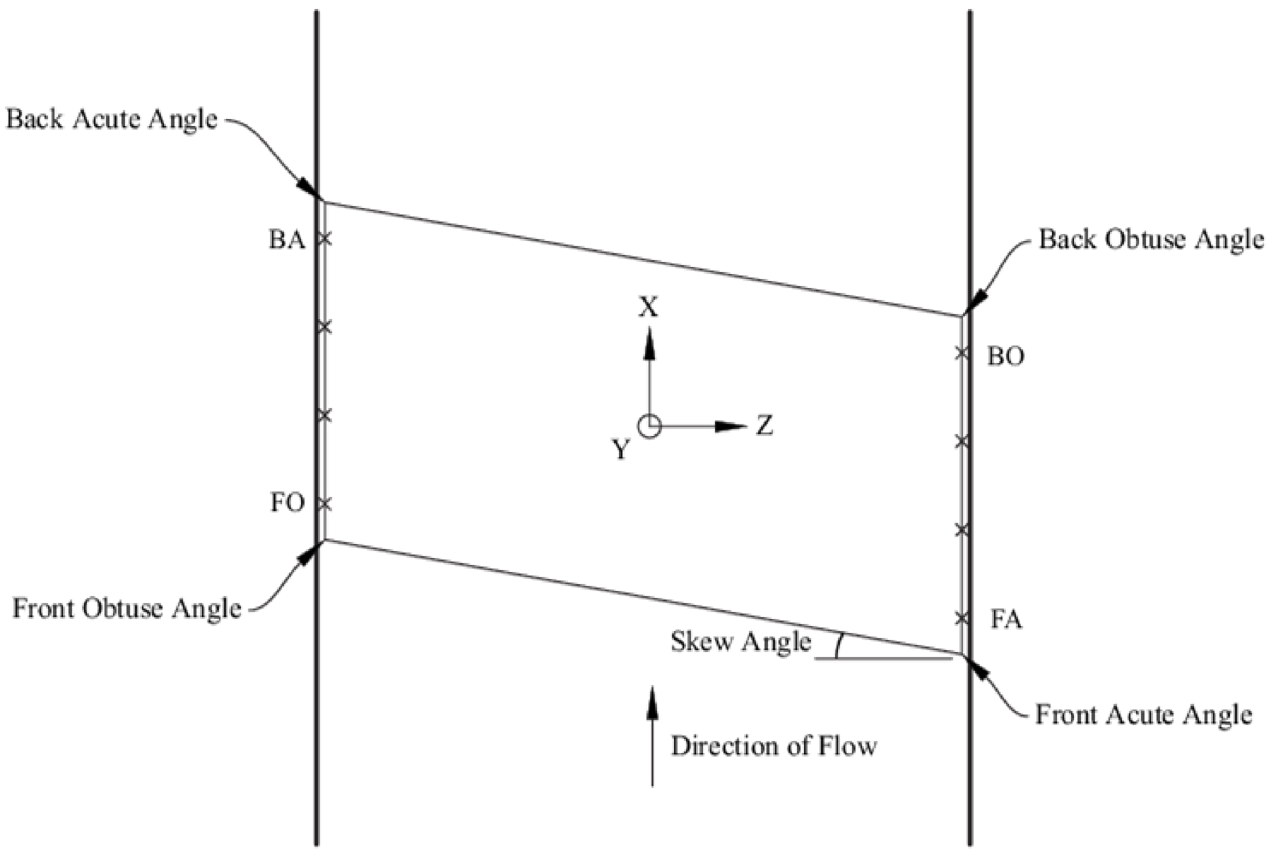
Experimental Data from Flume Tests



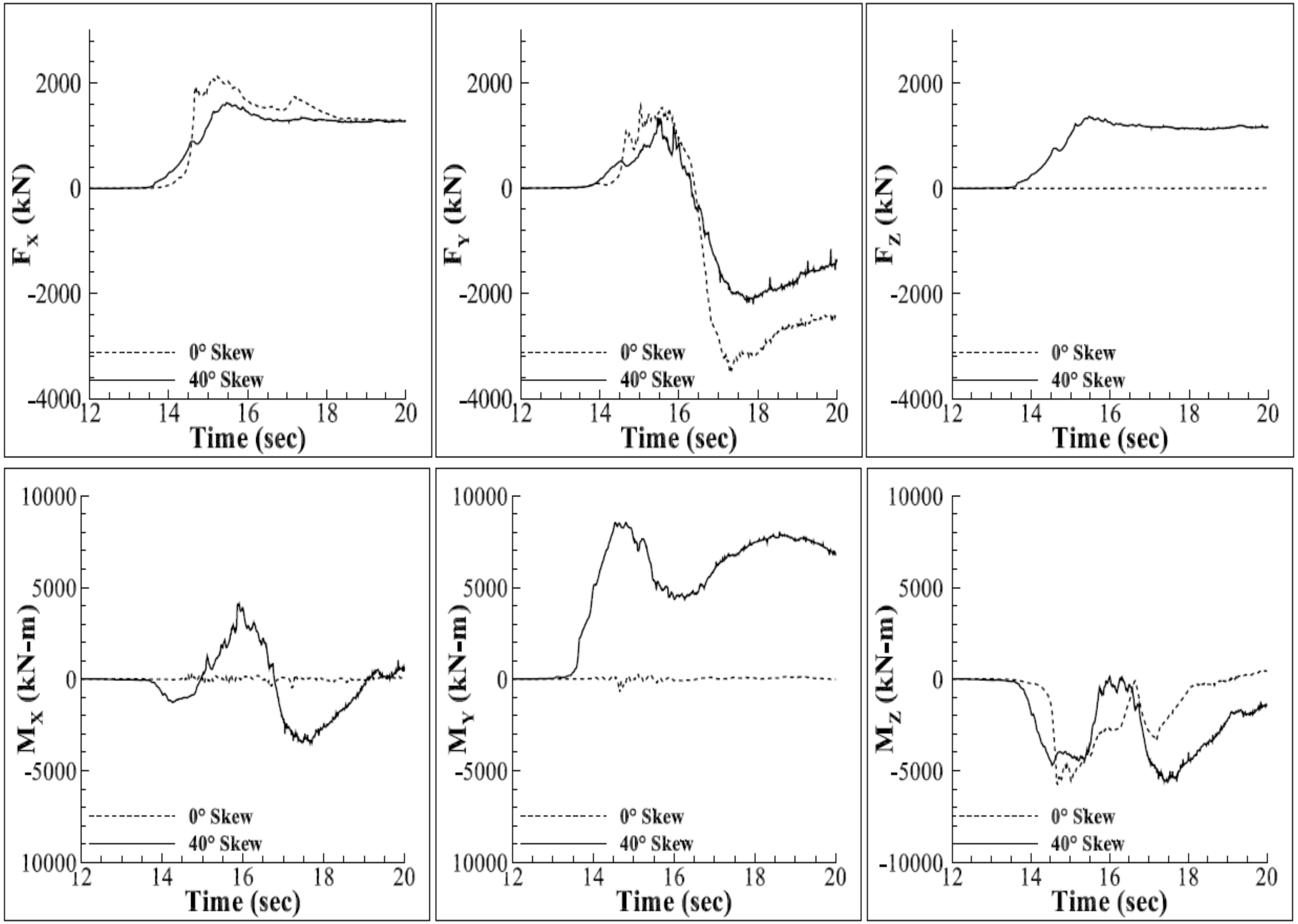
Modifying the Geometry

By slightly modifying the geometry of the bridge, we can create scenarios where extrapolating a two-dimensional model does not accurately represent the response of the structure to wave loads.

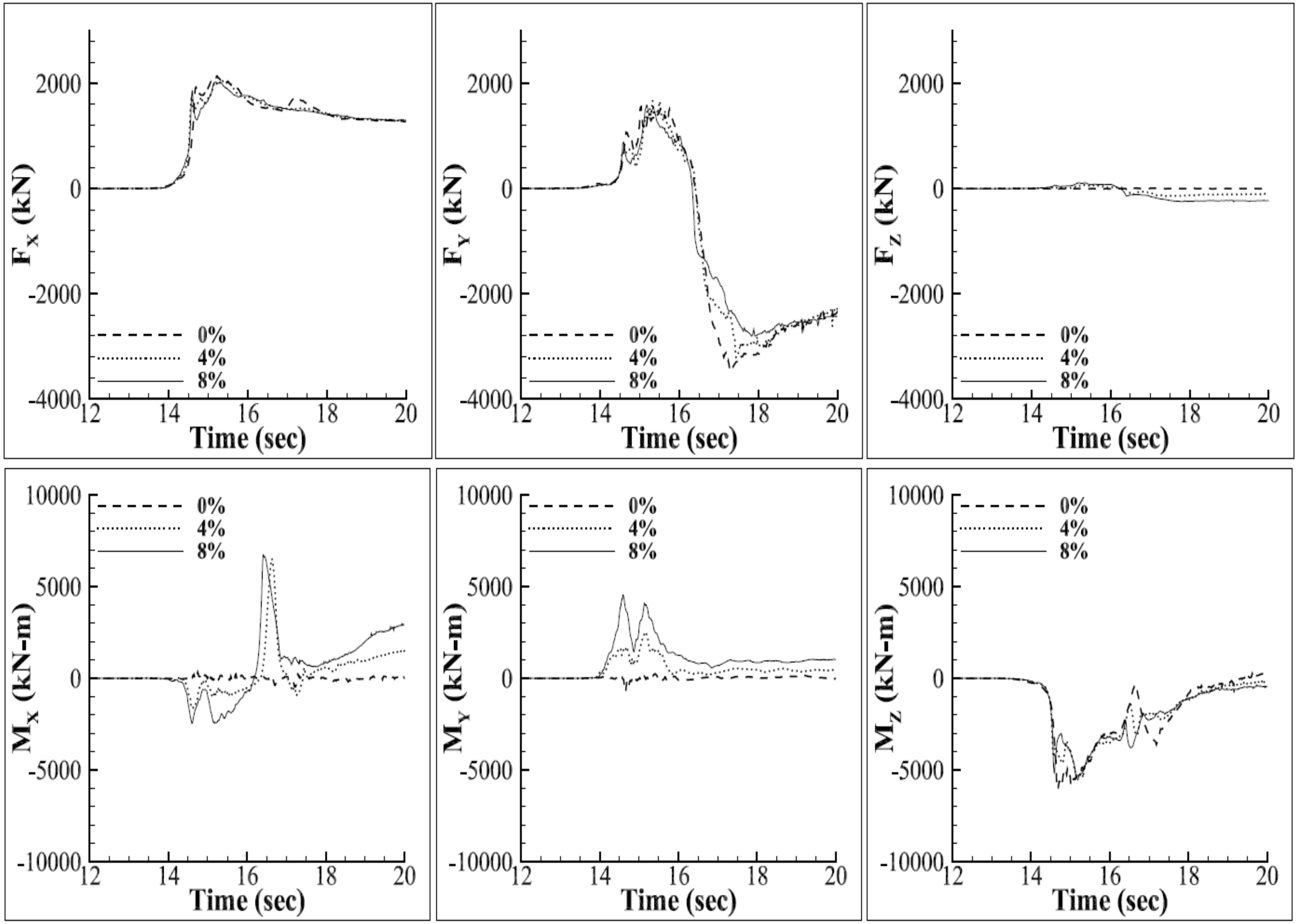
Consider a skewed bridge:



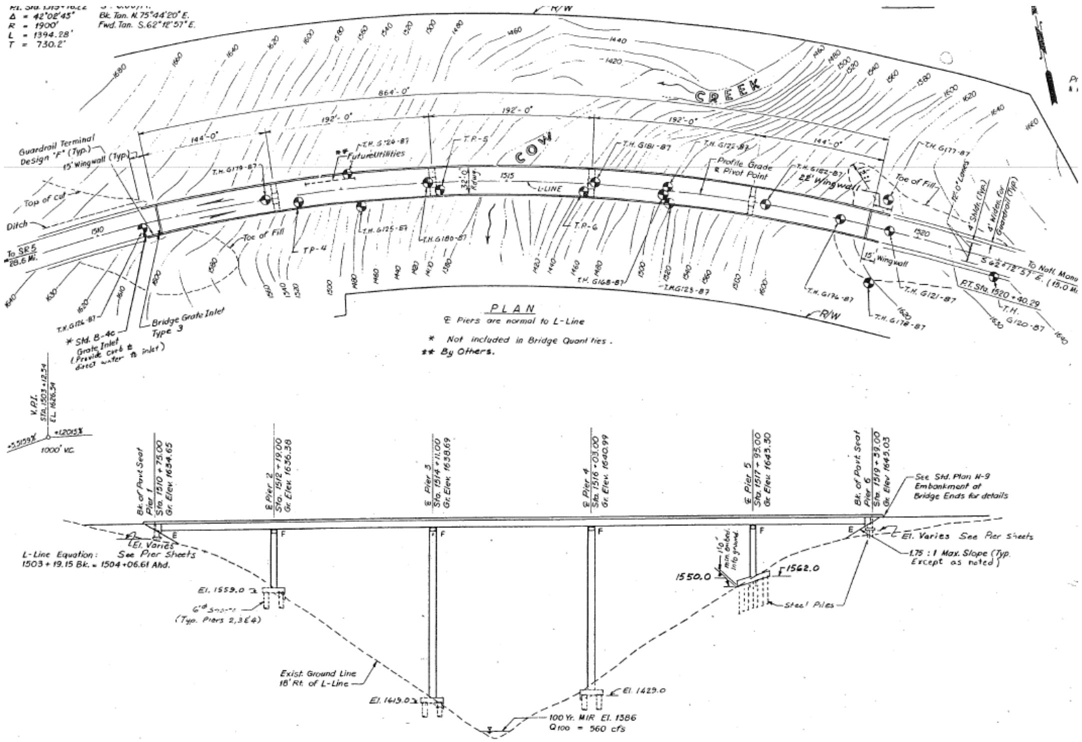
Resulting Loading Histories

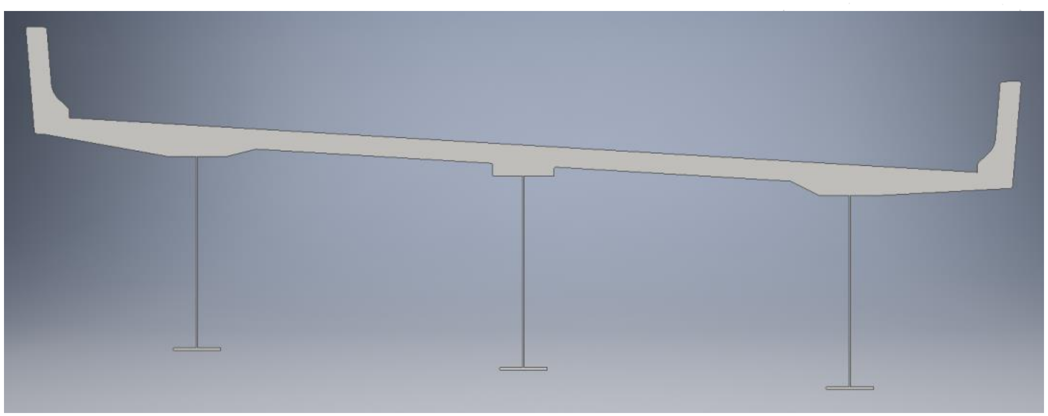


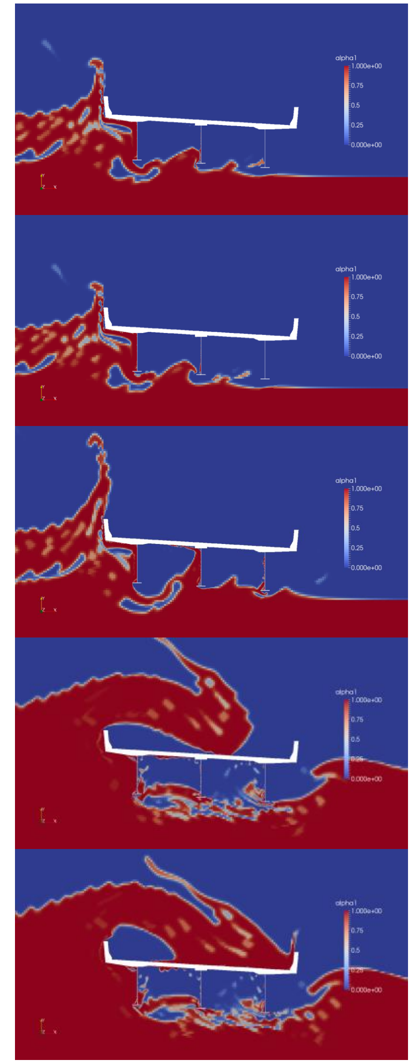
What about slope effects?



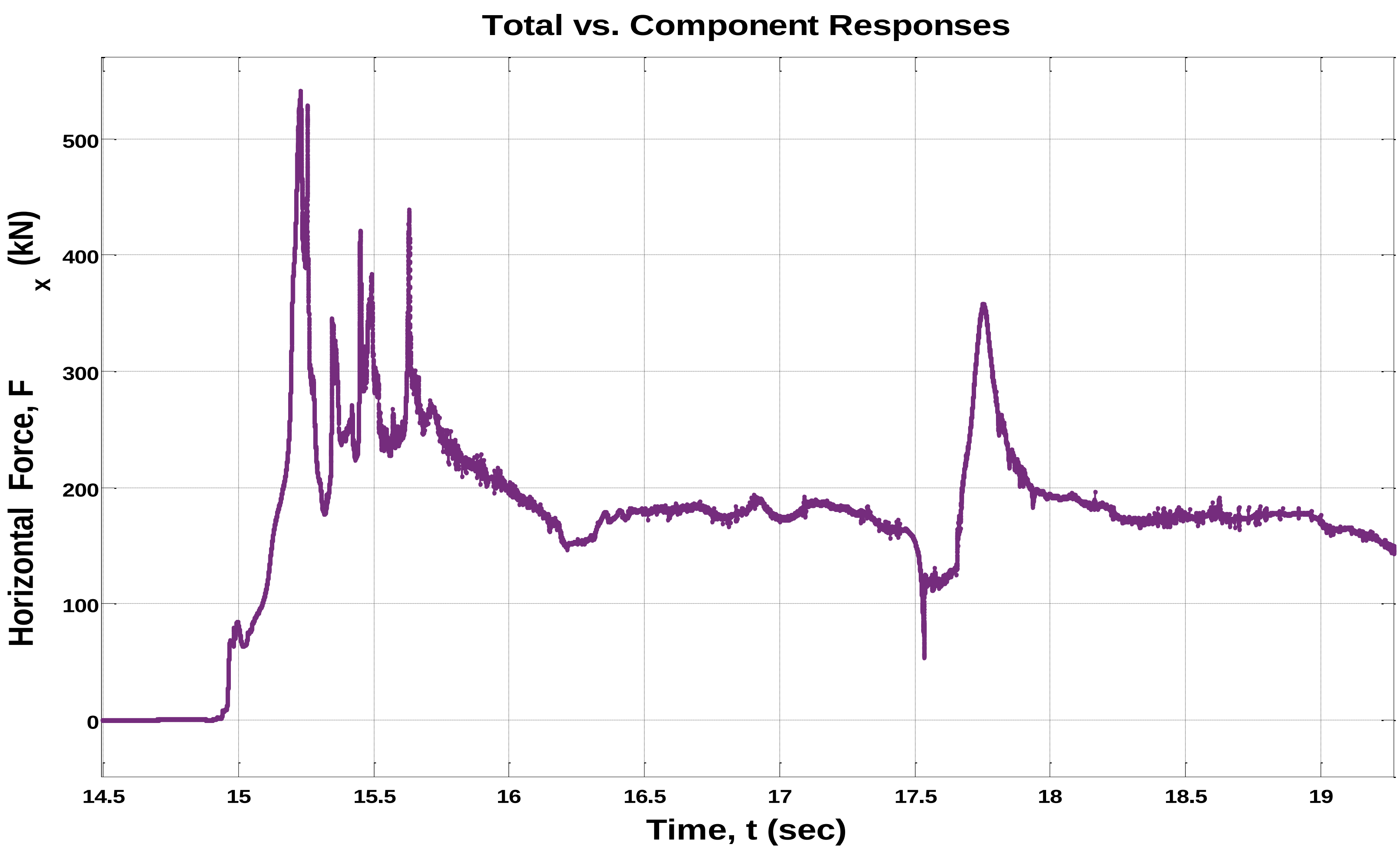
Fluid–air–structure interactions



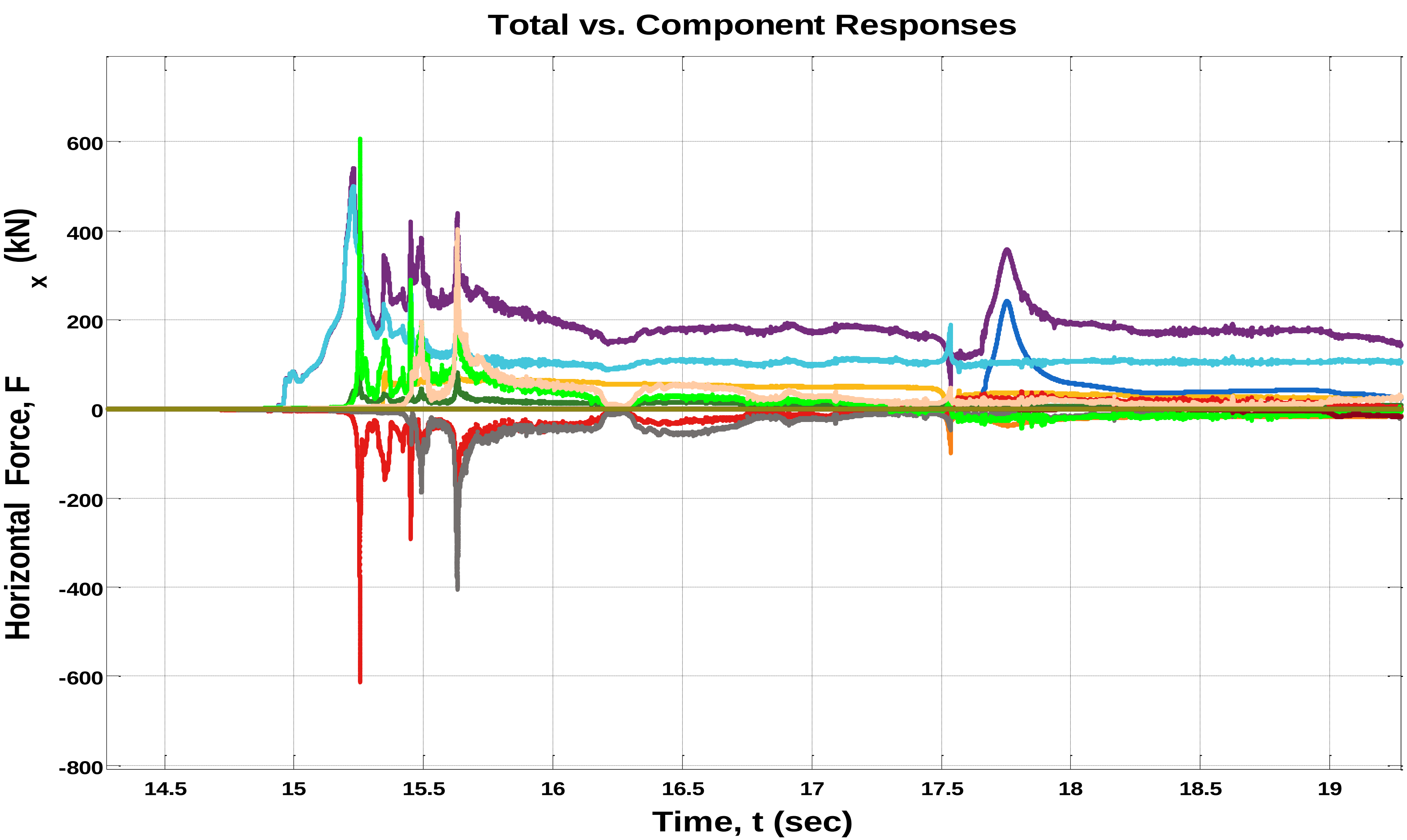




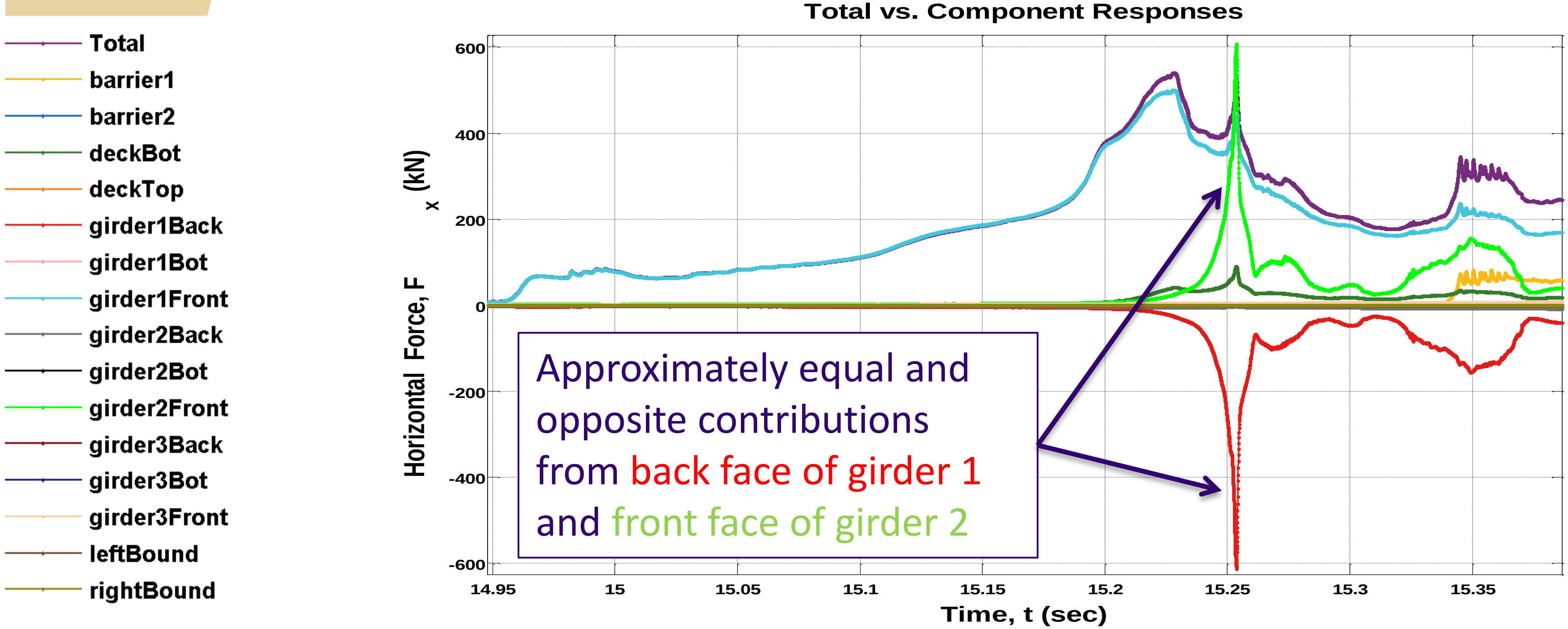
Fluid–air–structure interactions

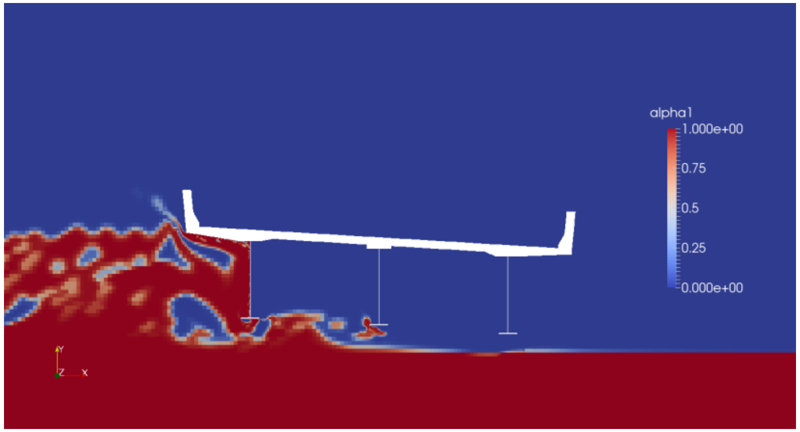


Fluid-air-structure interactions

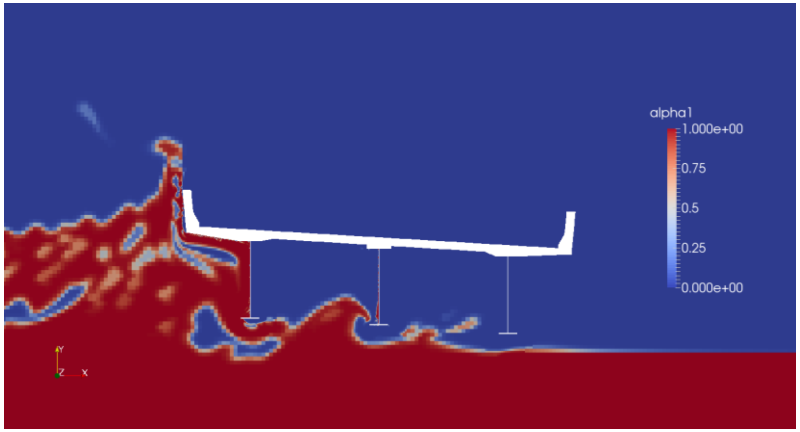


Structure-Scale Models



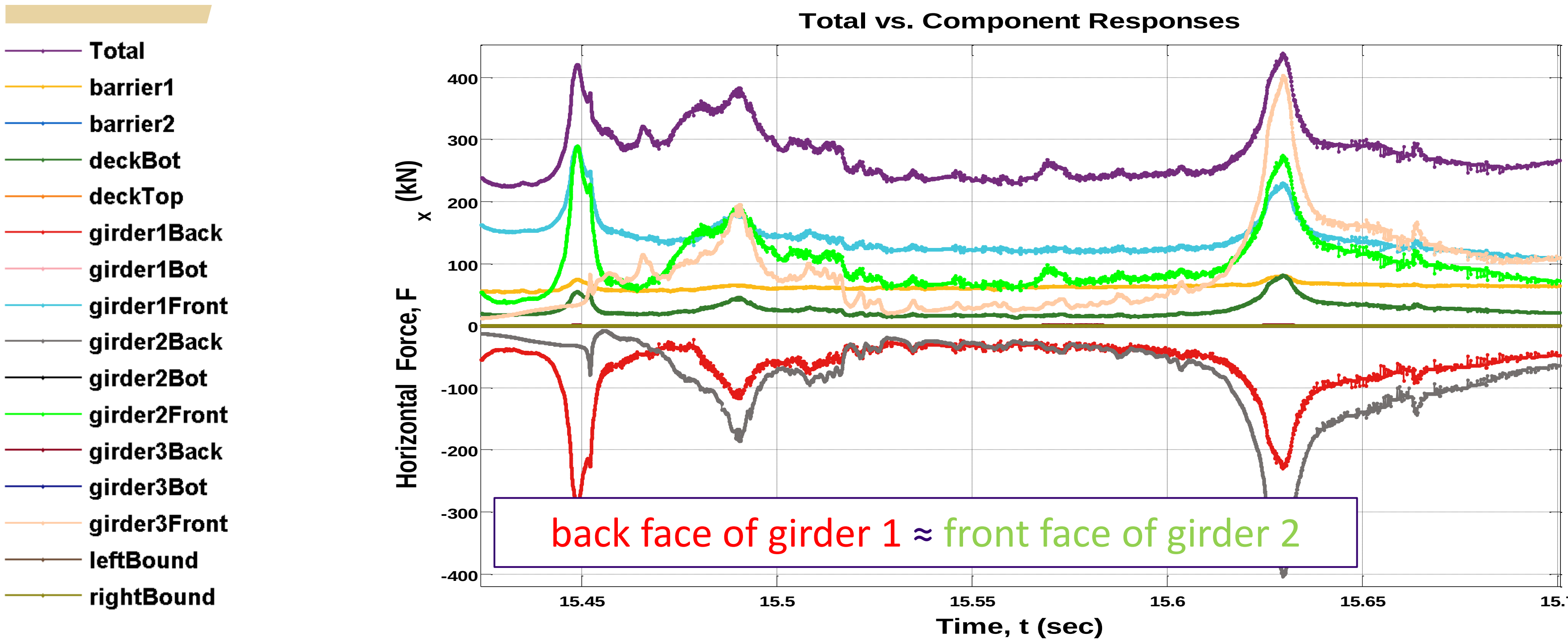


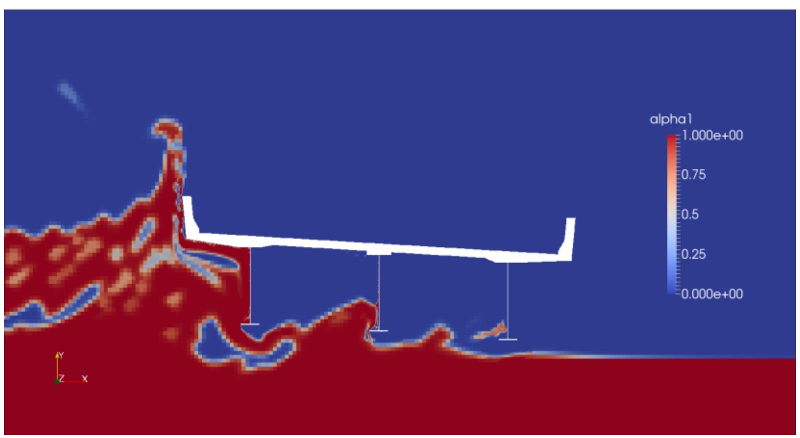
Front Faces at 15.25 s



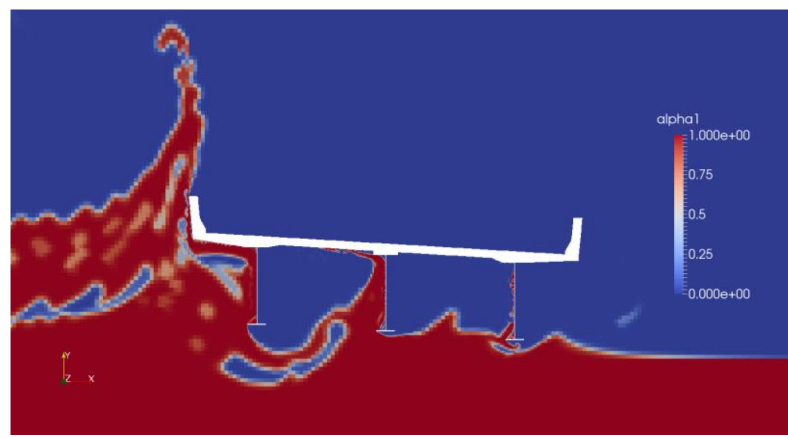
Front Bay at 15.35 s

Structure-Scale Models



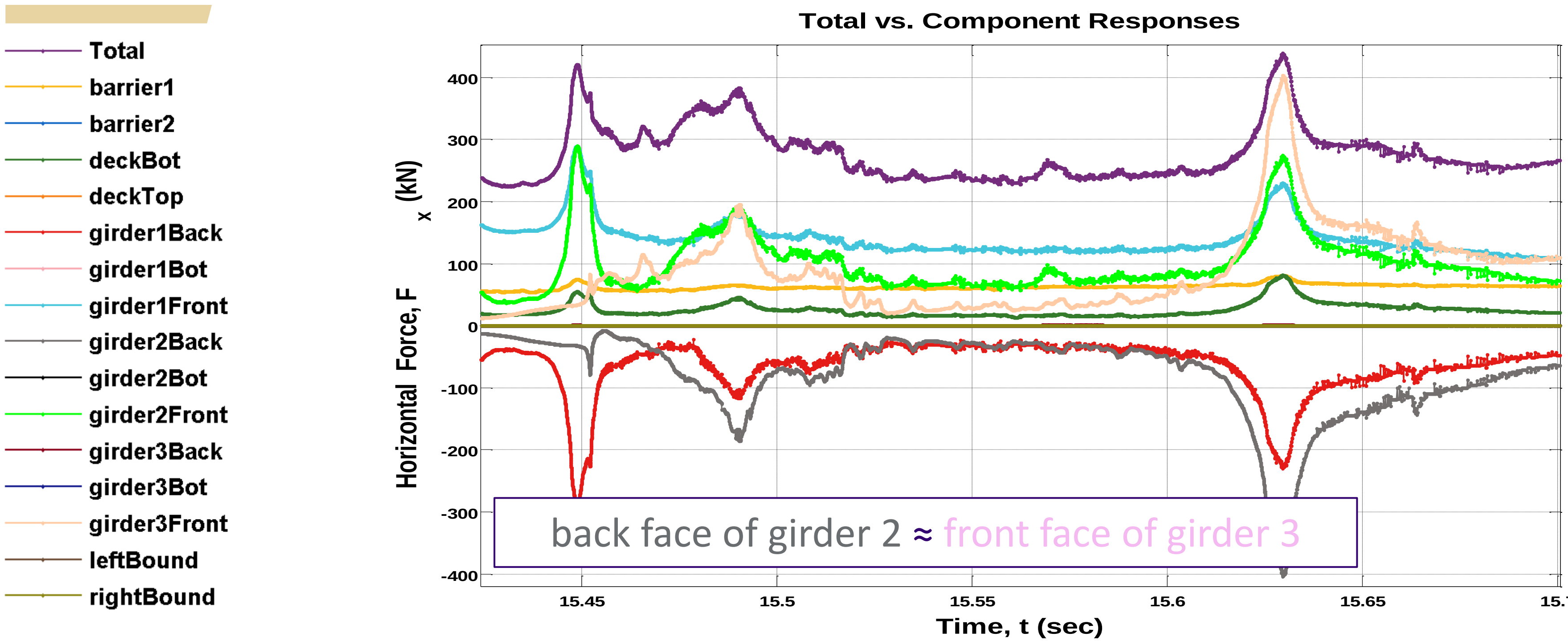


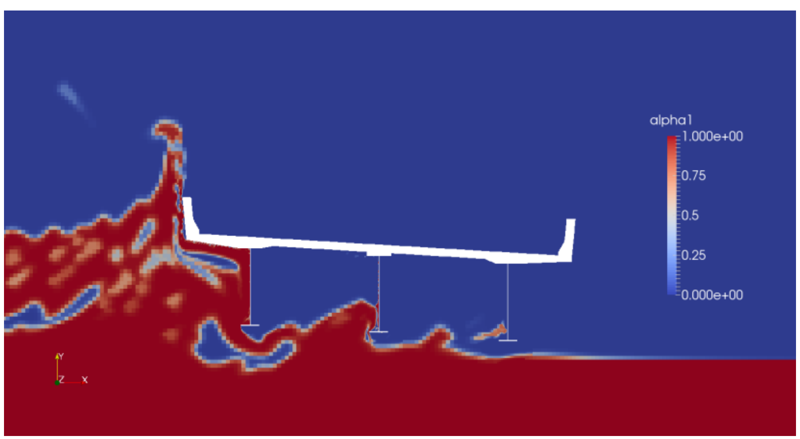
Front Faces at 15.45 sec

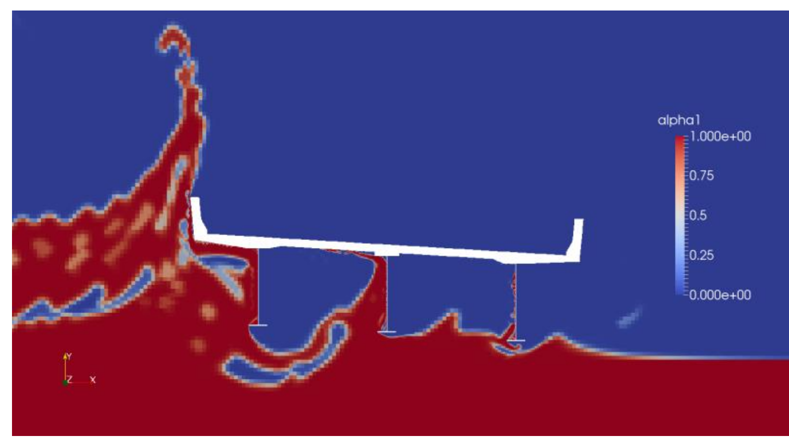


Bays and Front Barrier at 15.625 s

Structure-Scale Models







Front Faces at 15.45 sec

Bays and Front Barrier at 15.625 s

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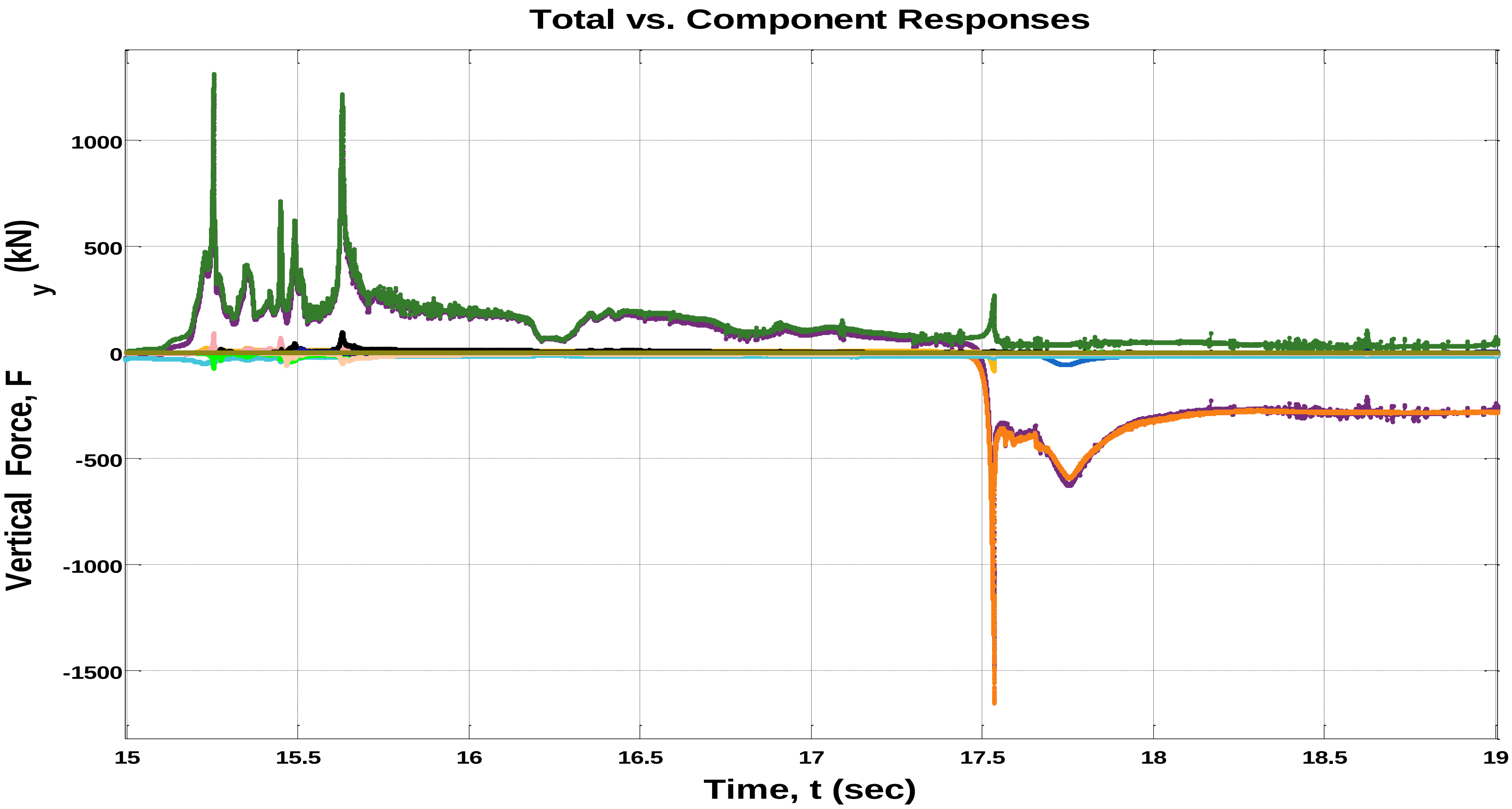
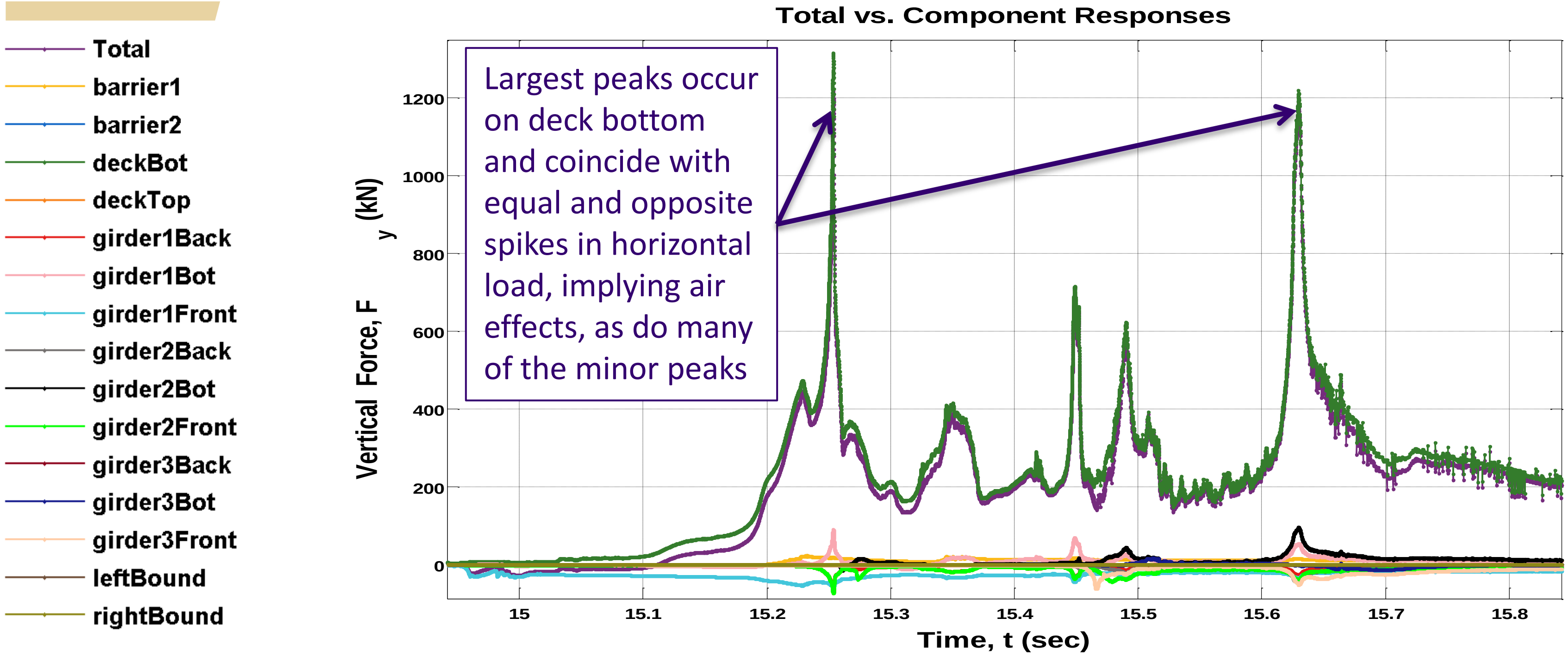
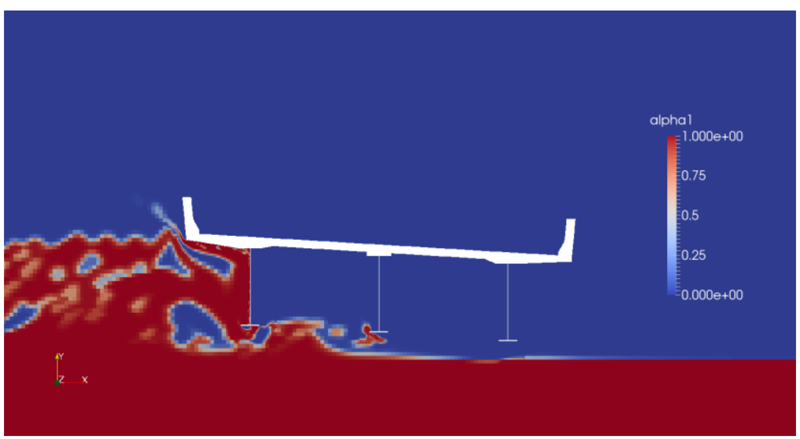
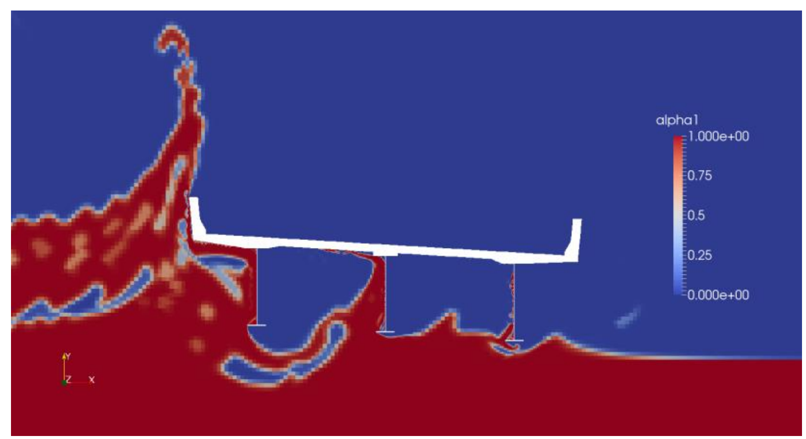


Structure-Scale Models



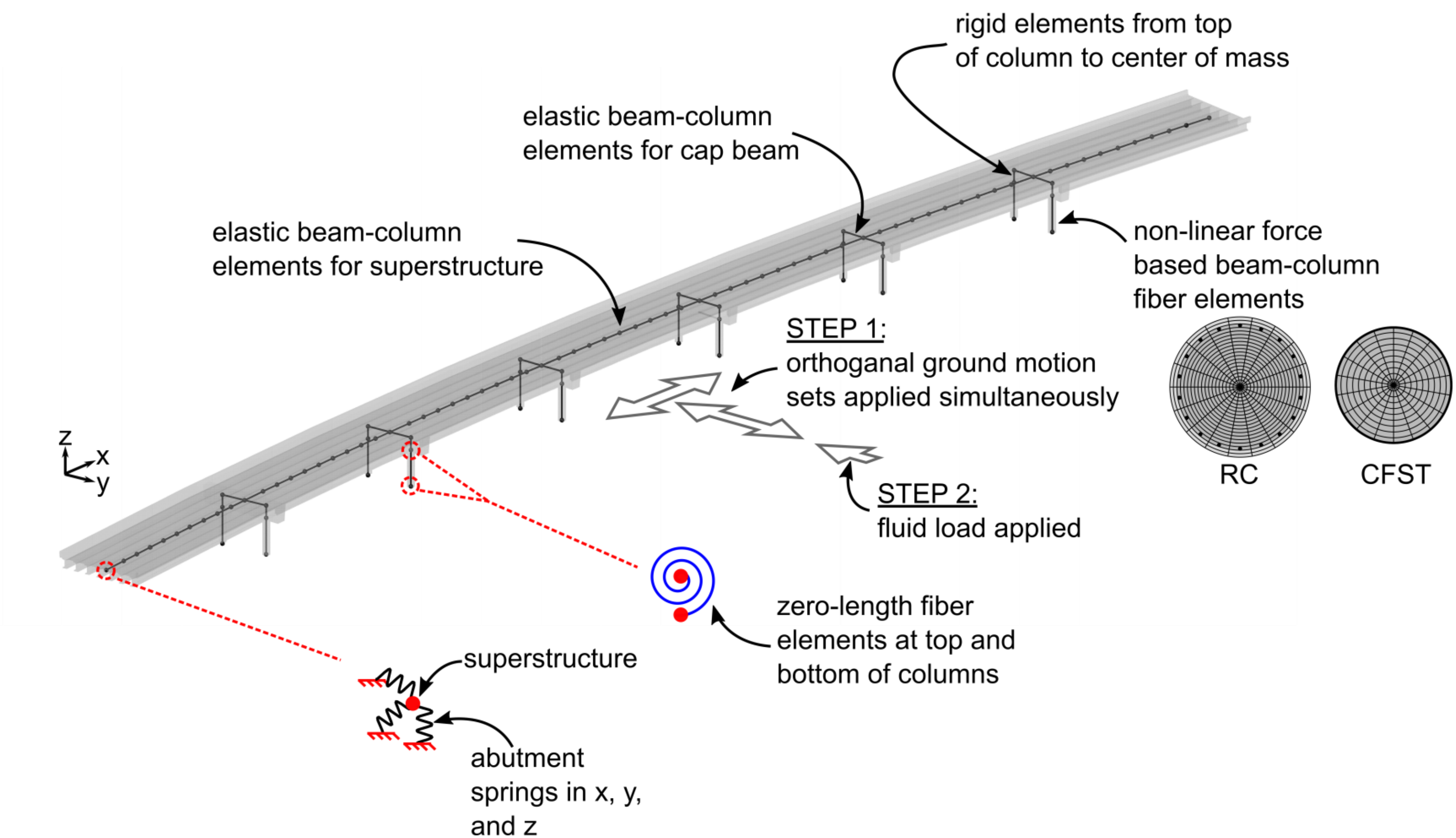


Deck Impact at 15.25 s



Internal Deck Impact at 15.65 s

OpenSees/OpenFOAM Model Overview



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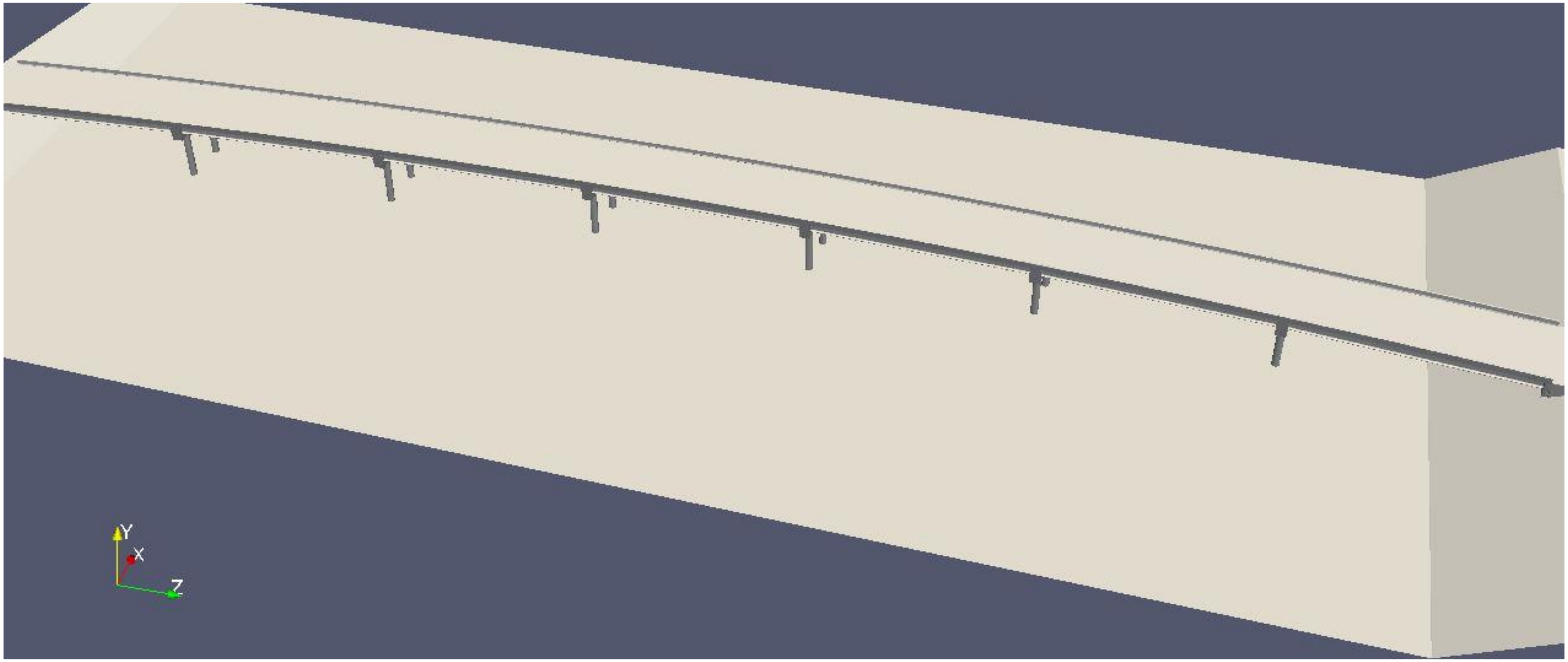

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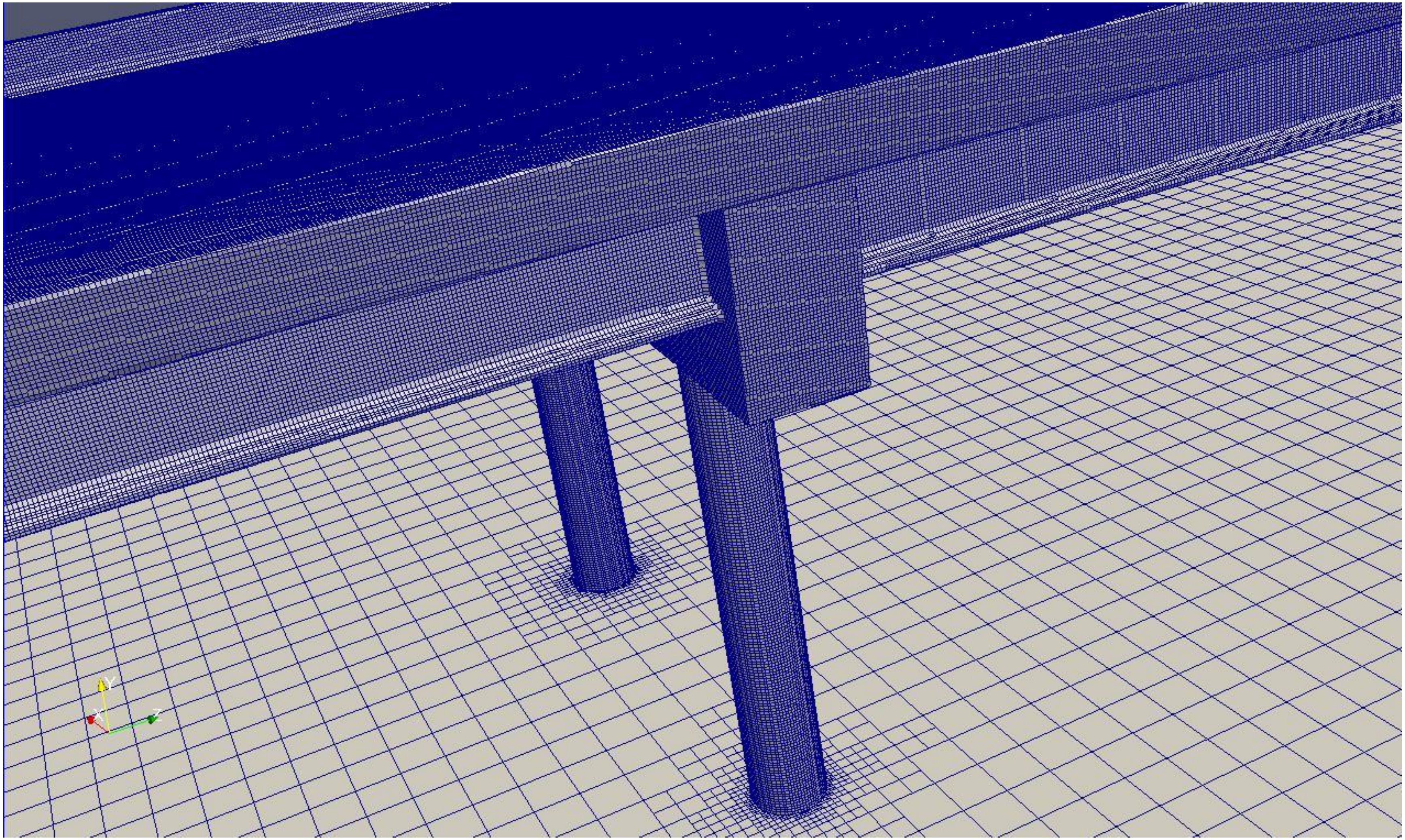

Earthquake/Tsunami Response