Hydrodynamic Uplift Dynamics: Analysis of Impulse and Quasi-Static Force Distribution on Flat Decks vs. Decks with Cap Under Extreme Storm Waves

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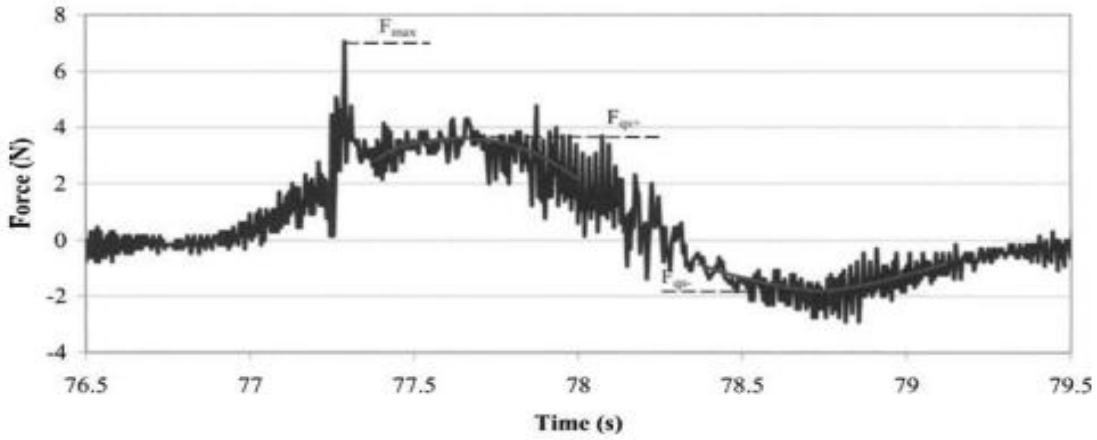
Introduction

- Coastal infrastructure such as seawalls faces escalating risks from climate-driven increases in wave energy, leading to structural fatigue and failure.
- Coastal loads are very dynamic and complex.
- Use of advanced toolboxes required to analyze complex loading dynamics on coastal infrastructure.



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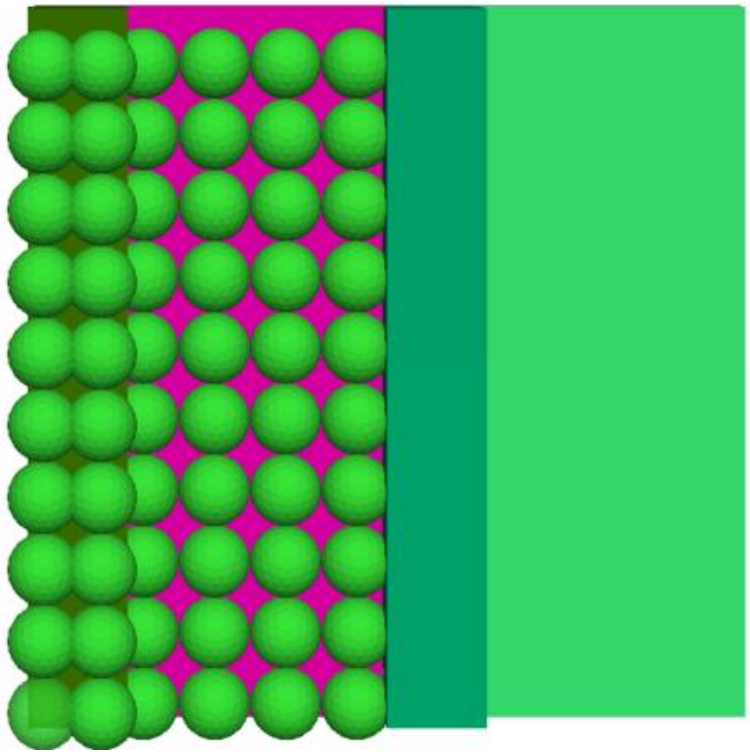
Numerical Modeling

- 3D CFD Investigation: Coupled Volume-of-Fluid (VOF) and Reynolds-Averaged Navier-Stokes (RANS) approach with a grid size of 0.1Hs
- CFL < 0.3
- Used 20 probes on cap and 40 probes on deck panel to measure pressure distribution across deck and cap surface
- Integrated pressures on bottom faces to determine total uplift and overtopping forces



Design Conditions

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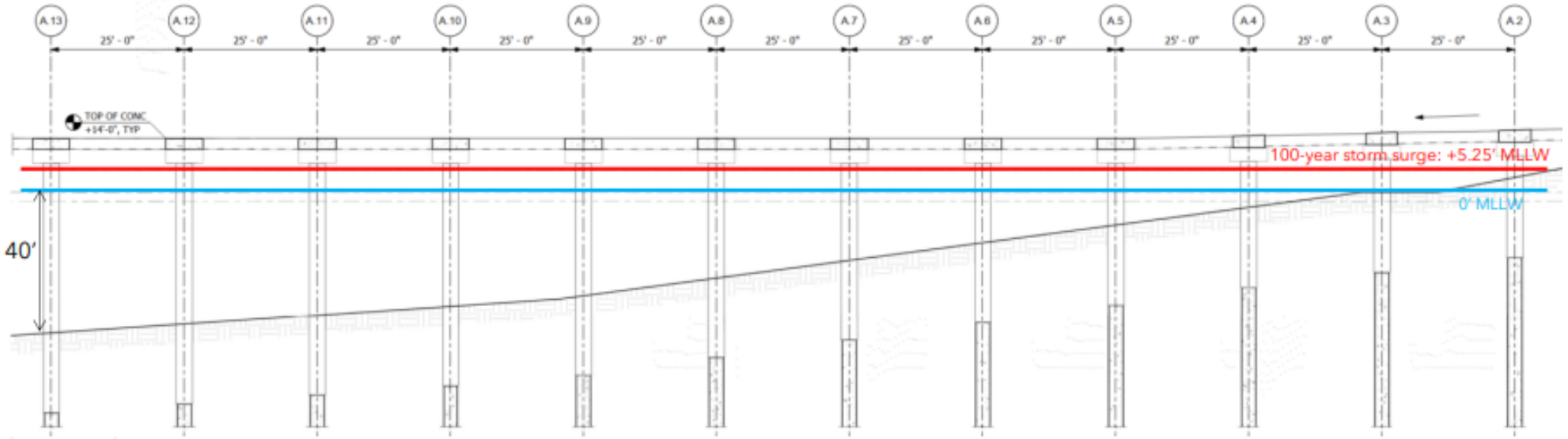
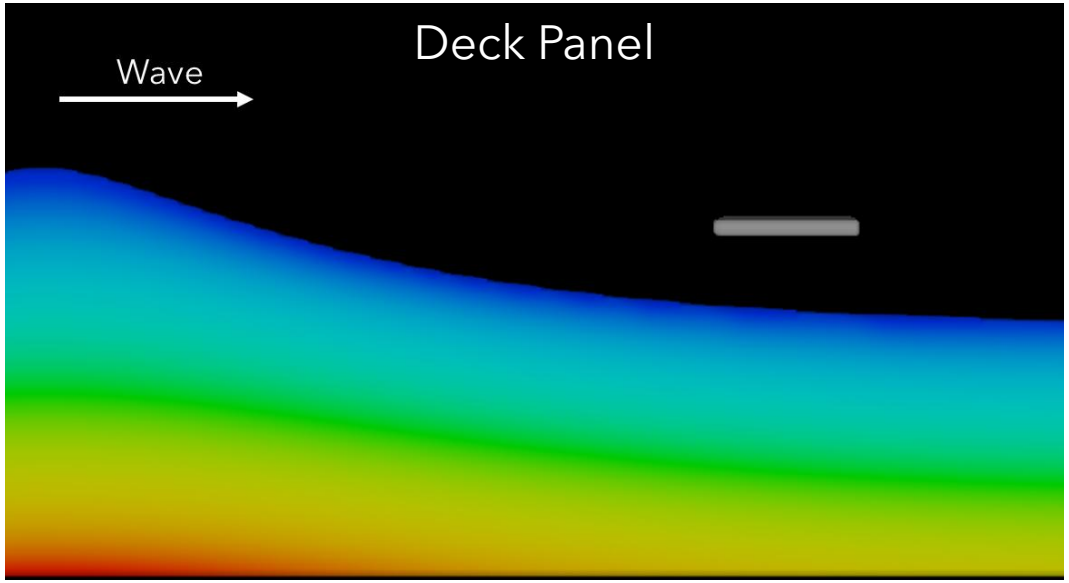
Top of deck/cap elevation: +14′ MLLW
Bottom of deck elevation: +11.8′ MLLW
Bottom of cap elevation: +8.5′ MLLW

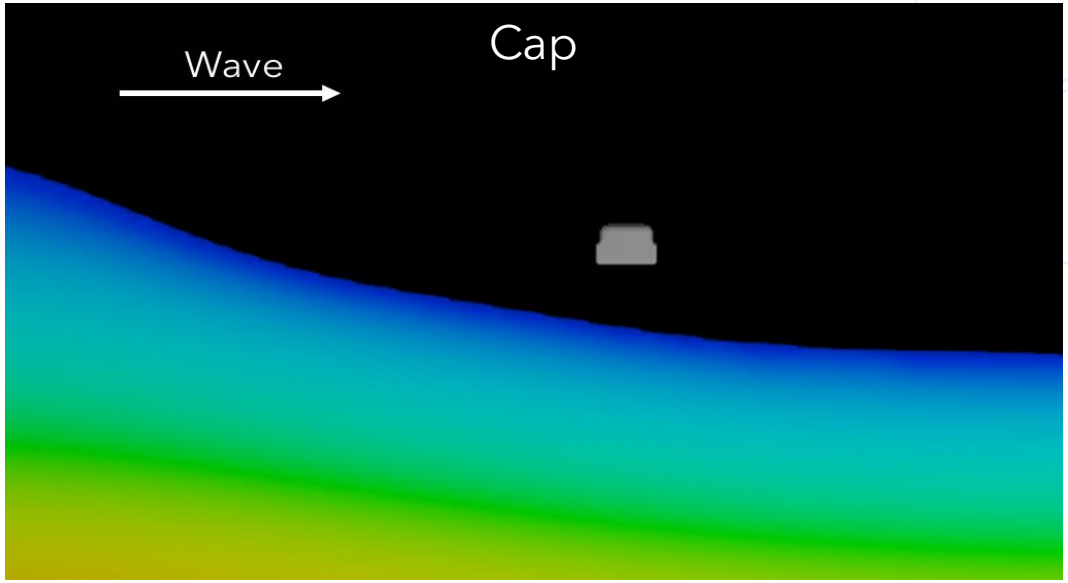
Deck clearance: 6.55′
Cap clearance : 3.25′

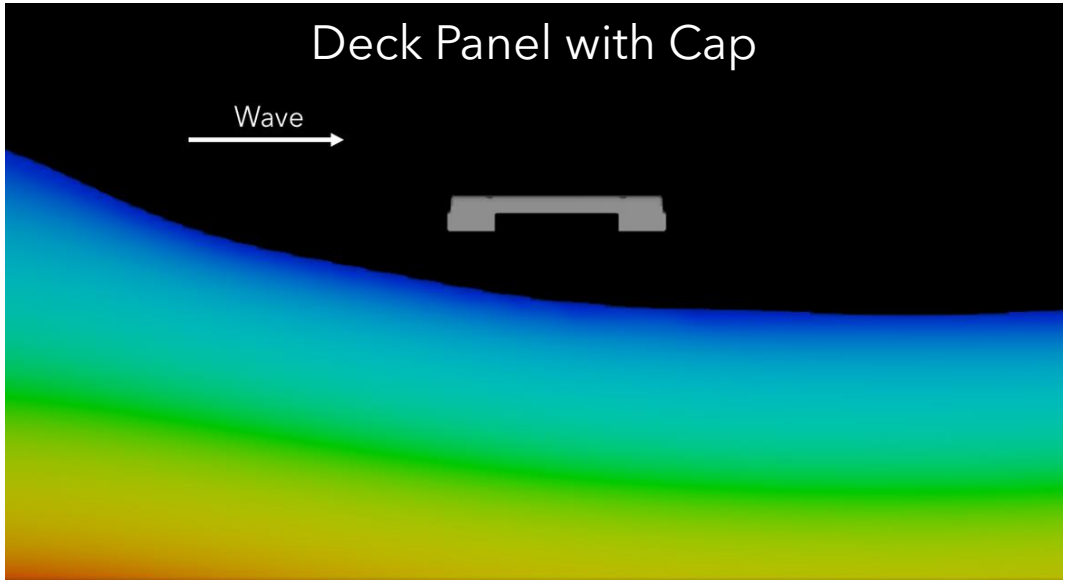


Bottom Elevation [m, MLLW]	Maximum Surface Elevation [m, MLLW]	Significant Wave Height [m]	Maximum Wave Height [m]	Peak Wave Period [s]
16 m Depth	1.50	8.0	10.8	11.0
12 m Depth	1.57	6.7	8.4	10.4
10 m Depth	1.63	5.4	6.9	11.1
6 m Depth	1.68	4.7	5.4	12.1

Case Scenarios

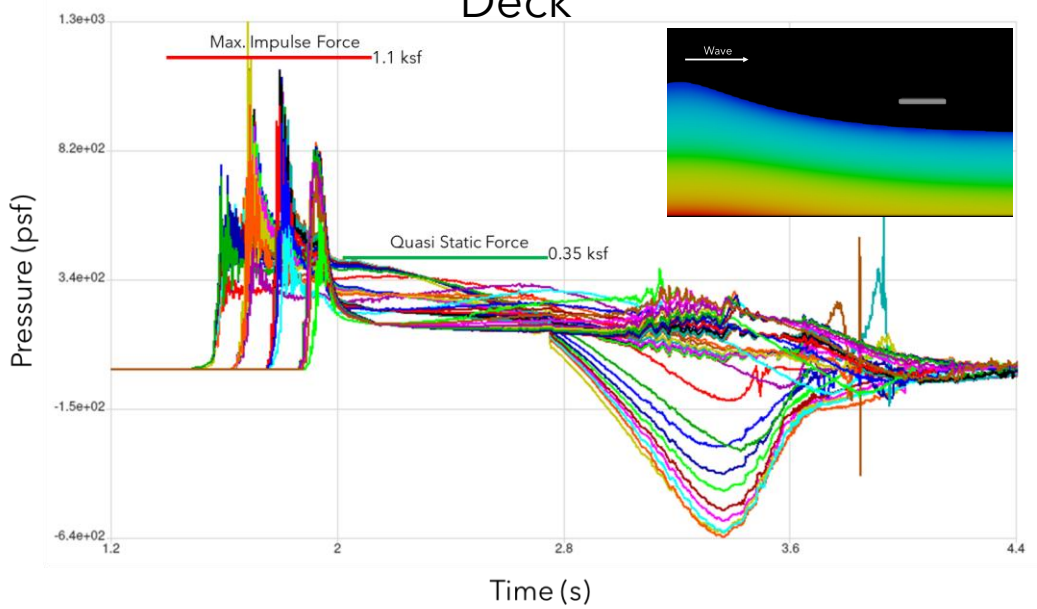




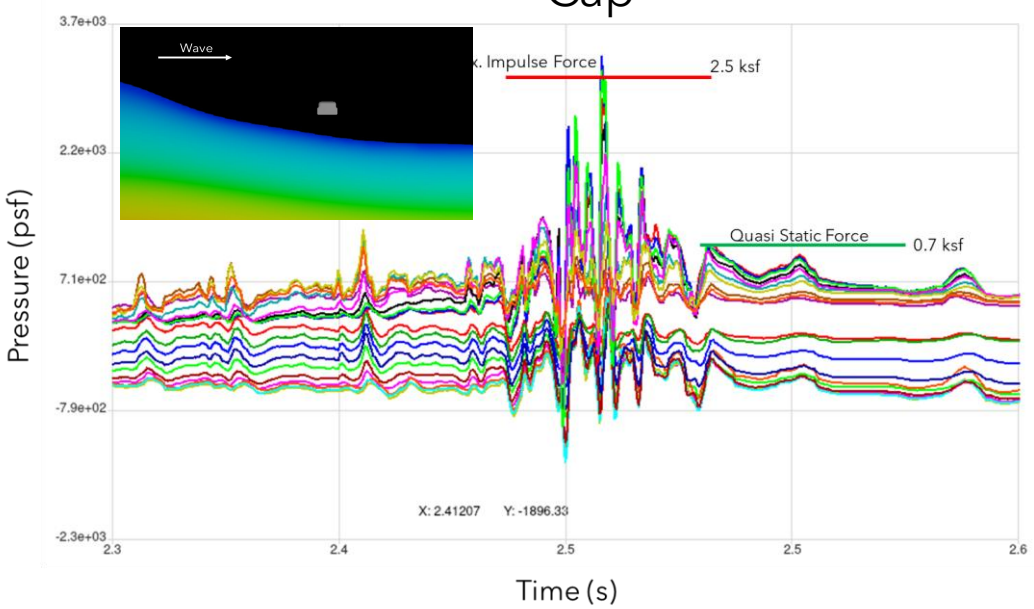


Loading Results

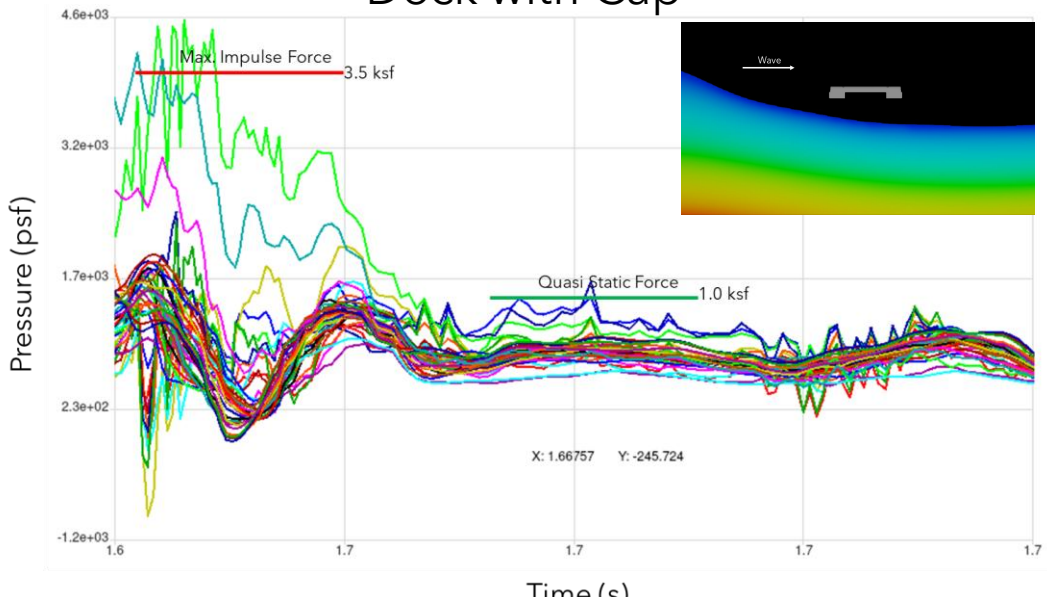
Deck



Cap



Deck with Cap



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Force Distribution on Wetted Area

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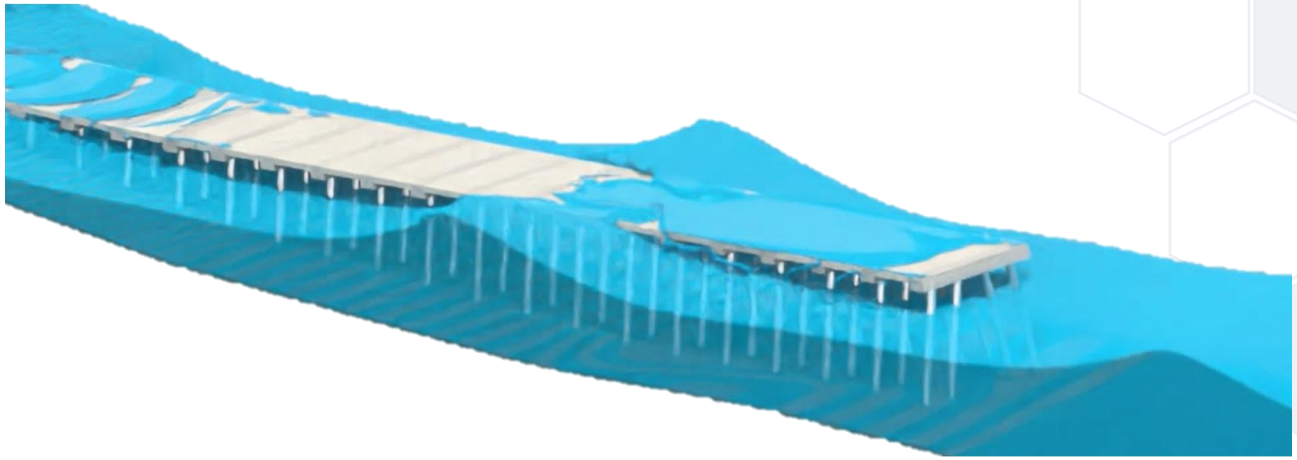
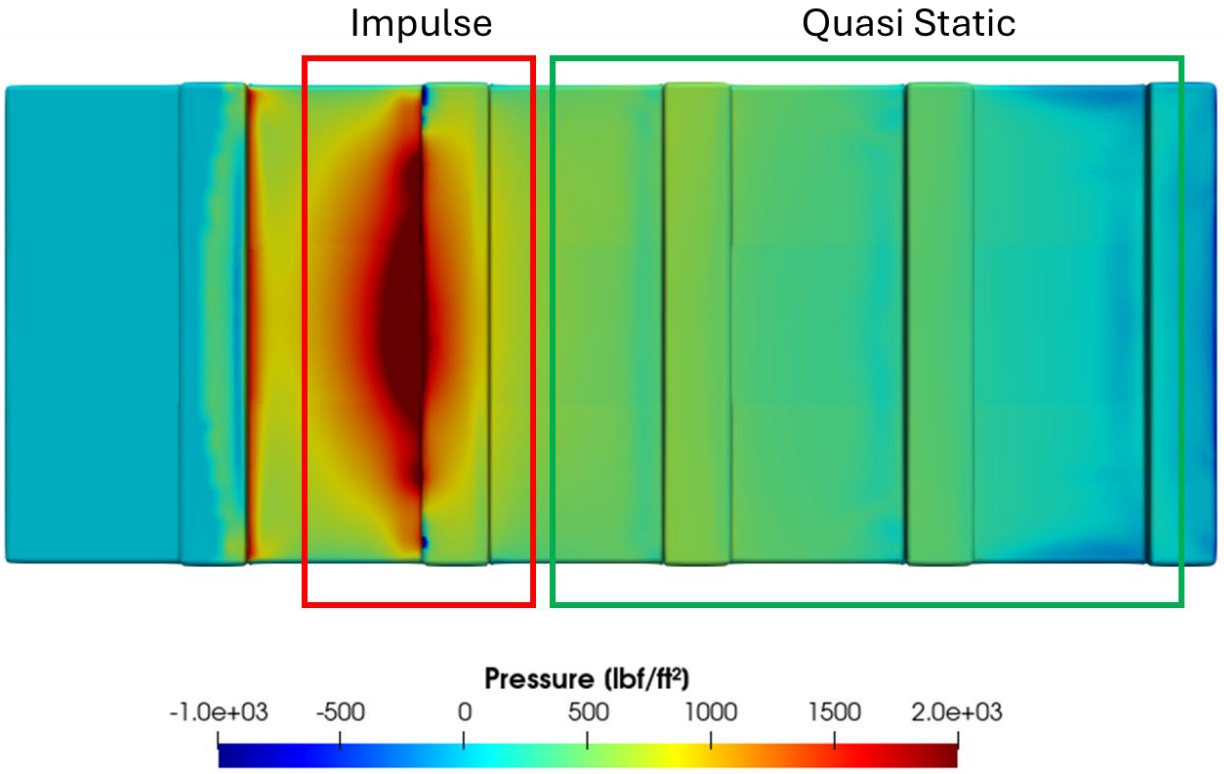
- Analyzed extreme waves on deck with cap on multiple bents with length equivalent to wetted area
- Impulse and quasi-static components of forces observed on the wetted area
- Impulse forces act on 20% of the wetted area and quasi static forces on 80% of the wetted area





Summary

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+ Confinement Impact: Cap structures create confinement effects that amplify uplift forces compared to flat deck geometries

+ Force Distribution Variation: Capped decks significantly alter the distribution of impulse and quasi-static forces

+ Wetted Area Dependency: Impulse forces occur on 20% of the wetted area