UNIVERSITY *of* WASHINGTON

Department *of* Civil Engineering

# Towards Improved Lateral Force Resisting Systems for Marginal Wharves

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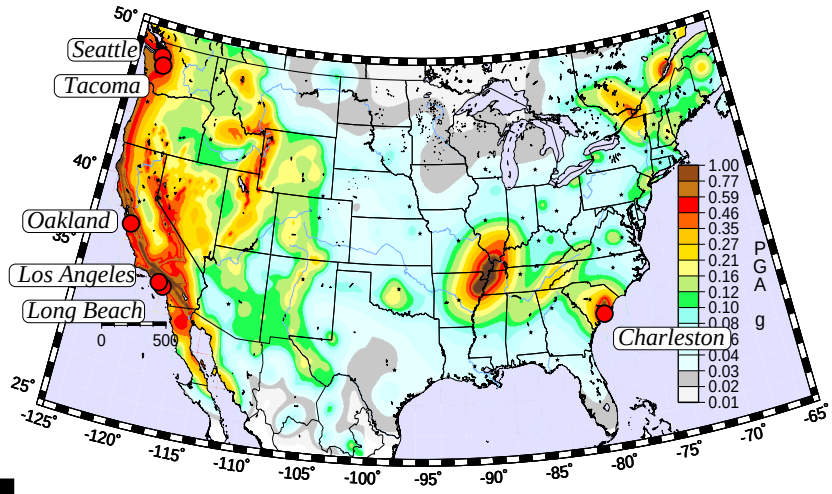
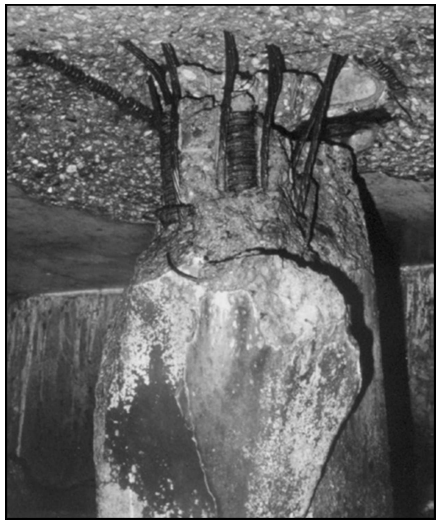
# Overview

# Objective & Motivation

- Many US port facilities located in highly seismic regions
- Responsible for the daily transfer of $ 5.5 billion of goods
- Current design susceptible to damage with small deformations
- Develop ductile system and less susceptible to damage




2% probability of exceedence (USGS 2008)



Port of Oakland damage (Serventi 1990)

# EXPERIMENTAL PROGRAM

# Overview

- Recent emphasis on pile-to-wharf connections
- Tested 16 connection specimens
  - Specimen 9 current detail
  - Specimen 15 & 16 improved controlled rocking detail
  - Developed connection design procedure

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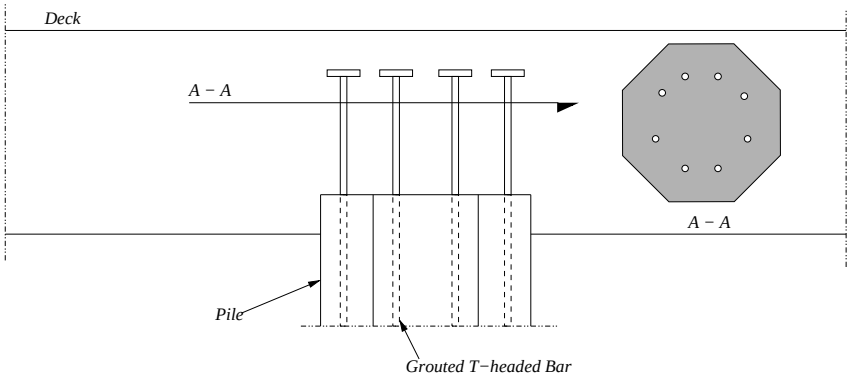


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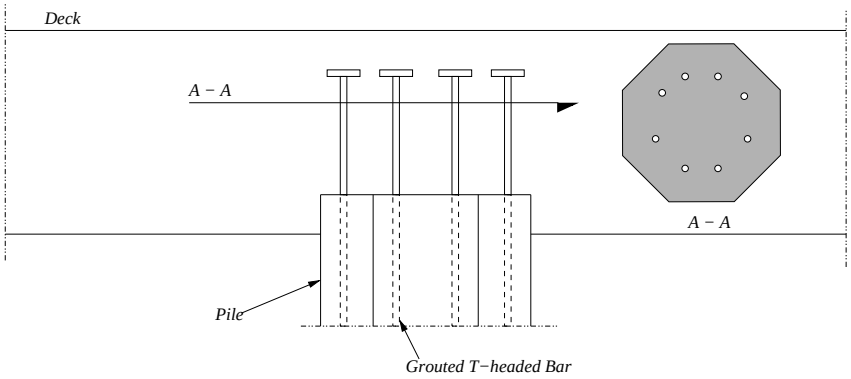


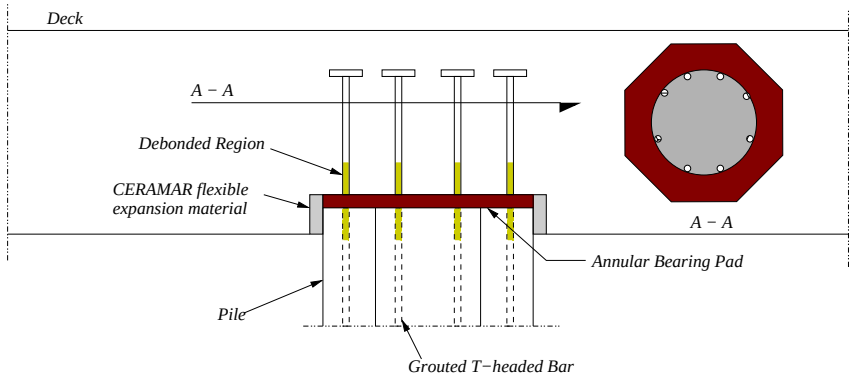


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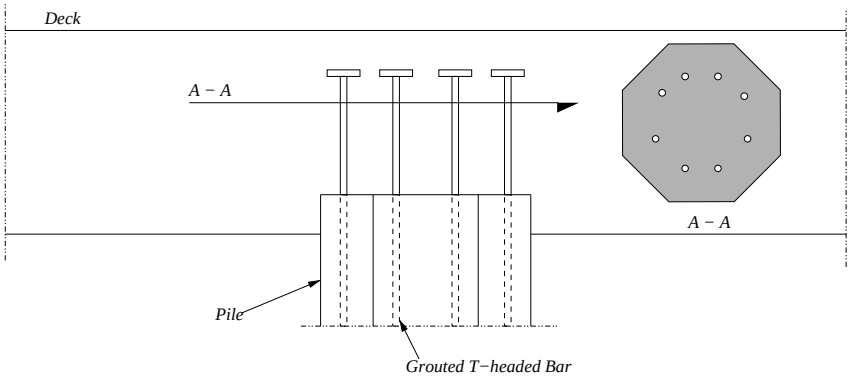


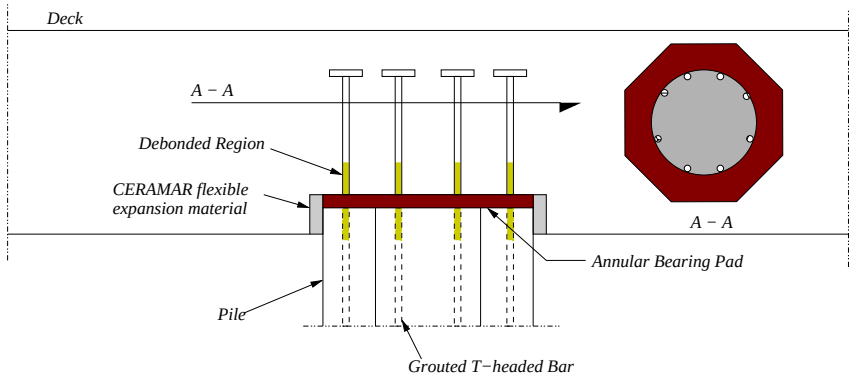


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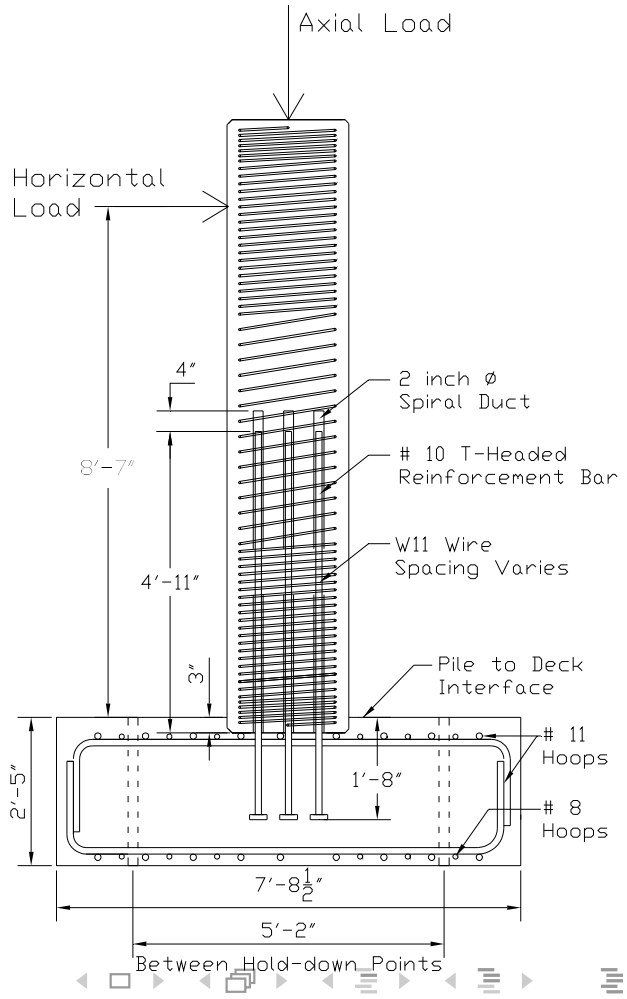
# Test Specimens

- Pile
  - 24 in octagonal, precast, prestressed concrete piles
  - 1000 psi design prestress
  - 3 in clear cover
- Connection
  - (8) #10 T-Headed dowel bars
  - 3 in pile embedment into deck
  - 15 in debonded length of dowels
  - 3/4 in CERAMAR wrap
  - Annular bearing pad



# Test Results

| Damage state | Specimen 9 | Specimen 15 | Specimen 16 |
|---|---|---|---|
| Minor Pile Spalling | 1.4% | 5.5% | 5.4% |
| Substantial Pile Spalling | 3.9% | 7.4% | 6.4% |

The values provided are percentage radians rotation at the assumed inflection point

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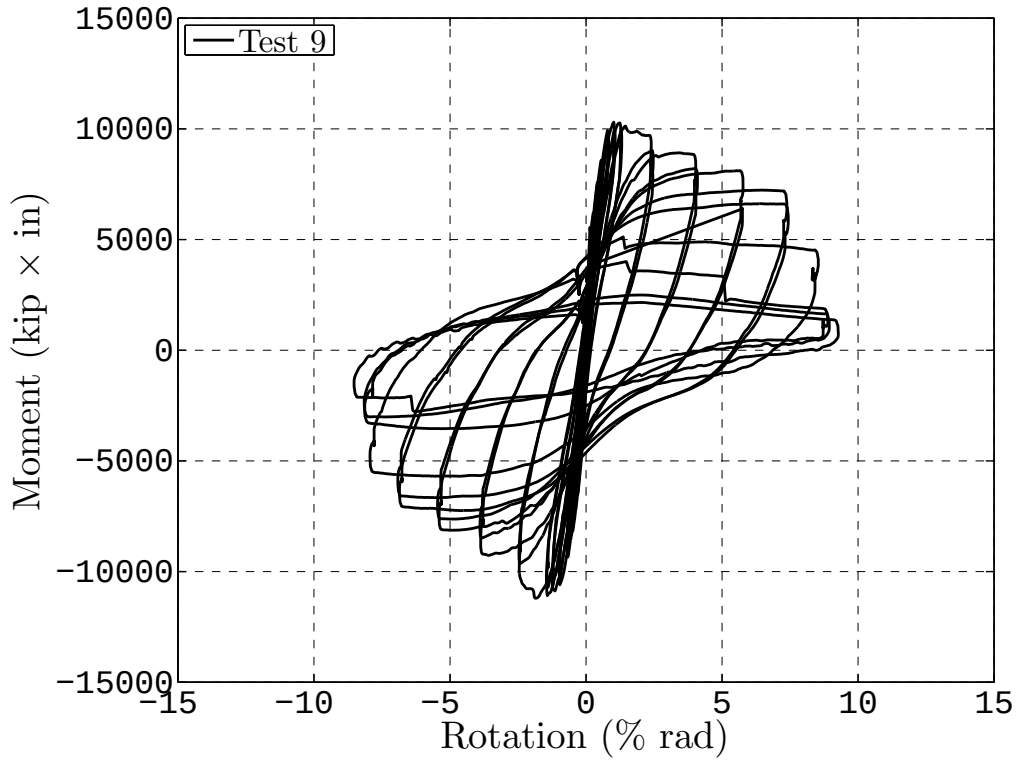

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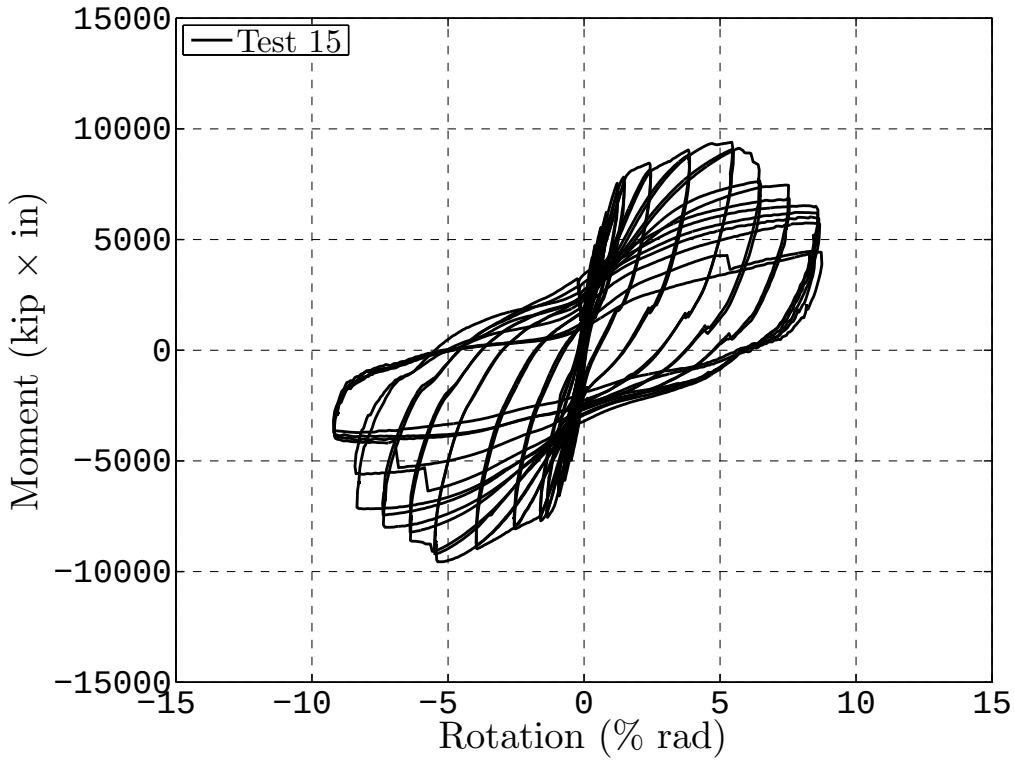

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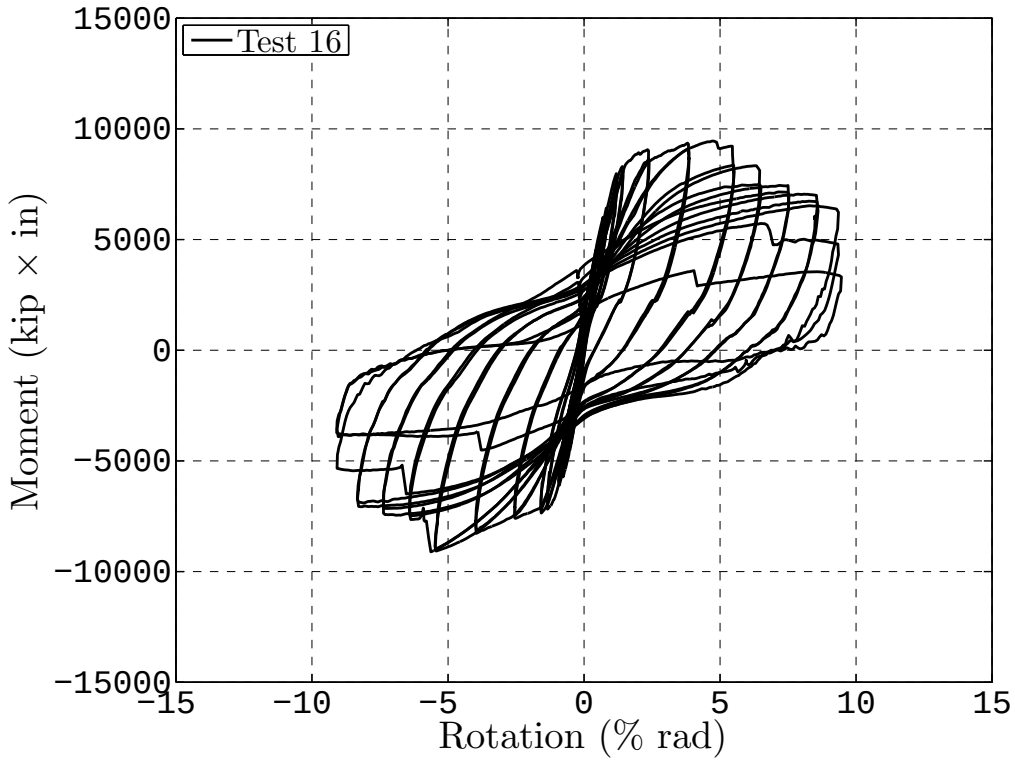

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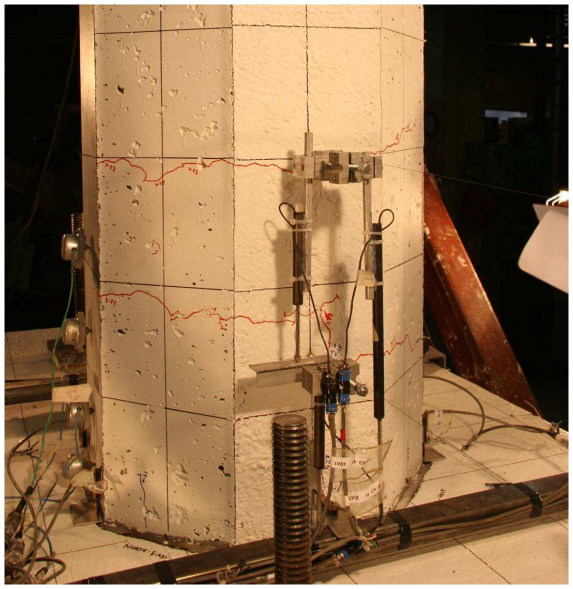
Specimen 9 2.5% rotation



Specimen 15 2.5% rotation

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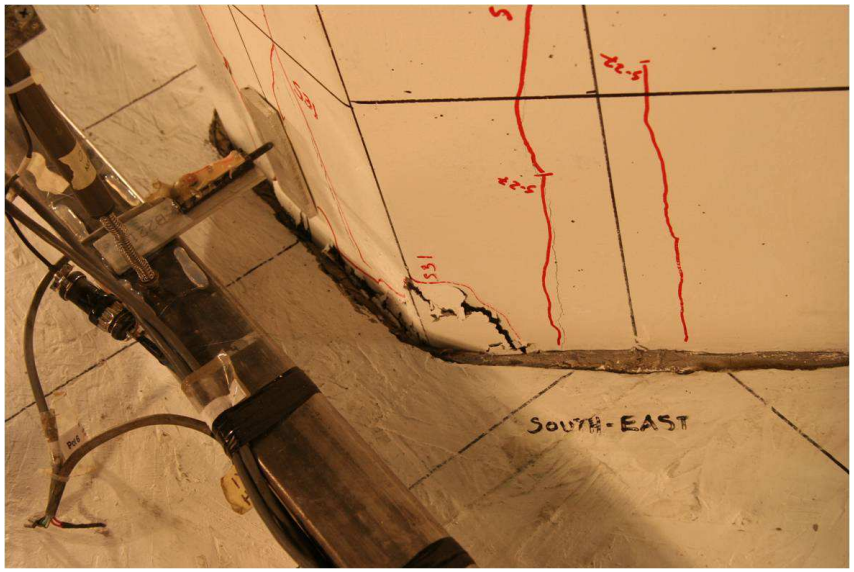
Specimen 9 5.5% rotation




Specimen 15 5.5% rotation

# ANALYTICAL INVESTIGATION

# Objective

Using OpenSees as the analysis platform and GiD as the postprocessor ...

- Model a reference wharf facility and evaluate the response with varying connection types
  - Model structure
  - Model soil-pile interaction
  - Model soil continuum
  - Compare wharf response with varying connections

# Simulated Facility

- Port of Oakland - Berth 55/56
  - Reinforced concrete deck supported by 24 in octagonal prestress concrete piles w/ conventional dowel connections
  - Assumed typical bay soil profile

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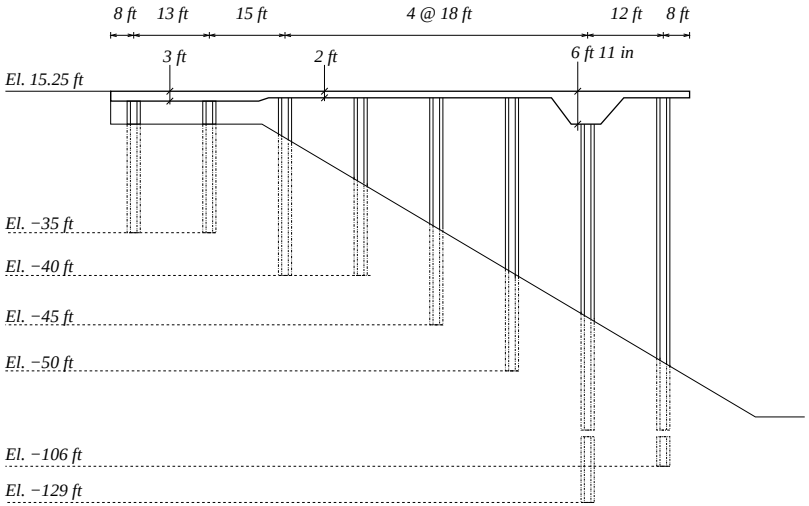


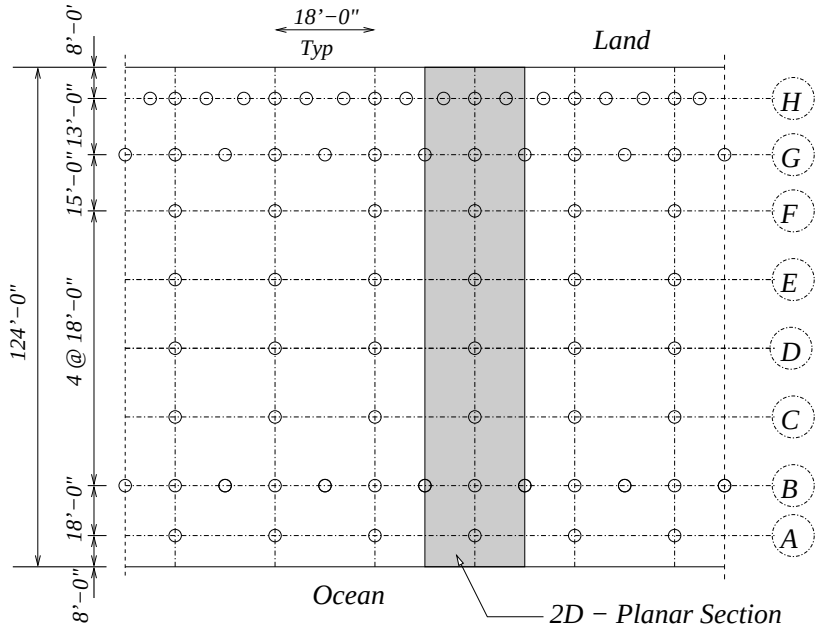

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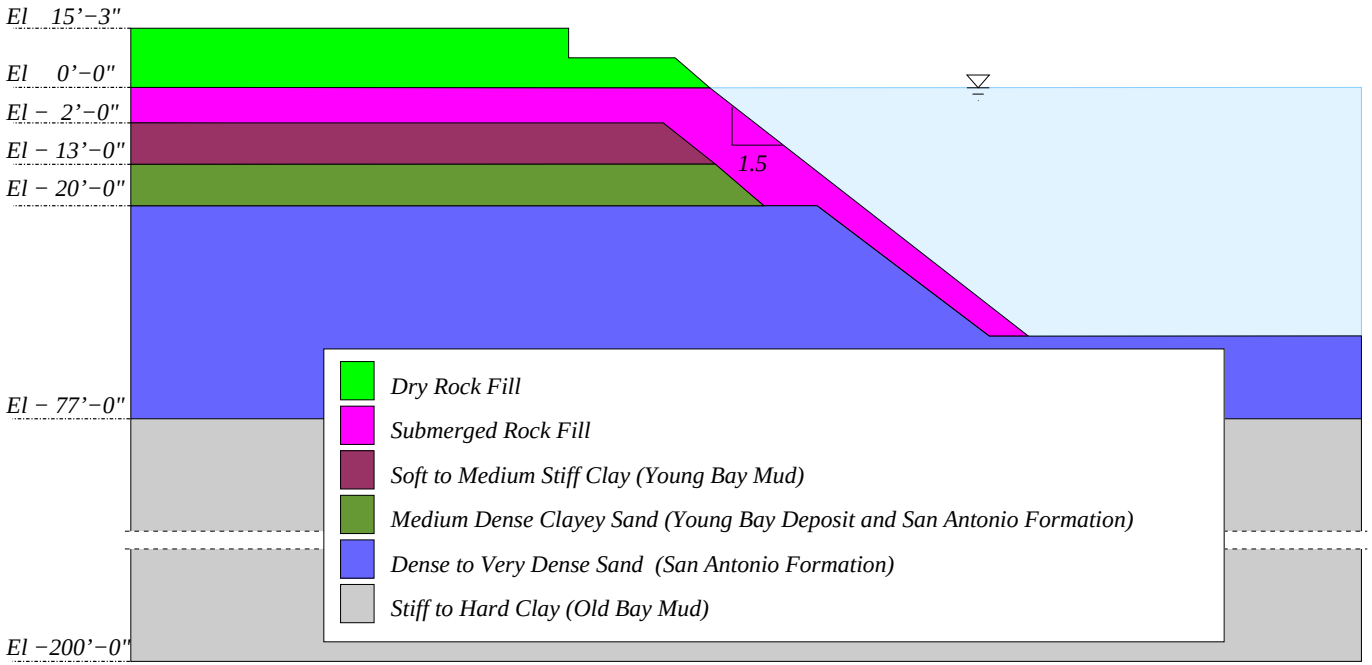

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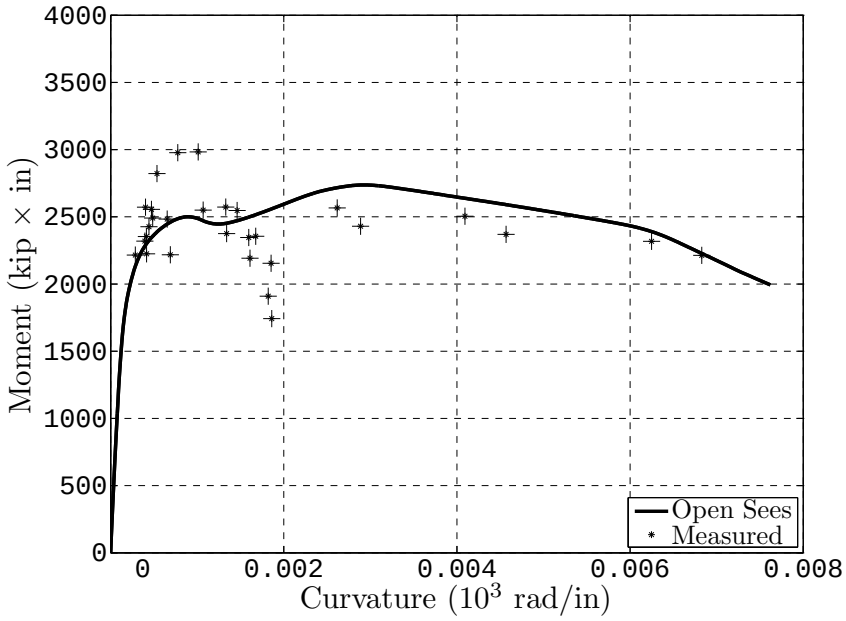
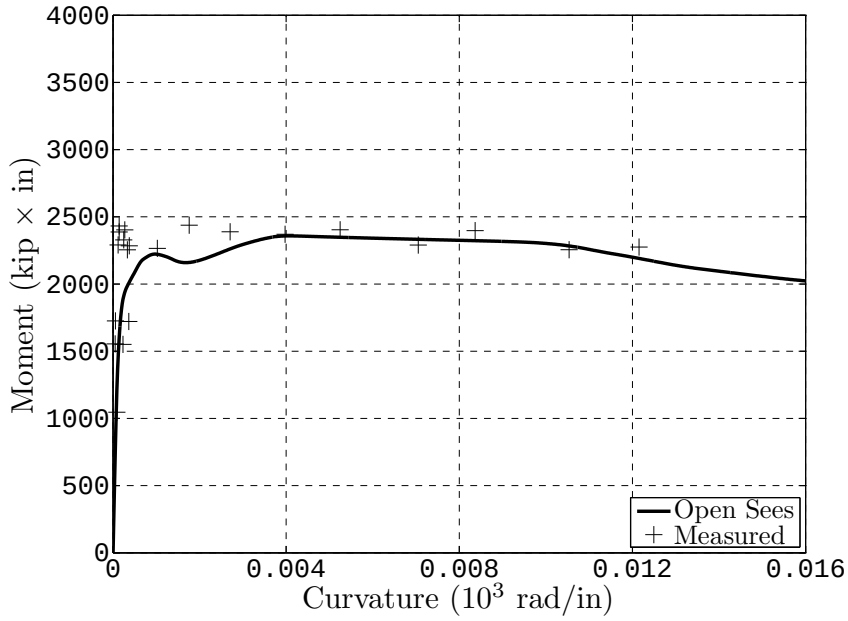
# Structure

- Developed pile model & validated against fifteen tests




Joen et al. (1988)




Falconer et al. (1988)

- Developed connection model & validated against four tests
- Implemented within the port model

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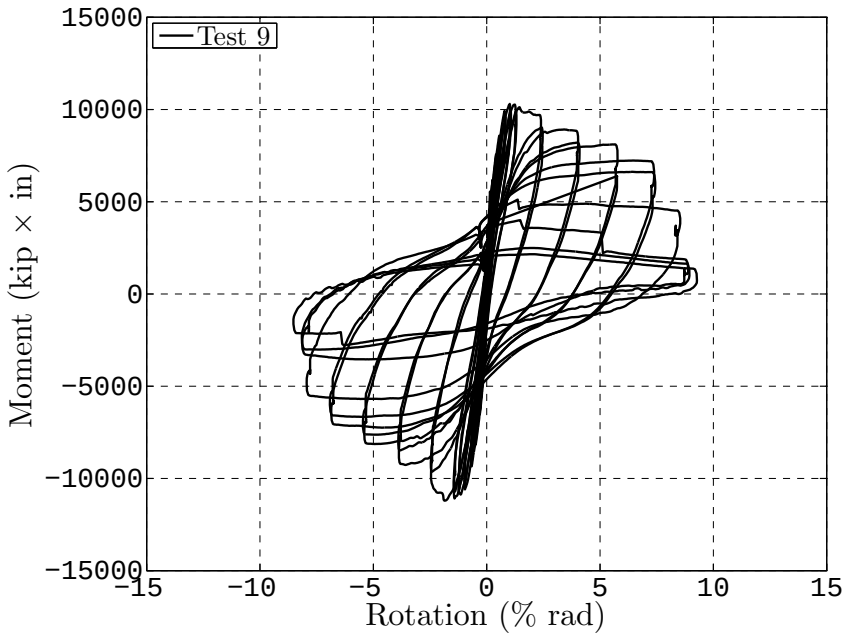
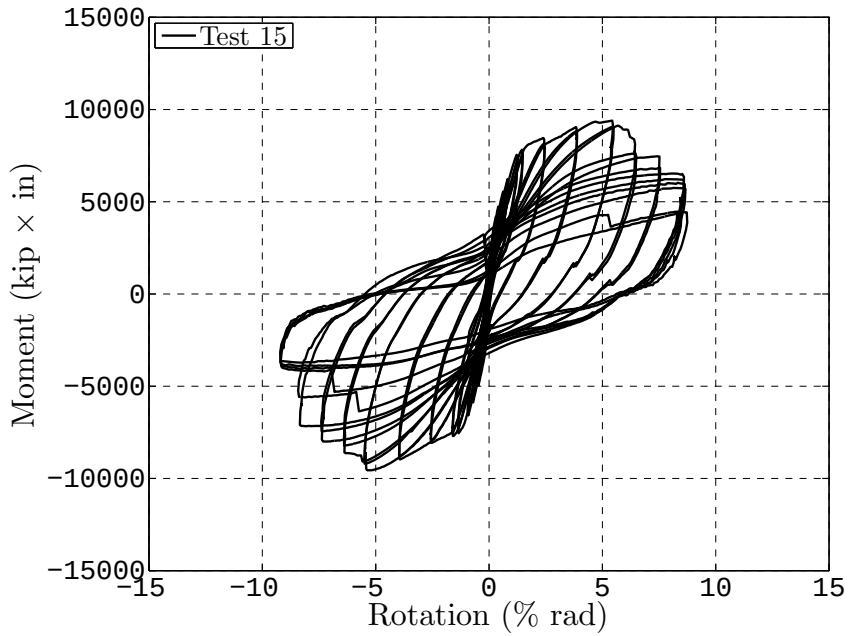



Jellin et al. (2007)




Stringer et al. (2010)

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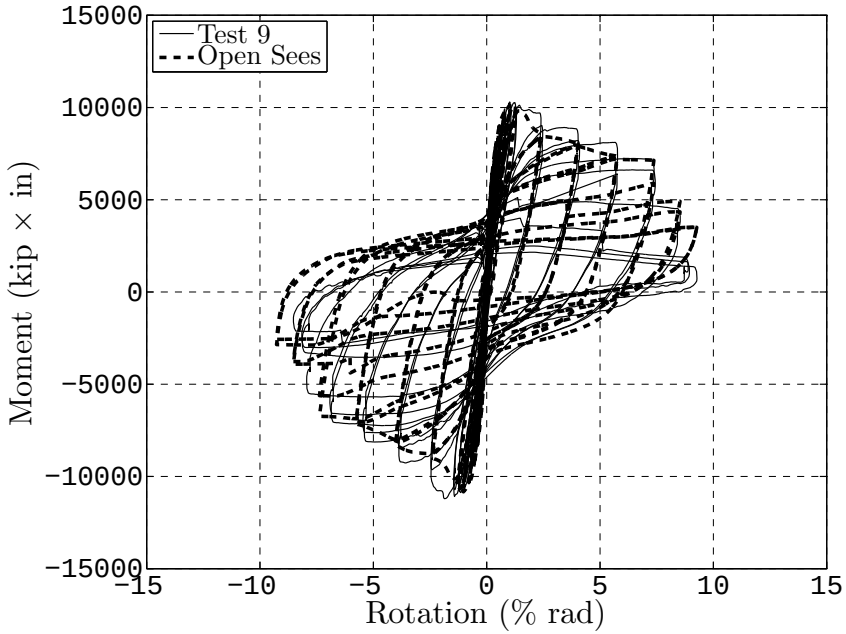


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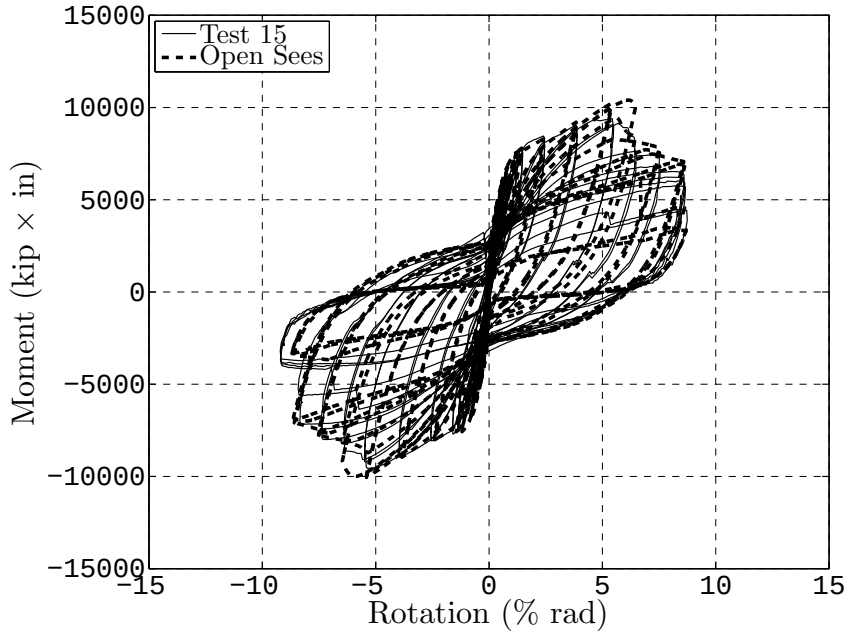


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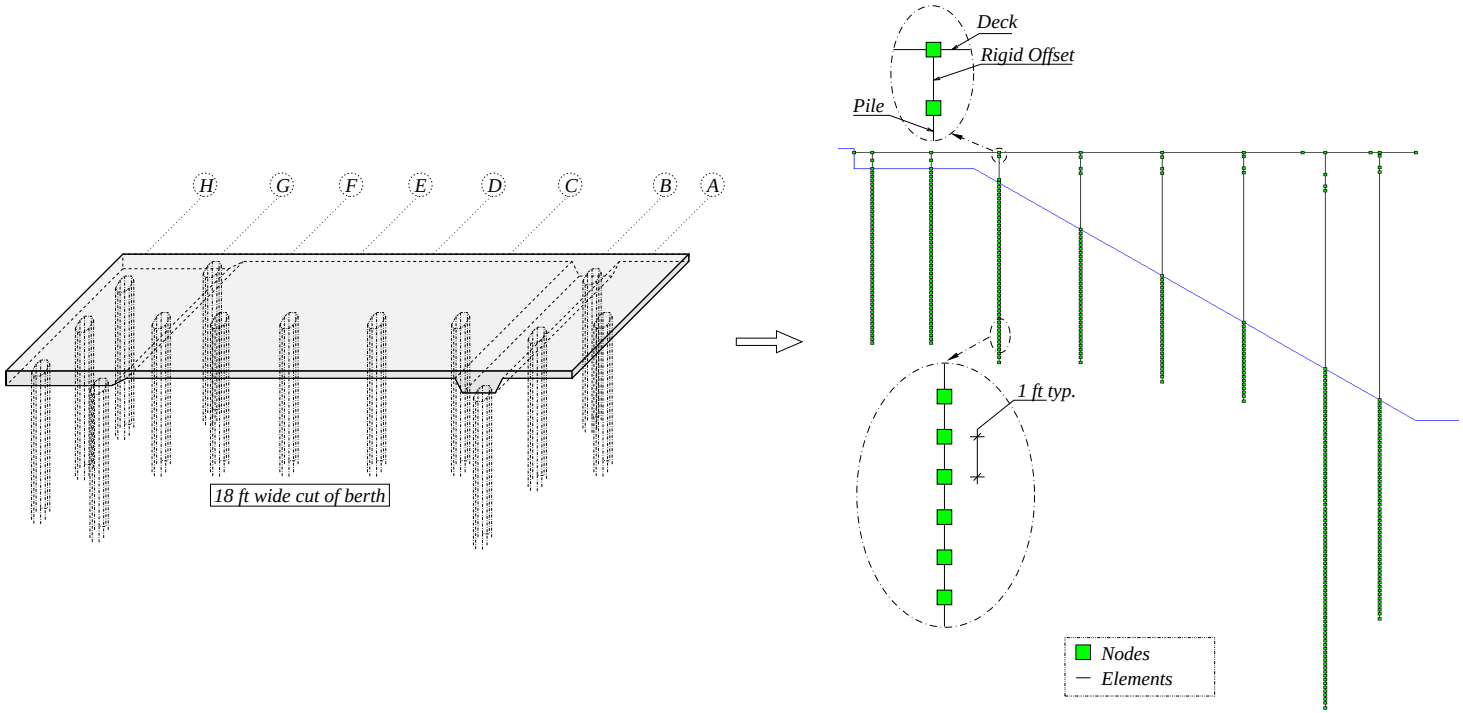
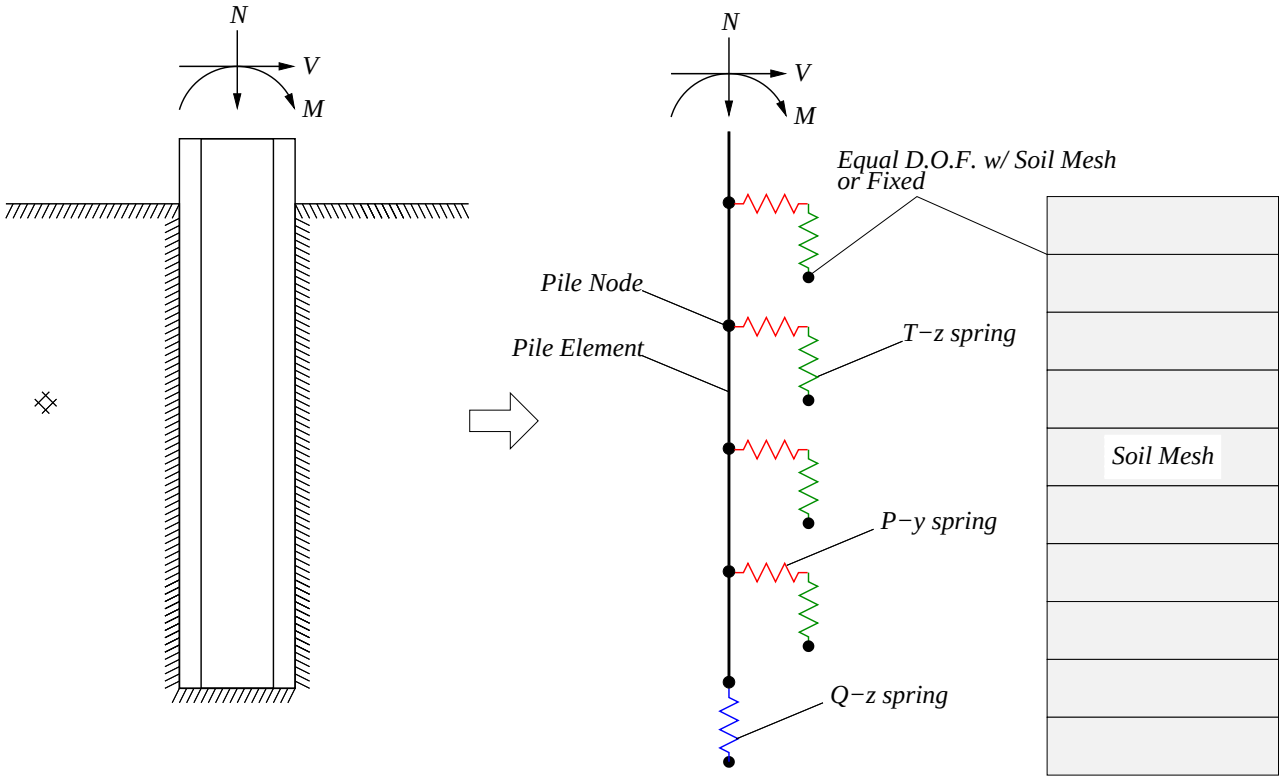


# Soil

- Pile-soil interaction through use of uniaxial springs




- Free field wave propagation and lateral movement

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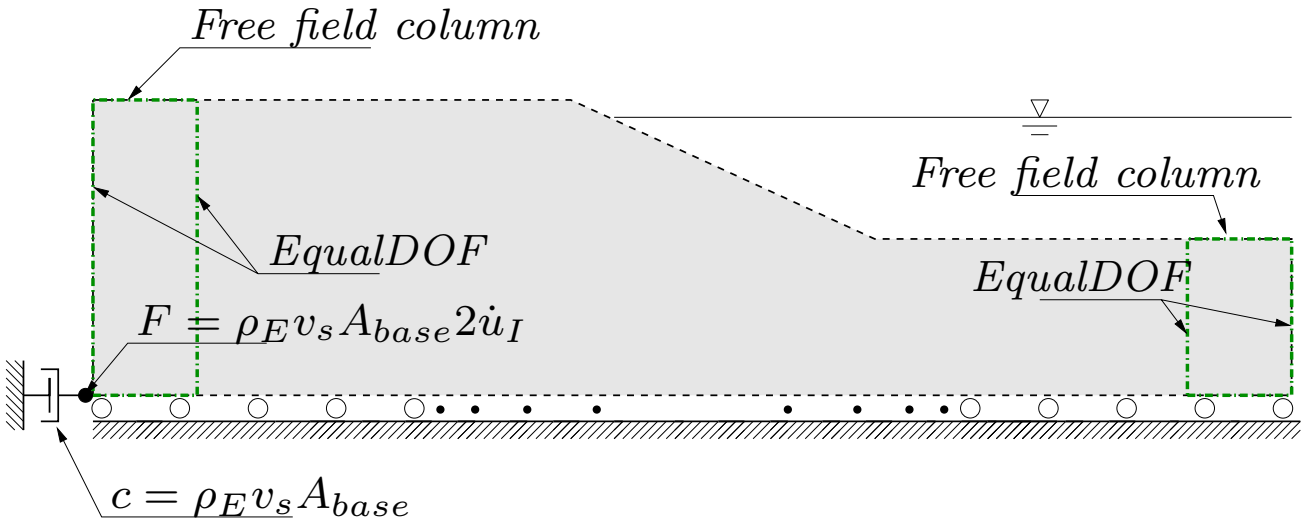

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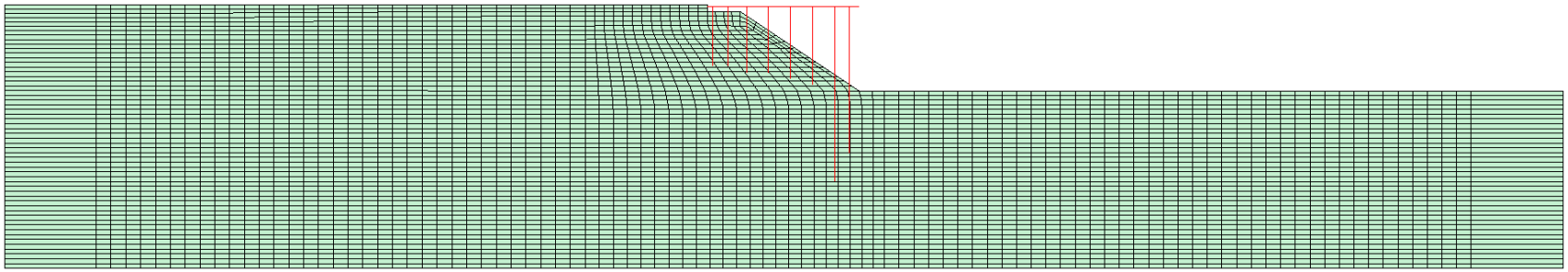

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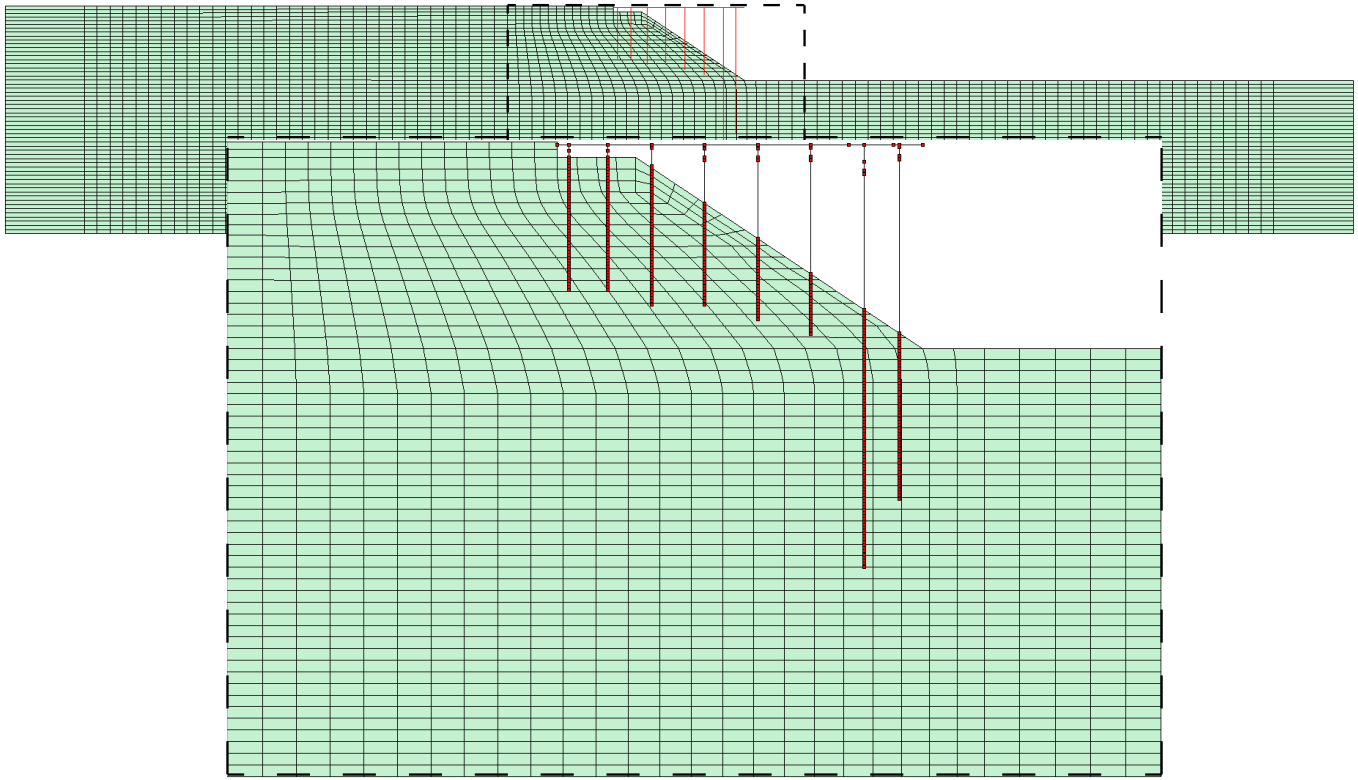

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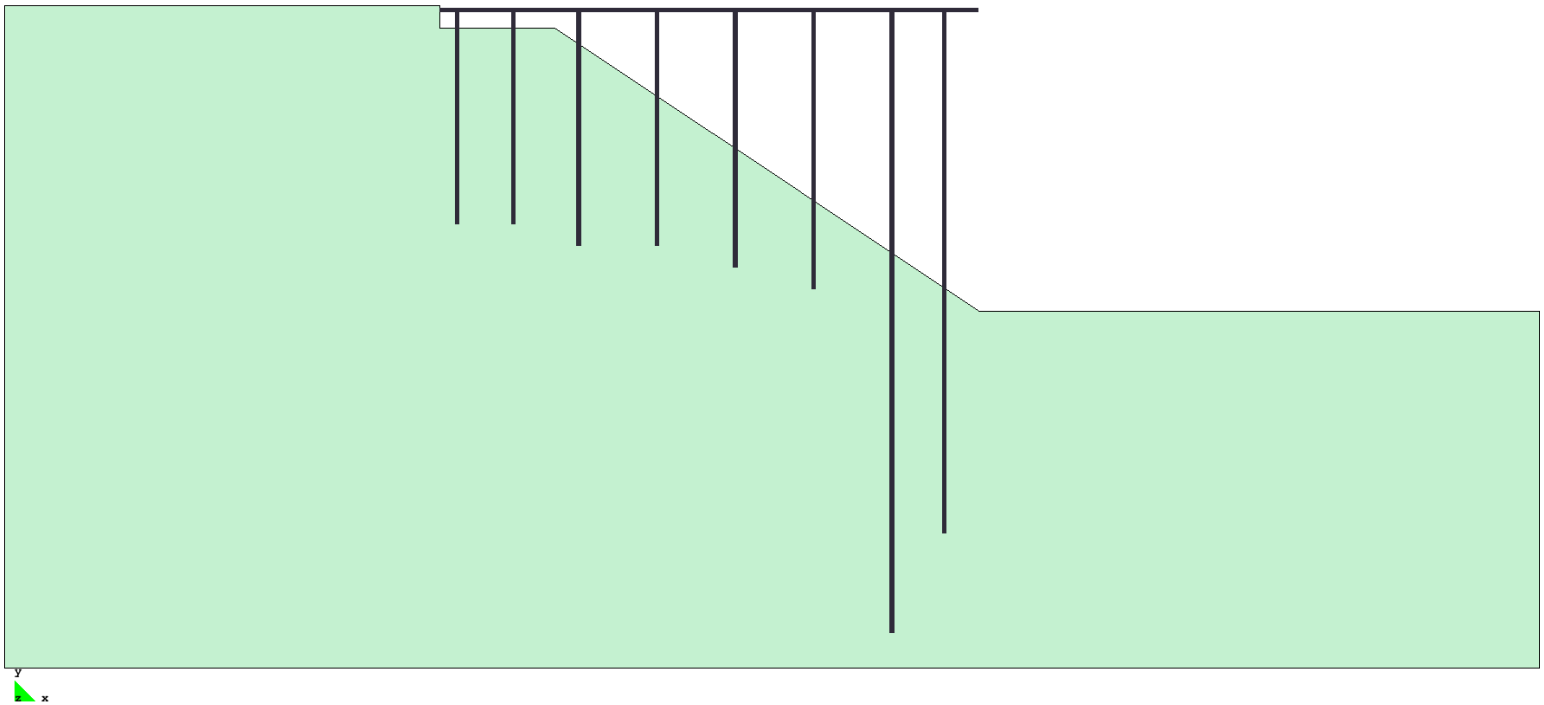
# Analysis & Results

- Static pushovers




- Dynamic time hystories

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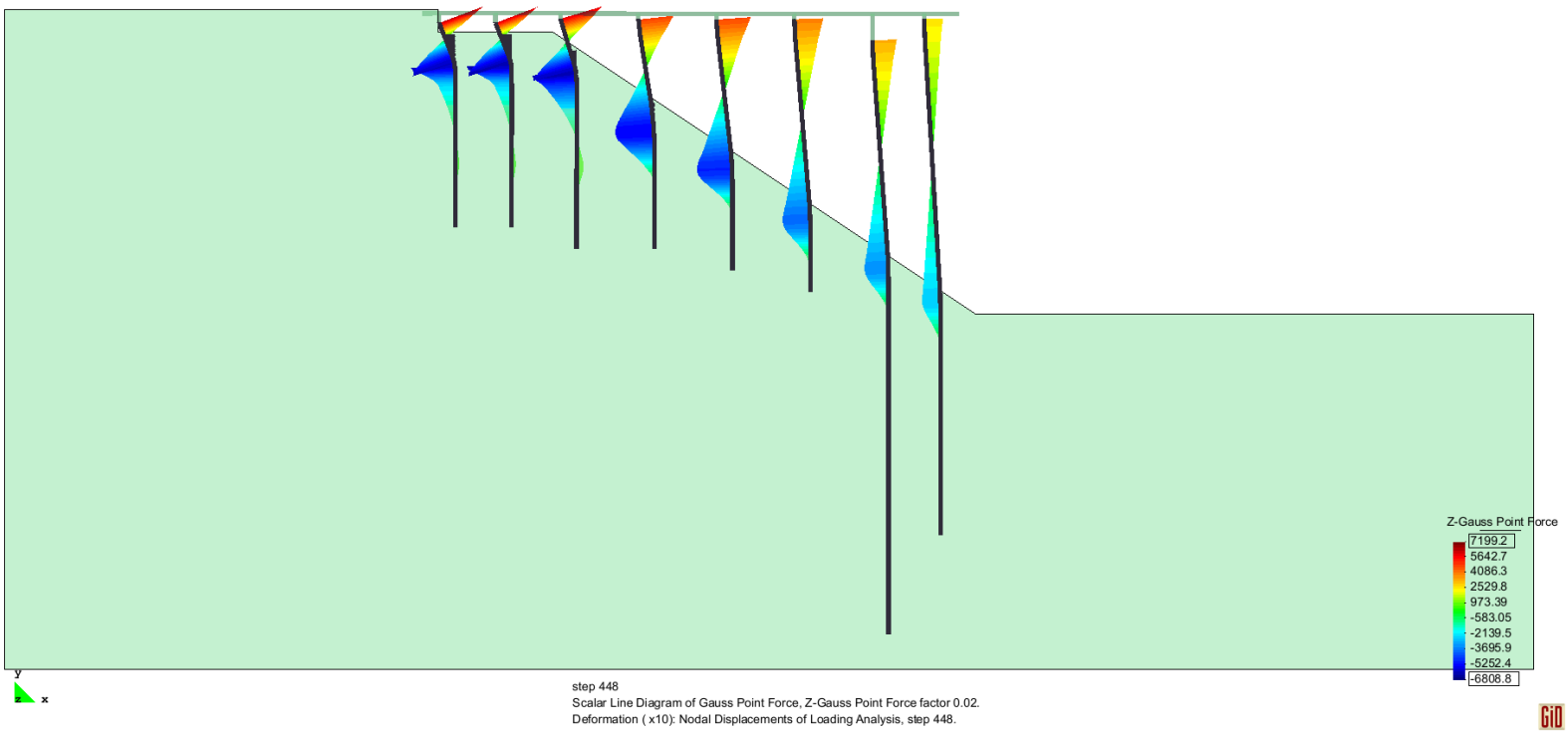


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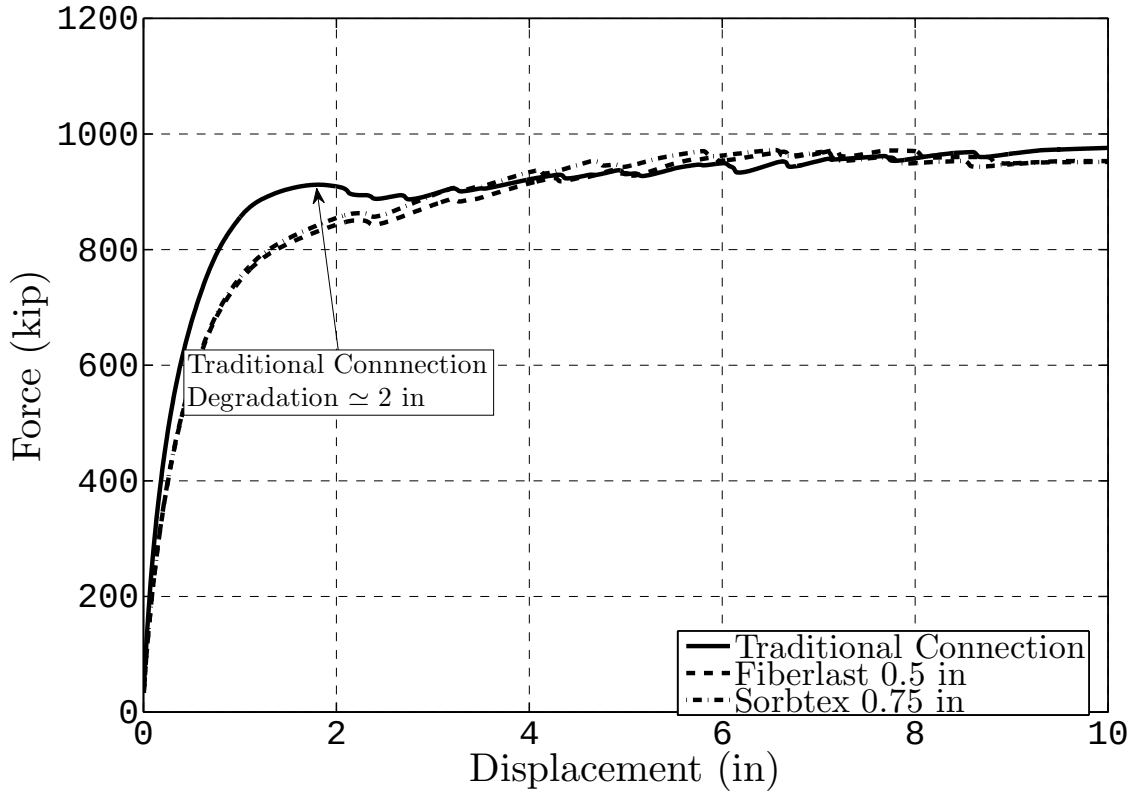


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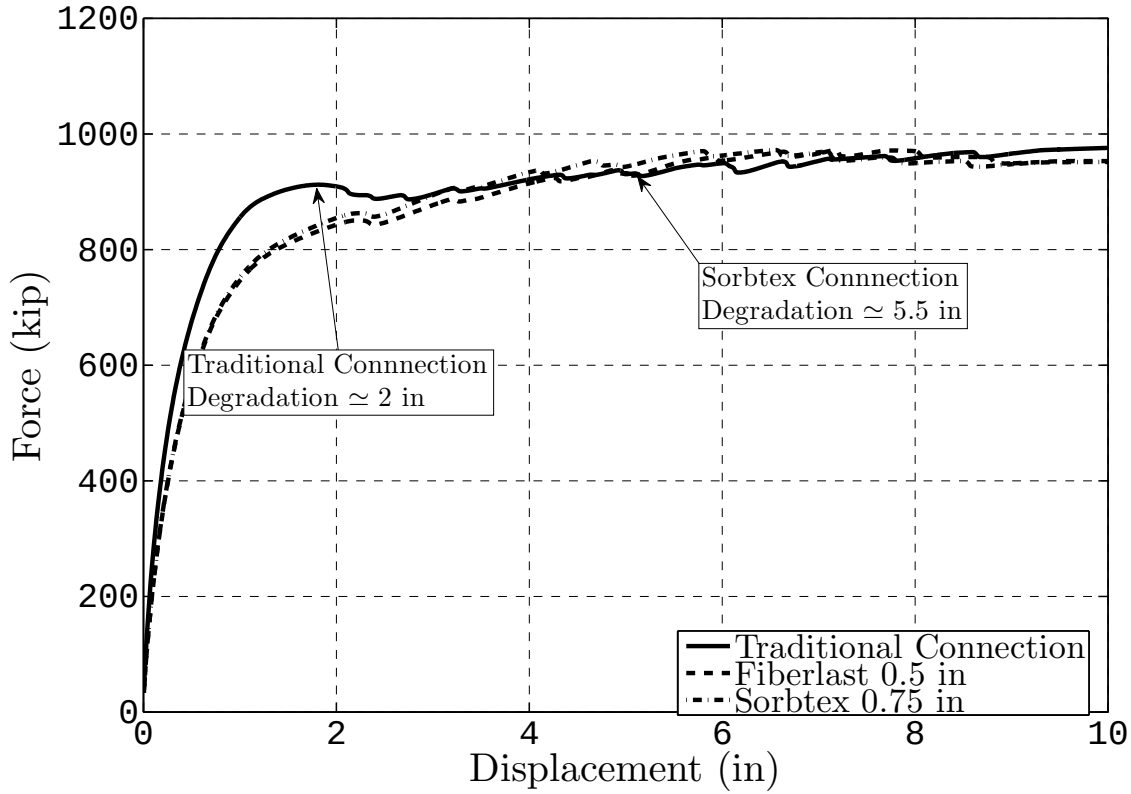


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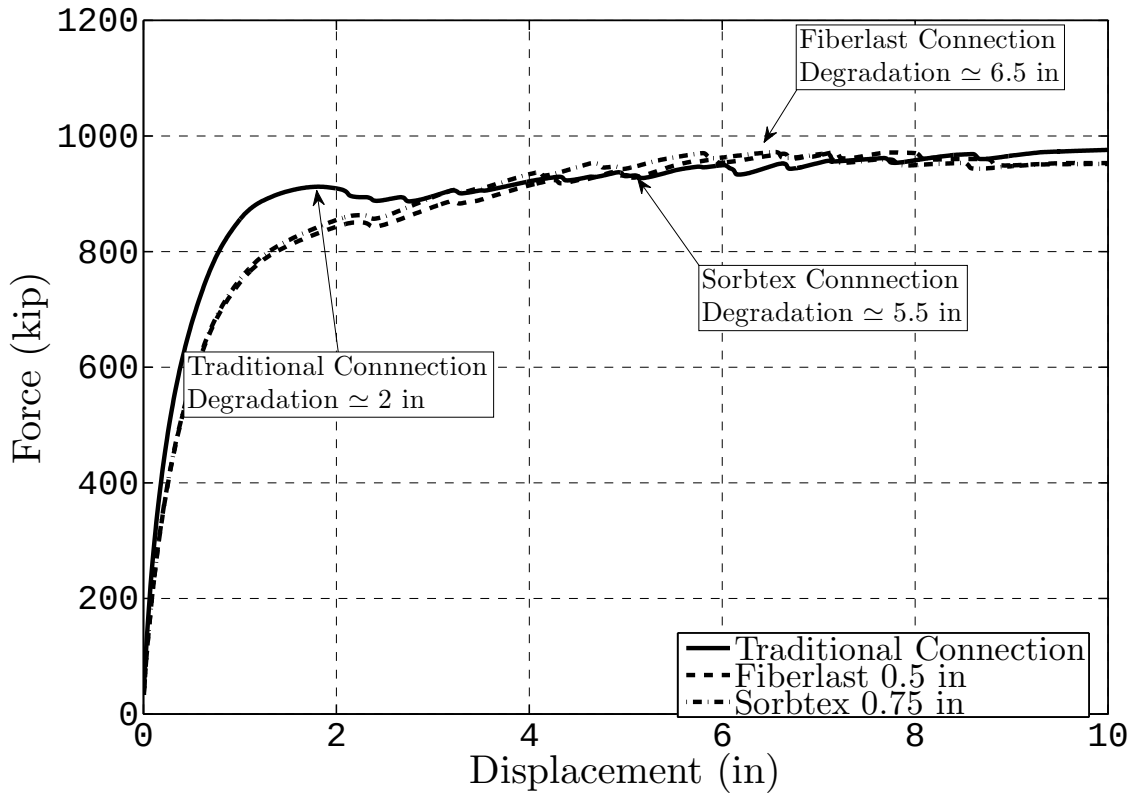


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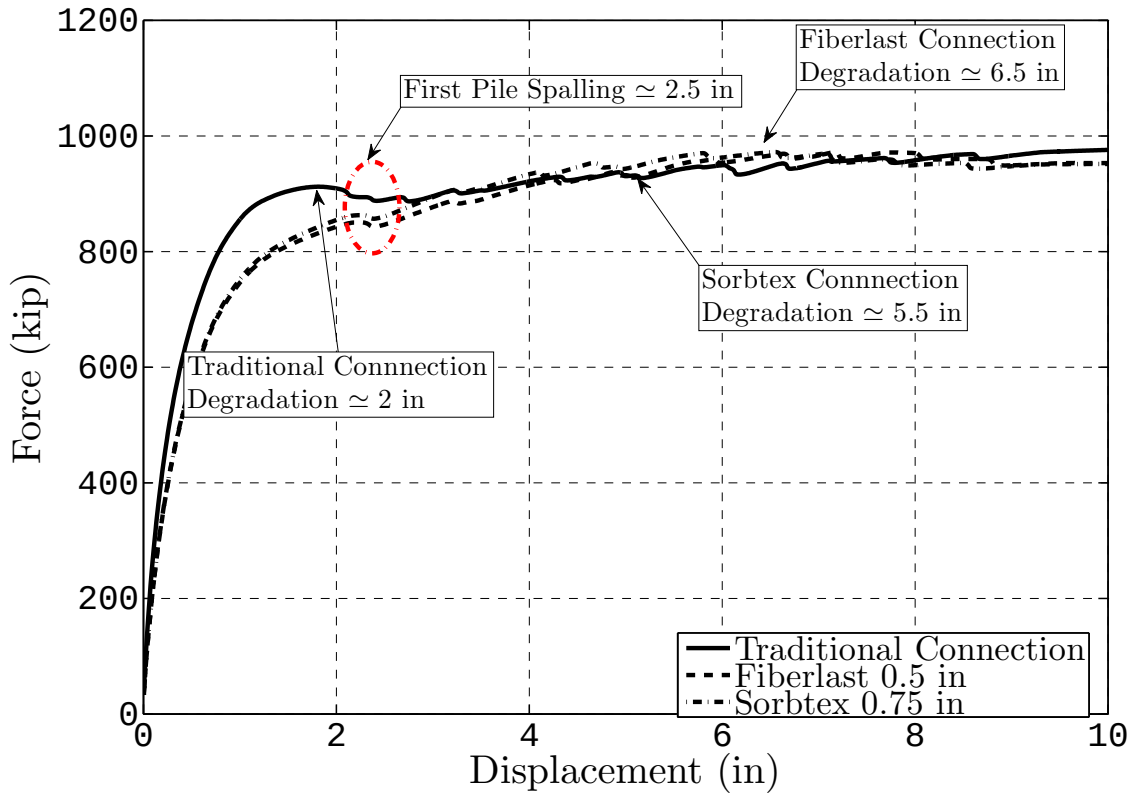


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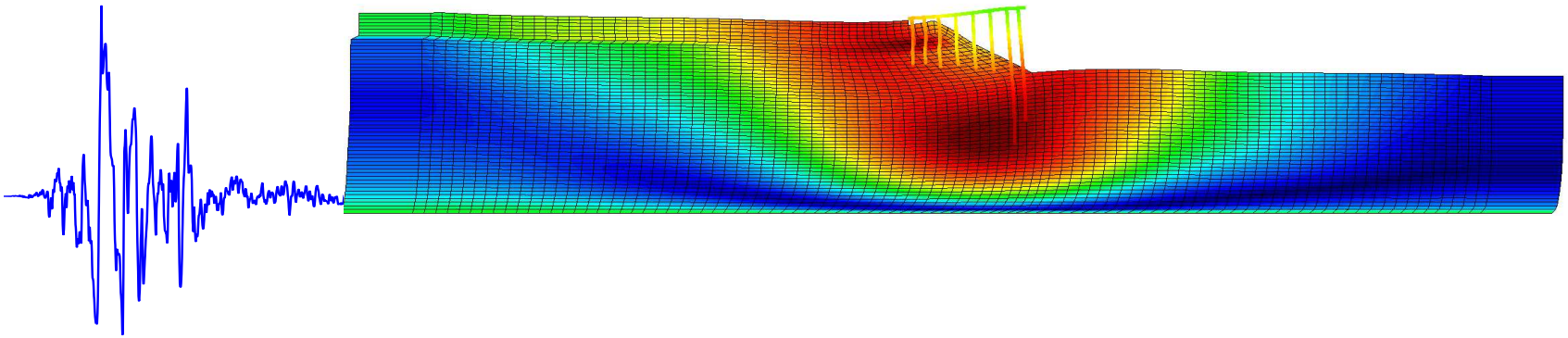
# Analysis & Results

- Static pushovers
- Dynamic time hystories
  - Selected suite of thirteen ground motions
  - Scaled ground motions to 2%, 5%, and 10% P.E. in 50 yrs



# FUTURE WORK

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- Probabilistic analysis of crane response ( Kosbab & Jacobs 2010)
- Final report
- Evaluate wharf response with large displacements - liquefiable layers
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# THANK YOU!
# QUESTIONS?

Click for movie

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