Towards a Performance Assessment Calculation Tool (PACT) for Bridge Systems
and
Other Pile Supported Structures

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PEER

Acknowledgements
Pacific Eq. Eng Research Center (Steve Mahin, ….)
Caltrans (Mark Mahan, Toorak Zokaie, Tony Youn, ….)
OpenSees (Frank McKenna, Filip Filippou, ….)

PEER Annual Meeting – Berkeley, CA January 18-19, 2018

Background

Build on PEER Products and Capabilities

OpenSees: Robust Nonlinear Earthquake SSI Simulation Framework

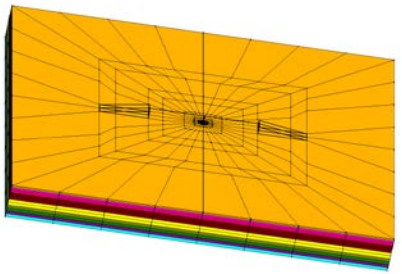
PEER PBEE Framework: Developments related to Bridges

Ground response and SSI: Nonlinear FE modeling, and OpenSeesPL GUI for pre- and post-processing

Ground motion Databases

All were integrated to develop the Bridge PEER PBEE SSI Analysis Framework BridgePBEE

http://peer.berkeley.edu/bridgepbee/



Background


bridge PBEE
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BridgePBEE*
BridgePBEE is a PC-based graphical pre- and post-processor (user-interface) for conducting Performance-Based Earthquake Engineering (PBEE) studies for bridge-ground systems (2-span single column). The three-dimensional (3D) finite element computations are conducted using OpenSees developed by the Pacific Earthquake Engineering Research Center (PEER). The analysis options available in BridgePBEE include: 1) Pushover Analysis, 2) Base Input Acceleration Analysis, and 3) Full Performance-Based Earthquake Engineering (PBEE) Analysis.
*Lu, J., Mackie, K.R., and Elgamal, A. (2011). BridgePBEE: OpenSees 3D Pushover and Earthquake Analysis of Single-Column 2-span Bridges, User Manual, Beta 1.0. [pdf]
Download & Install BridgePBEE
Note: BridgePBEE only works on Windows based PC computers. It is best to use a relatively new Laptop or Desktop with a fast processor, and at least 2GB of memory.
The following steps describe how to download, install and run BridgePBEE. For detailed documentation, please see the user manual (6.4 MB pdf file, updated Aug 2017). In addition, a few demo examples are available at the Examples page.
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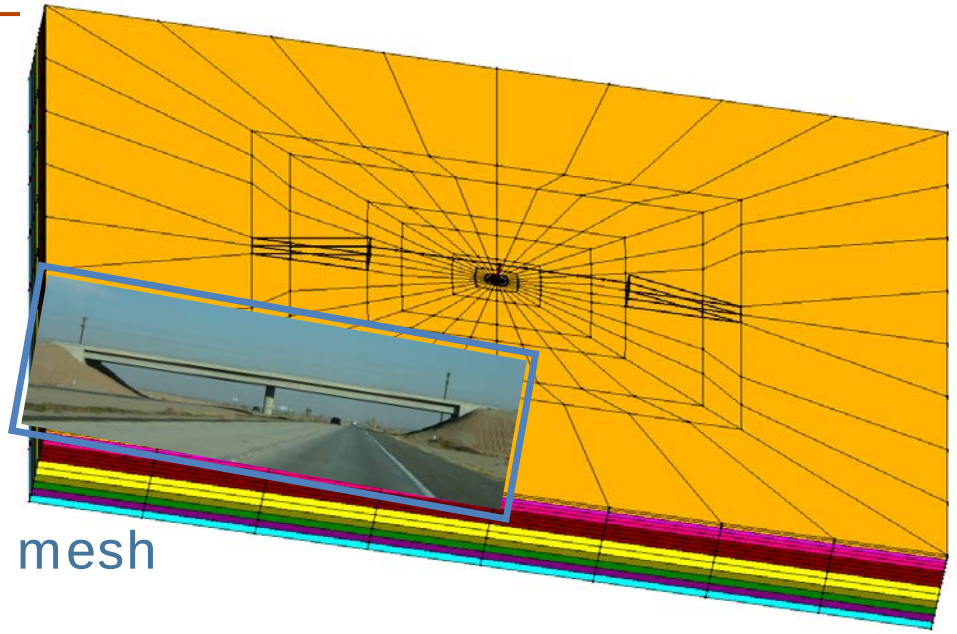
Background

BridgePBEE



- 2-span Bridges

- Single column Bent

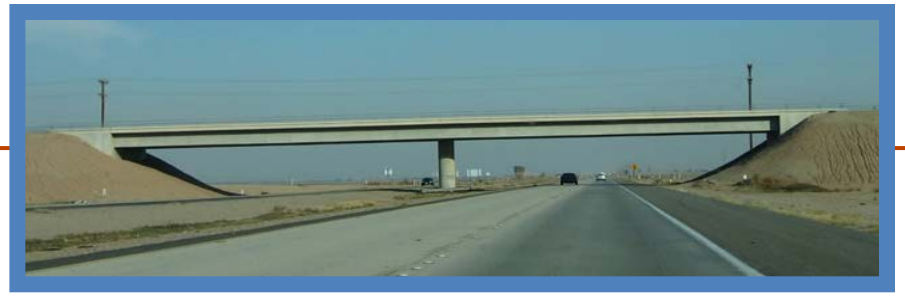
- SSI by 3D Finite Element soil mesh

- Fully Integrated with the bridge PEER PBEE Framework

- Capabilities for users to modify the PBEE Framework parameters

- Runs on a laptop, and can be easily adapted to run on multi-processor machines, DesignSafe https://www.designsafe-ci.org/, and so forth …

Background

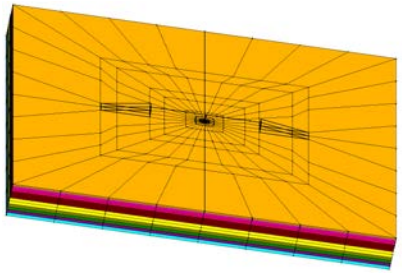


BridgePBEE

To some degree BridgePBEE was a *Proof of Concept (PoC) effort* with a simple bridge configuration (single column, 2-span)

Further, some potential users might be unfamiliar with:

- Nonlinear time-domain analysis of bridges (ESA)
- Nonlinear time domain ground response (SHAKE)
- 3D response
- 3D SSI



- The PEER PBEE Framework and involved assumptions

Recent developments

Document comparisons between NTHA and conventional ESA results for a range of “Ordinary Bridges”

Vastly extend the bridge modeling capabilities:

Multi-span bridges

Multi-column bents

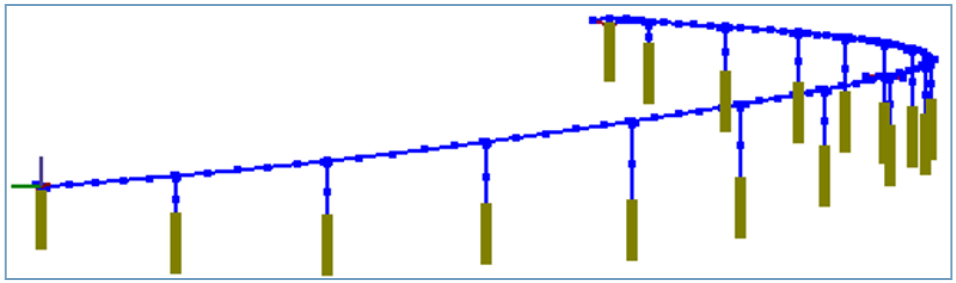
Variable height columns (capture irregular ground topography)

Bridge vertical curves

Bridge horizontal curves

Skew bridges

Hinges and expansion joints



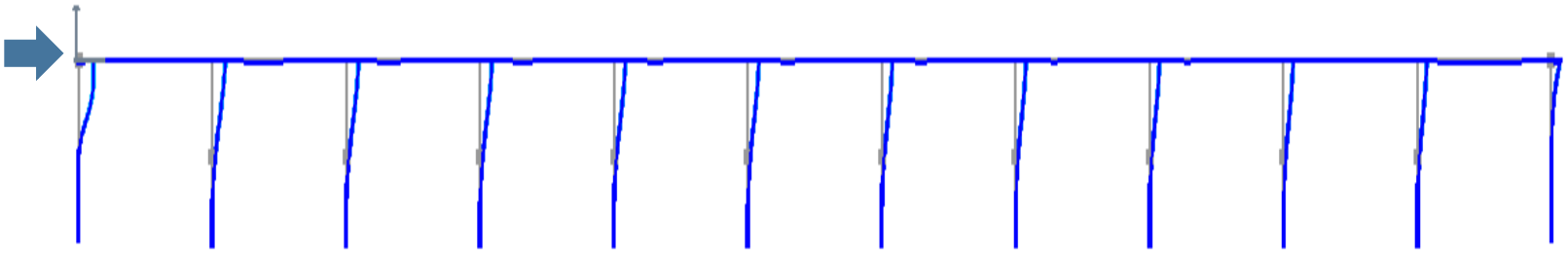
SSI by much simpler *p-y (t-z)* springs, rather than 3D soil mesh

Bent by bent multi-column configurations facilitated

column by column arbitrary cross-section and reinforcement

Recent developments

- In addition to loading by Seismic Excitation, deformed configurations can be specified and assessed (e.g., due to liquefaction-induced lateral spreading per Caltrans MTD 25-11)



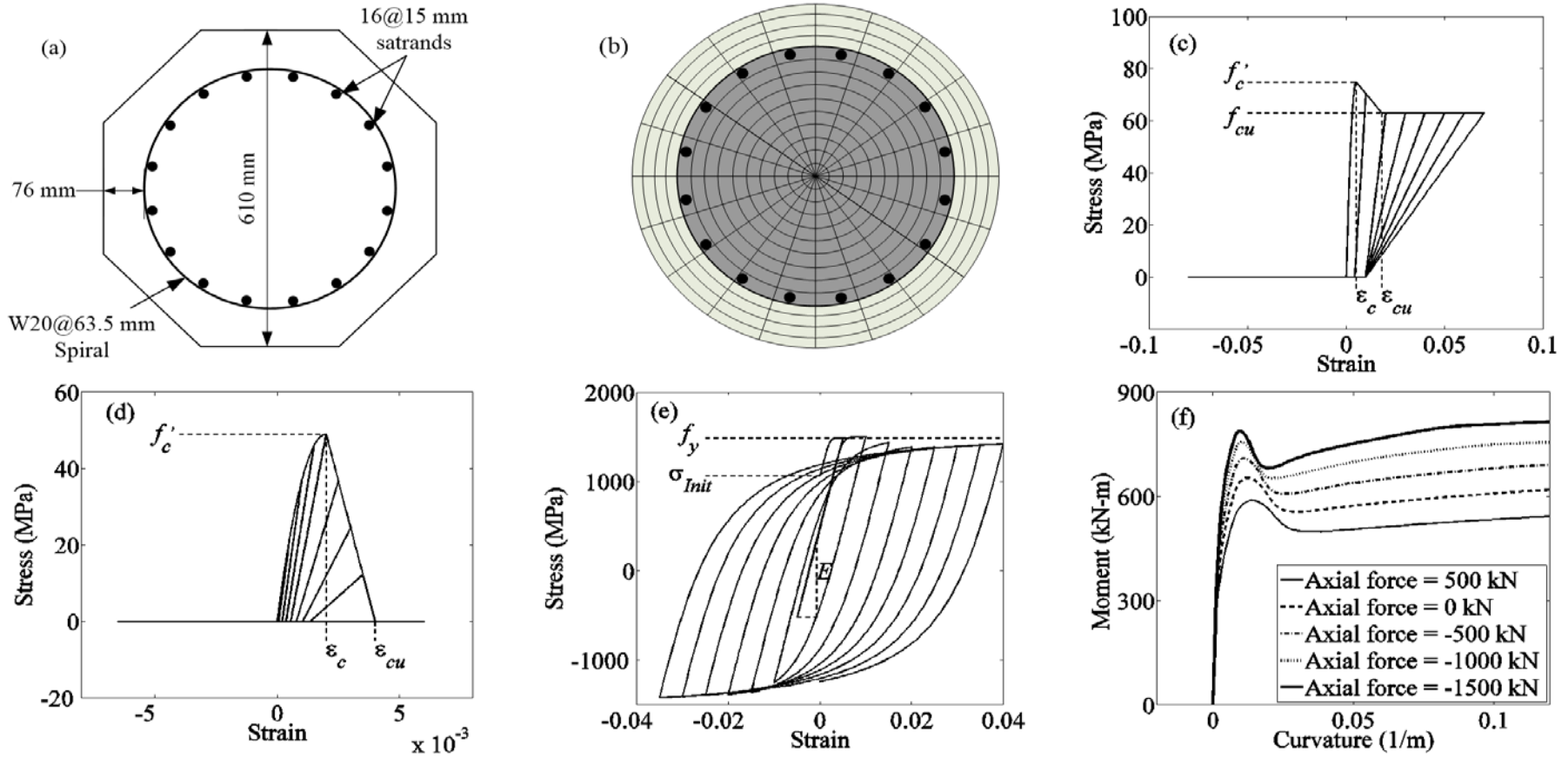
- Along with the PBEE
  - Repair Cost

  and
  - Repair Crew Working Days

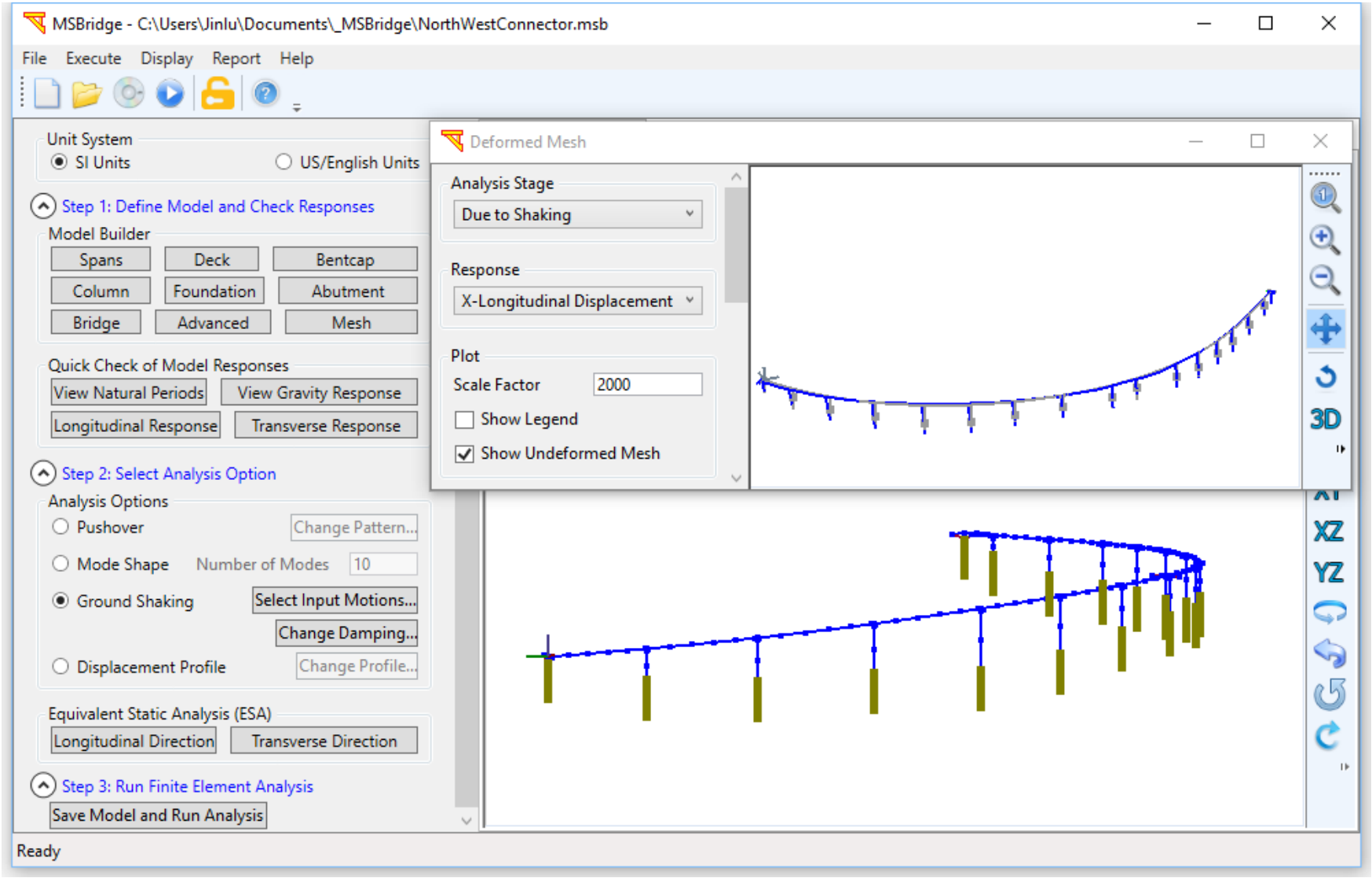
  Now also includes:
  - Repair Carbon Footprint

Mackie, K. R., Kucukvar, M., Tatari, O., & Elgamal, A. (2015). Sustainability Metrics for Performance-Based Seismic Bridge Response. Journal of Structural Engineering, ASCE, C4015001, 12p.

MSBridge Nonlinear OpenSees modeling capabilities

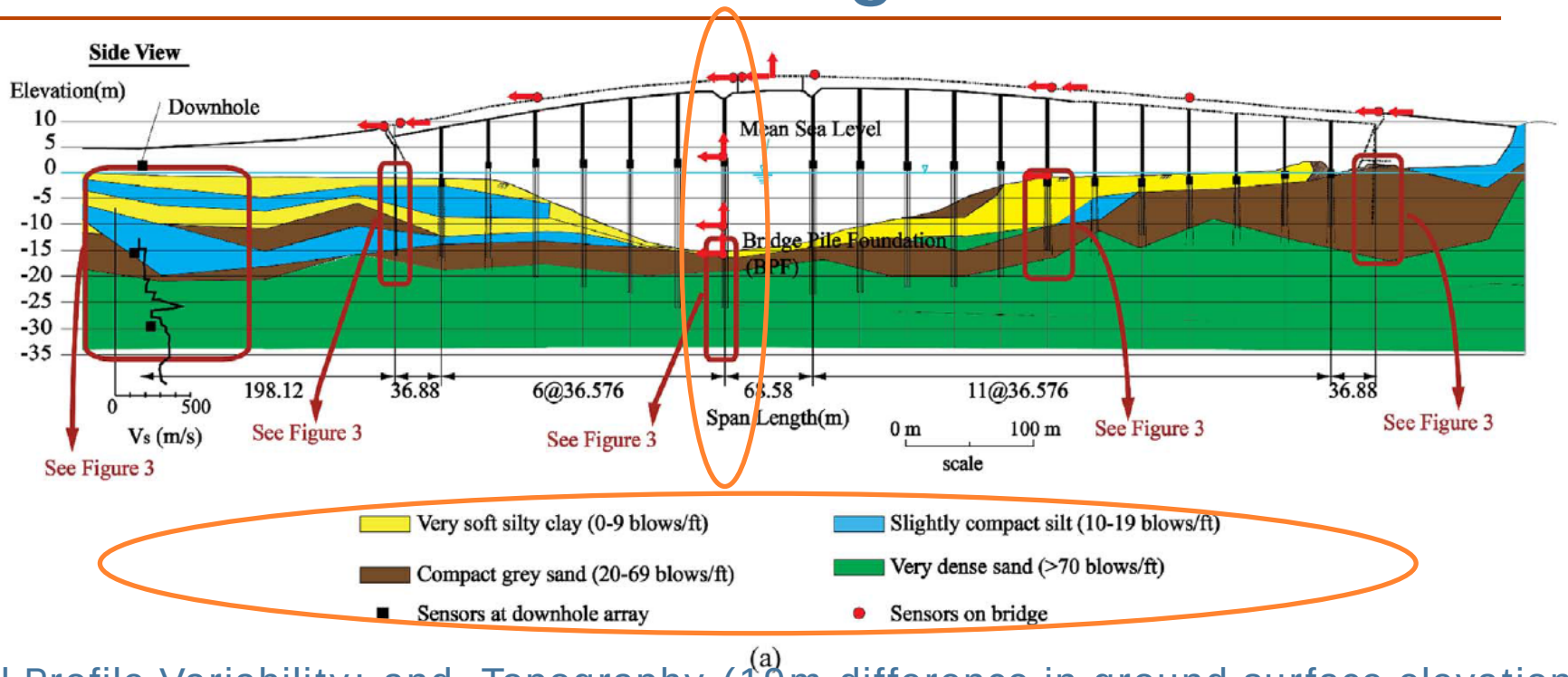


MSBridge


MSBridge - C:\Users\Jinlu\Documents_MSBridge\NorthWestConnector.msb
File
Execute
Display
Report
Help
Unit System
SI Units
US/English Units
Step 1: Define Model and Check Responses
Model Builder
Spans
Deck
Bentcap
Column
Foundation
Abutment
Bridge
Advanced
Mesh
Quick Check of Model Responses
View Natural Periods
View Gravity Response
Longitudinal Response
Transverse Response
Step 2: Select Analysis Option
Analysis Options
Pushover
Change Pattern...
Mode Shape
Number of Modes
10
Ground Shaking
Select Input Motions...
Change Damping...
Displacement Profile
Change Profile...
Equivalent Static Analysis (ESA)
Longitudinal Direction
Transverse Direction
Step 3: Run Finite Element Analysis
Save Model and Run Analysis
Ready
Deformed Mesh
Analysis Stage
Due to Shaking
Response
X-Longitudinal Displacement
Plot
Scale Factor
2000
Show Legend
Show Undeformed Mesh
3D
XZ
YZ

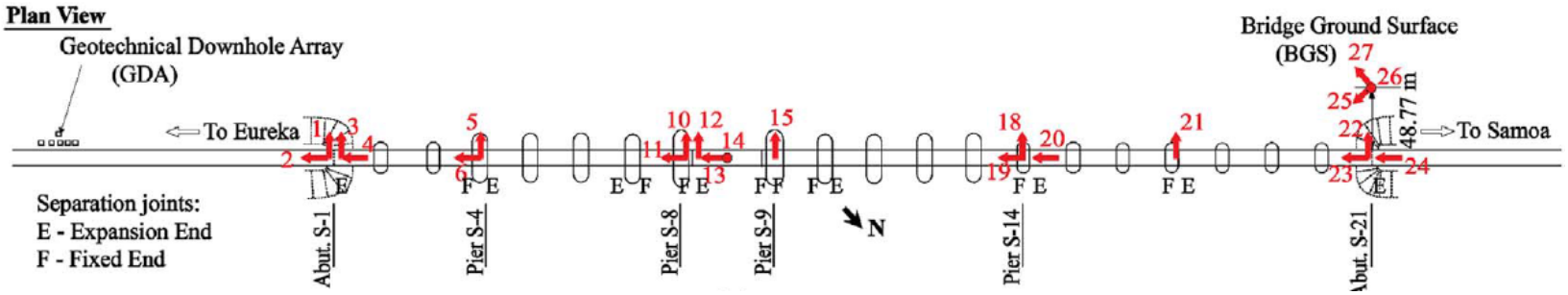
Instrumented Bridges (PEER Eureka, CA Testbed)

Samoa Channel Bridge, Eureka, CA



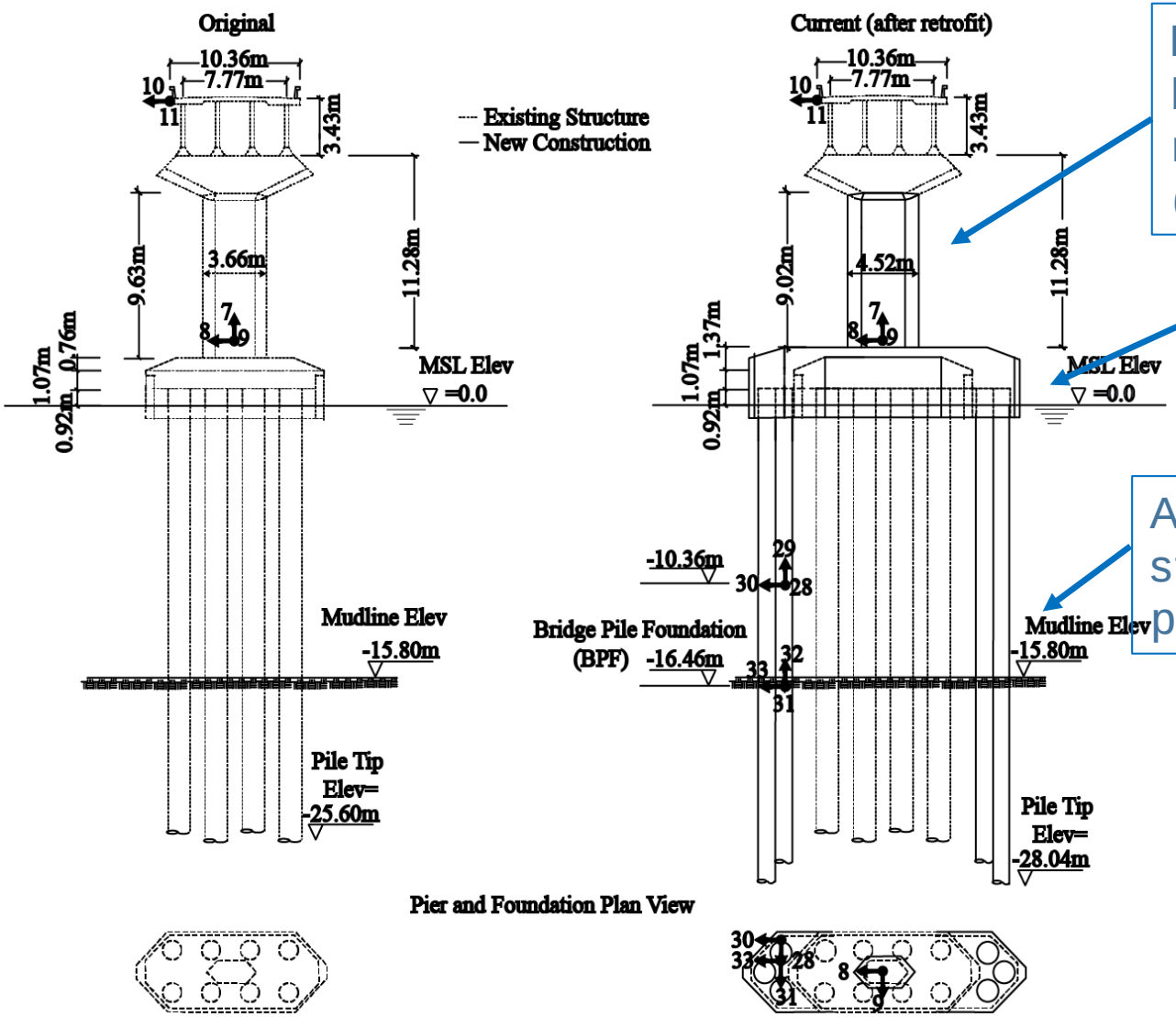
(a)

Soil Profile Variability; and Topography (19m difference in ground surface elevation)



Wang, N., Elgamal, A., & Shantz, T. (2017). Recorded seismic response of the Samoa Channel Bridge-foundation system and adjacent downhole array. *Soil Dynamics and Earthquake Engineering*, *92*, 358-376.

Samoa Channel Bridge, Eureka, CA

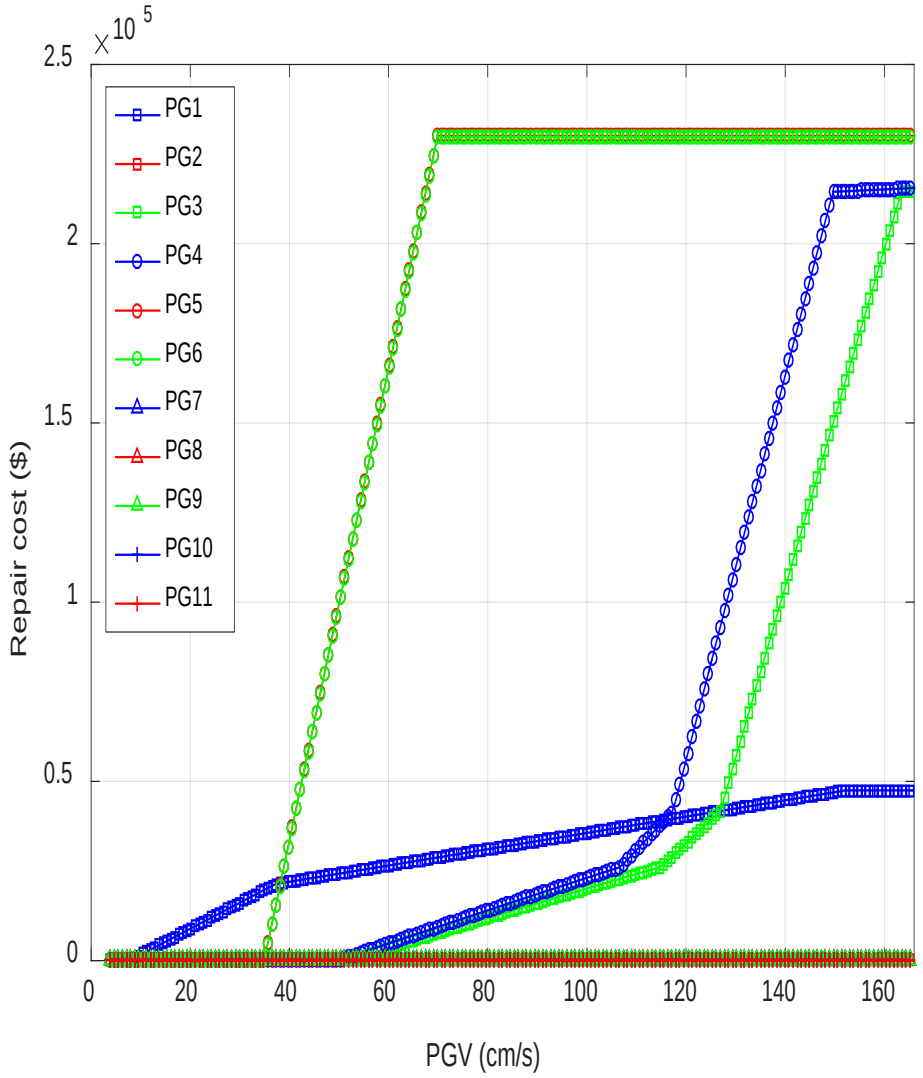


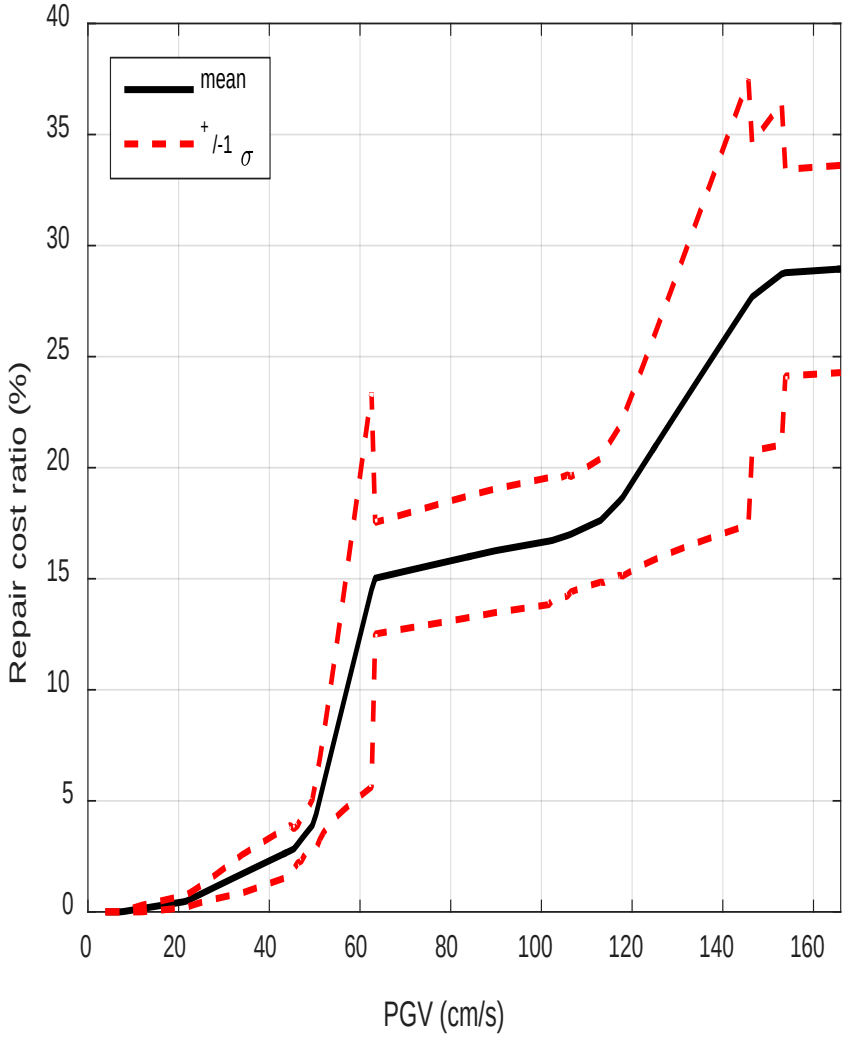
Encasing the original bridge columns in reinforced concrete (RC) jackets

Enlarging the pile caps to cover the new piles

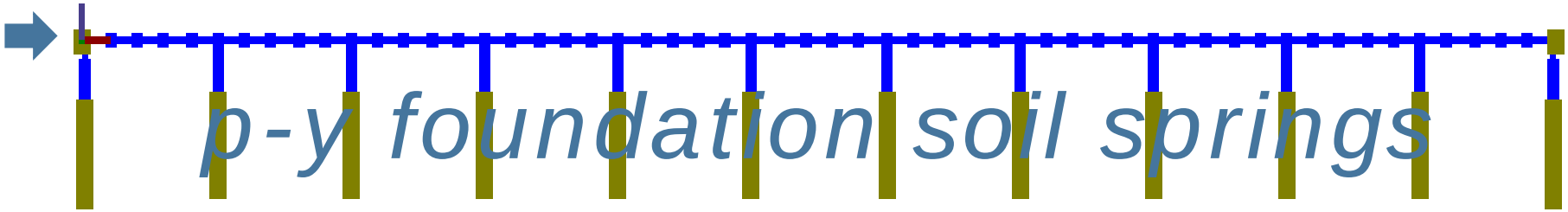
Additional cast-in-steel shell (CISS) piles

MSBridge: Bridge PBEE Outcomes



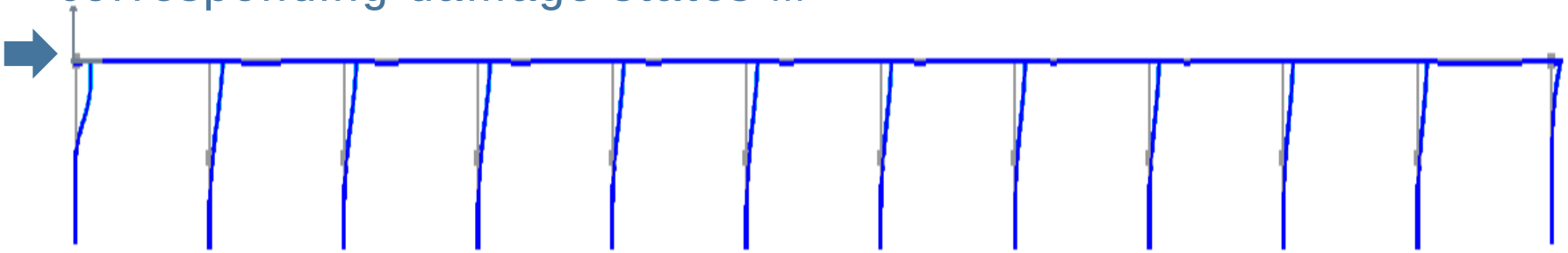


Liquefaction-Induced Lateral Spreading



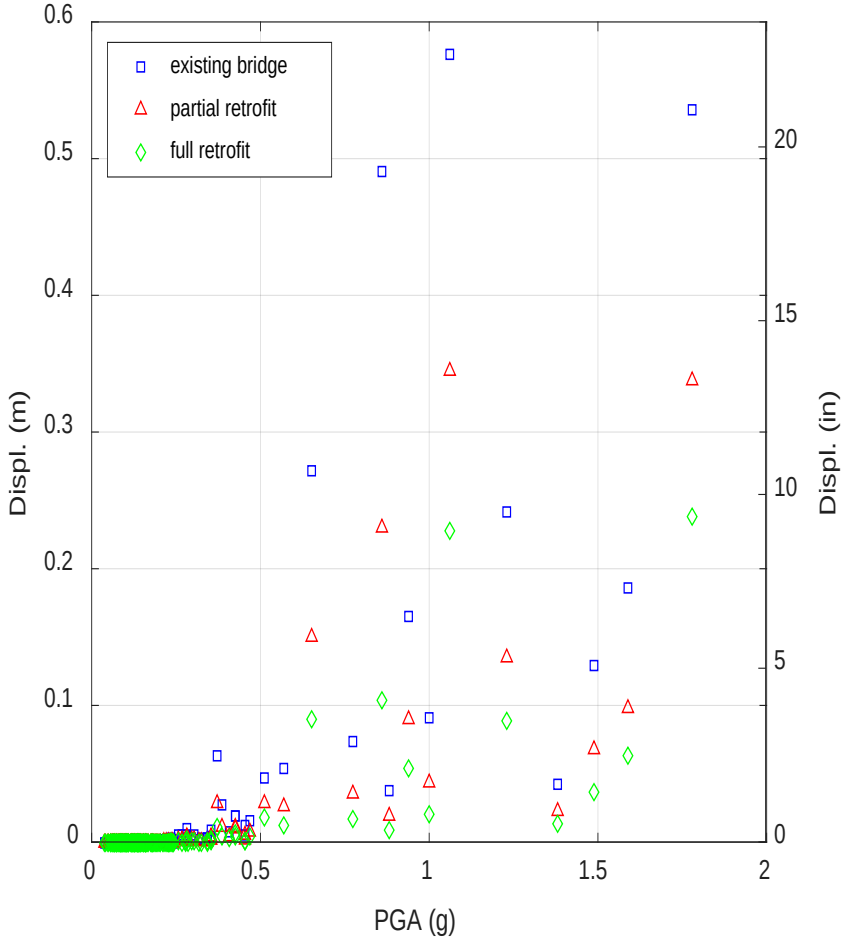
- From input ground motions, estimate Lateral slope deformation ➡ for each PBEE shaking event via **Bray and Travasarou (2007)**

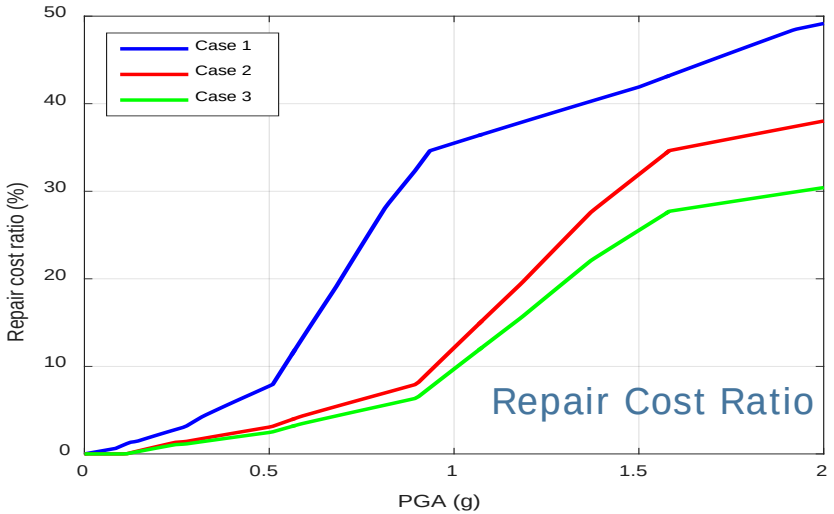
- Liquefaction-induced displacement estimates ➡ applied to bridge Model, to compute bridge deformation configurations and corresponding damage states …

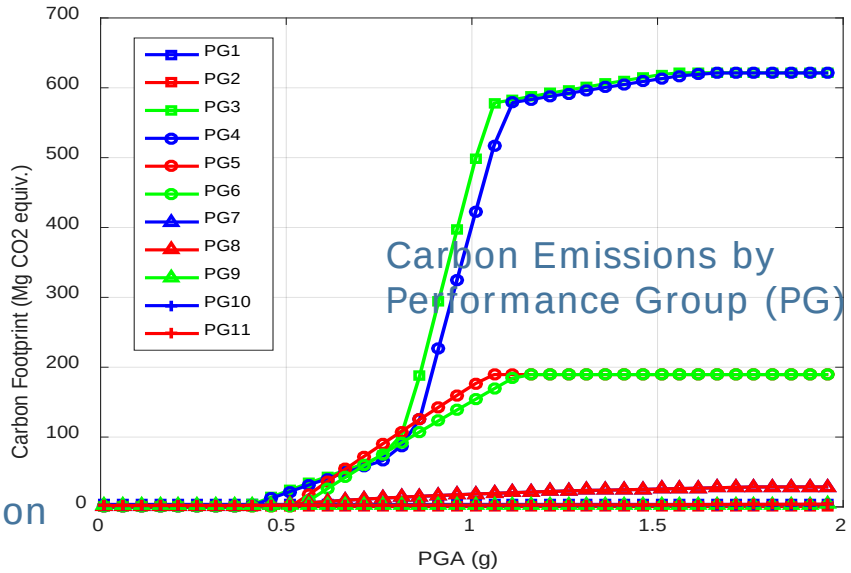


Bridge displaced Configuration

PBEE Response and Outcomes

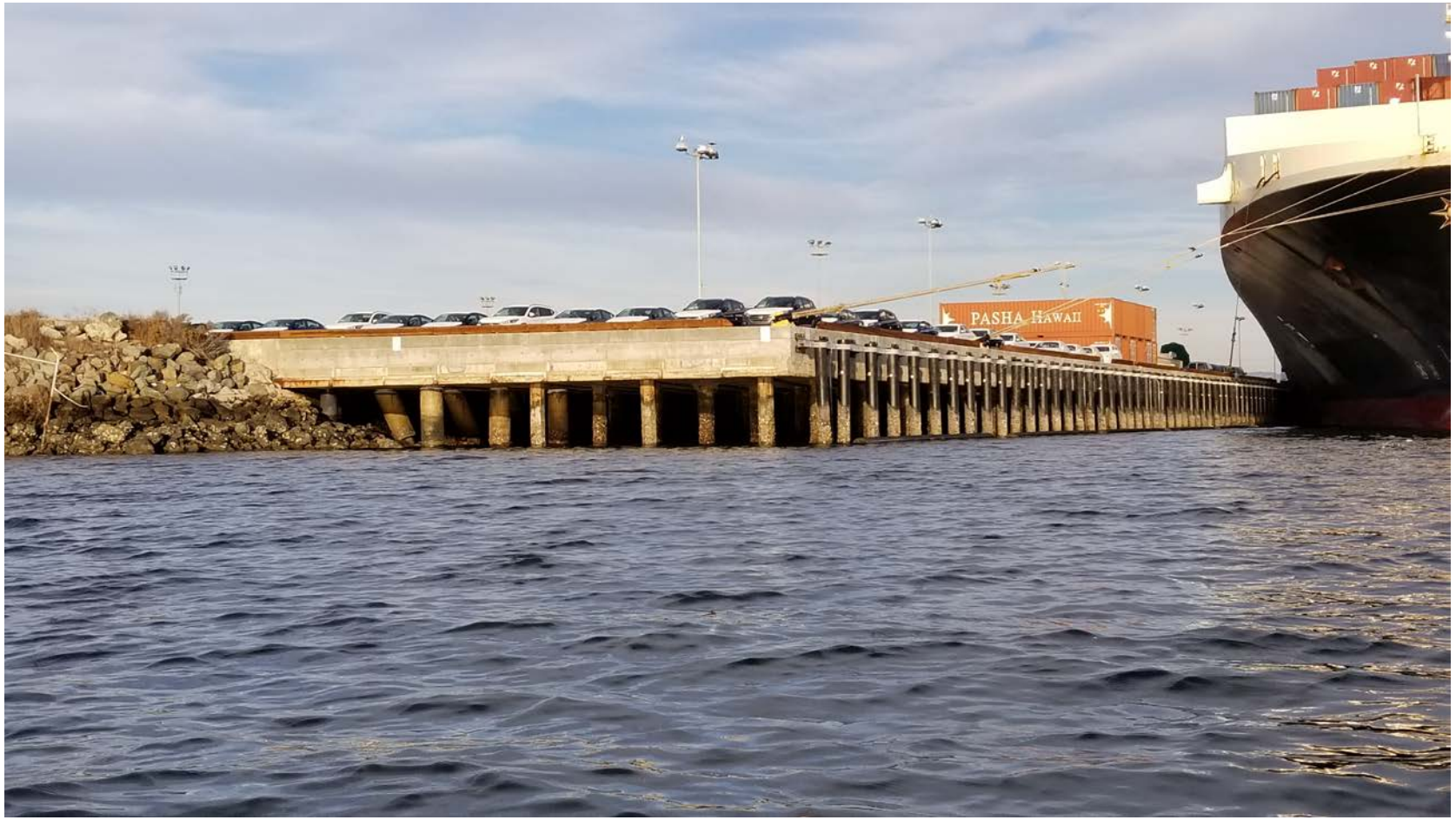






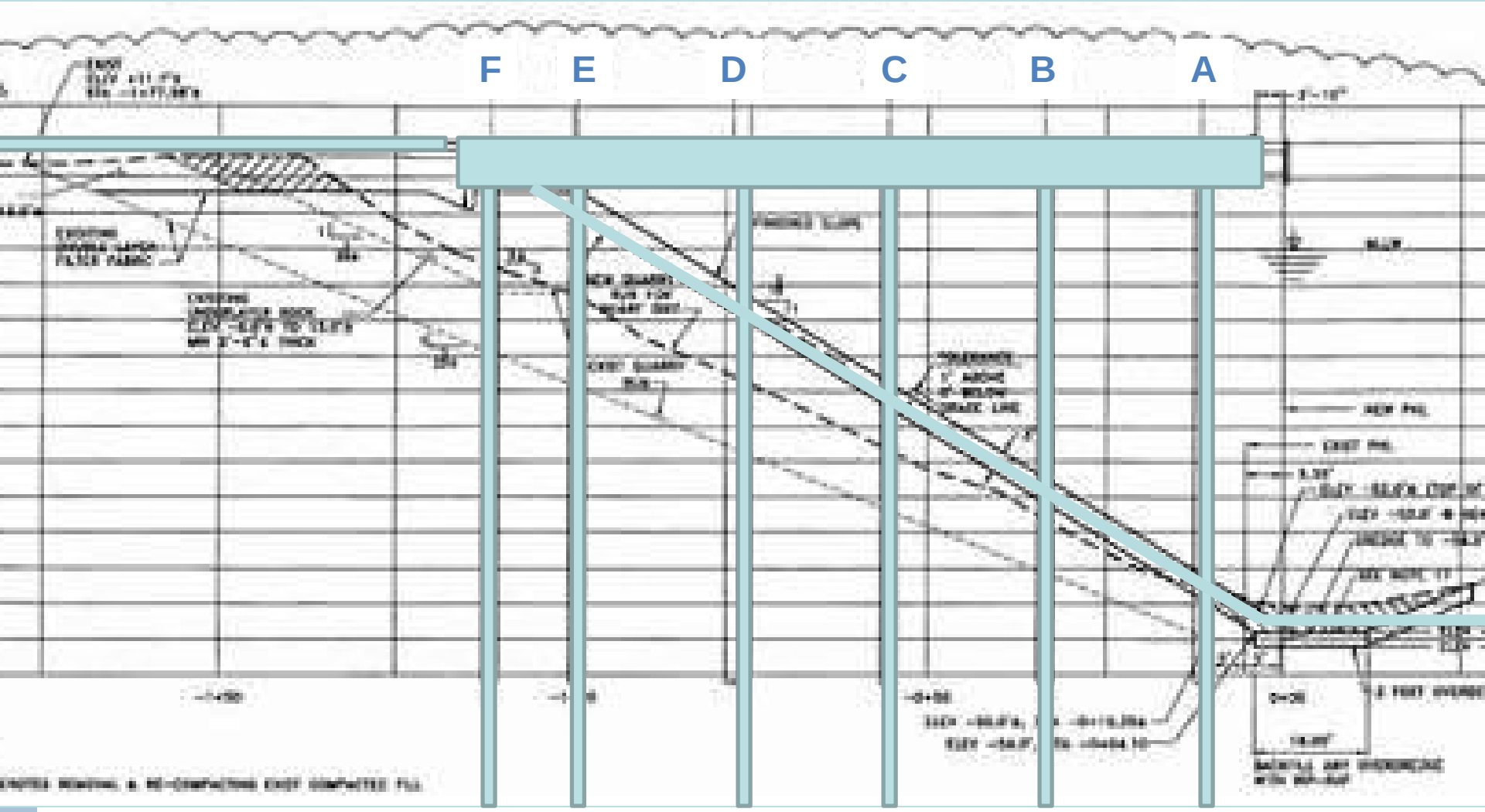
Lateral Spreading Dipl. estimates (**Bray and Travasarou 2007**), applied to Bridge Model with Caltrans MTD 20-15 (after **Shantz 2016**) liquefaction *p-y* foundation soil springs

PBEE for Pile-supported Wharf Structures



Su, L., Lu, J., Elgamal, A., & Arulmoli, A. K. (2017). Seismic performance of a pile-supported wharf: Three-dimensional finite element simulation. Soil Dynamics and Earthquake Engineering, 95, 167-179.

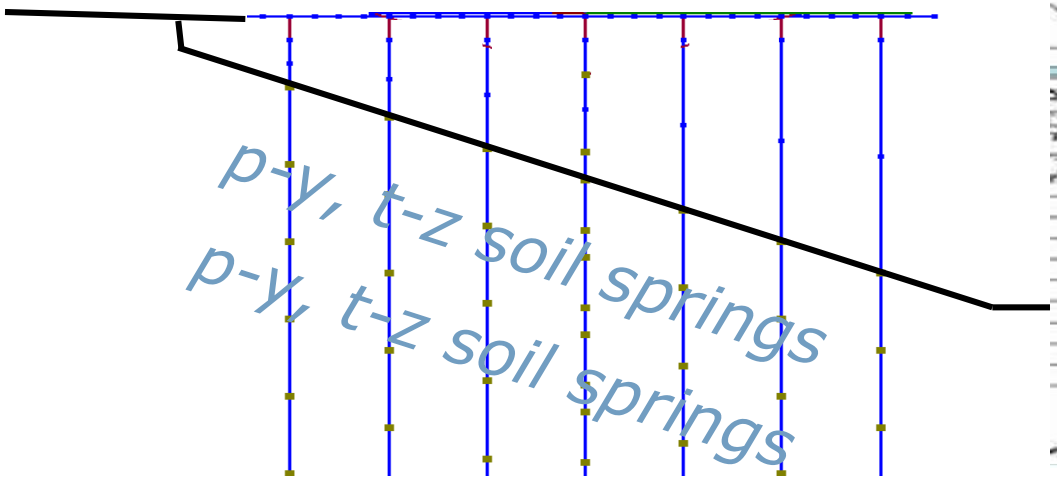
PBEE for Pile-supported Wharf Structures

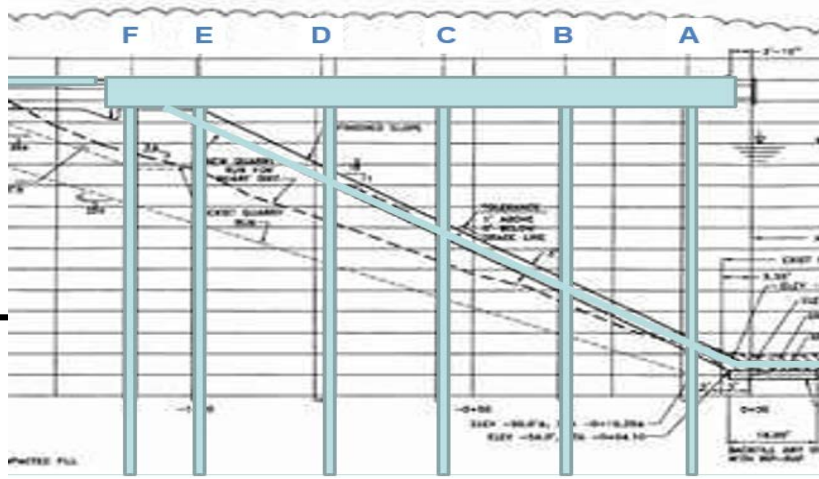


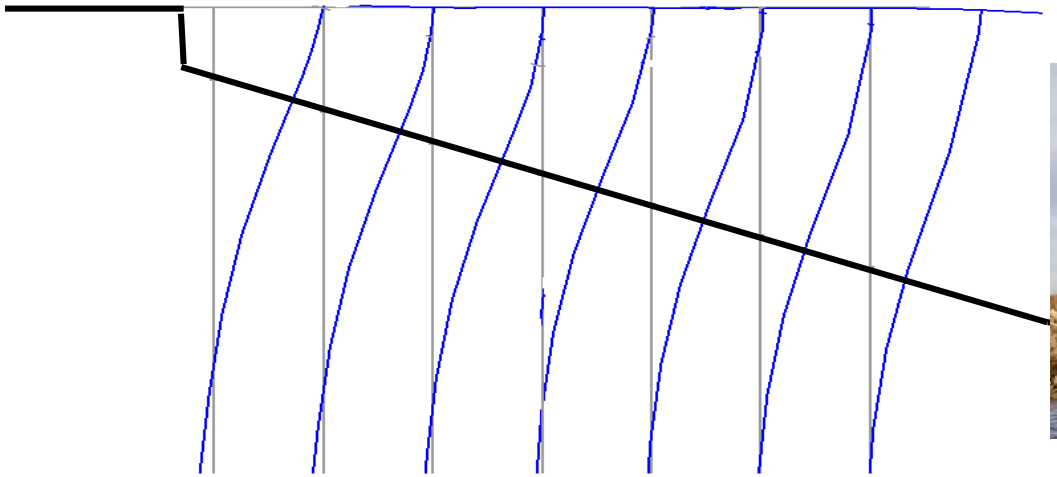
Cross-section

MSBridge: PBEE for Pile-supported Wharfs

Ubiquitous in US Ports … Port of LA, Long Beach, Oakland, SF, ..







… along with other potential applications,

Thank you!