

The 15<sup>th</sup> Annual Conference of Hong Kong Society of Theoretical and Applied Mechanics  
The 7<sup>th</sup> Jiangsu-Hong Kong Forum on Mechanics and its Application  
Symposium on the Development of Mechanics in Macau, March 11-12, 2011, Hong Kong - Macau

# Effects of Earthquake Loading on Pore-water Pressure Generation in Liquefiable Soils



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# Outline

- **Introduction**
- **Bounding Surface Model**
- **Port Island Simulation**
- **Ground Motion IM (Intensity Measures) and PWP (pore-water pressure)**
- **Conclusions**

# Introduction

- **Soil Liquefaction**



Soils at Port Island liquefied due to the Kobe Earthquake (M6.9) on Jan 17, 1995

\* Figure source. [http://web.engr.oregonstate.edu/~johnskri/template\\_01/Publish/Templates/design\\_template.html](http://web.engr.oregonstate.edu/~johnskri/template_01/Publish/Templates/design_template.html)

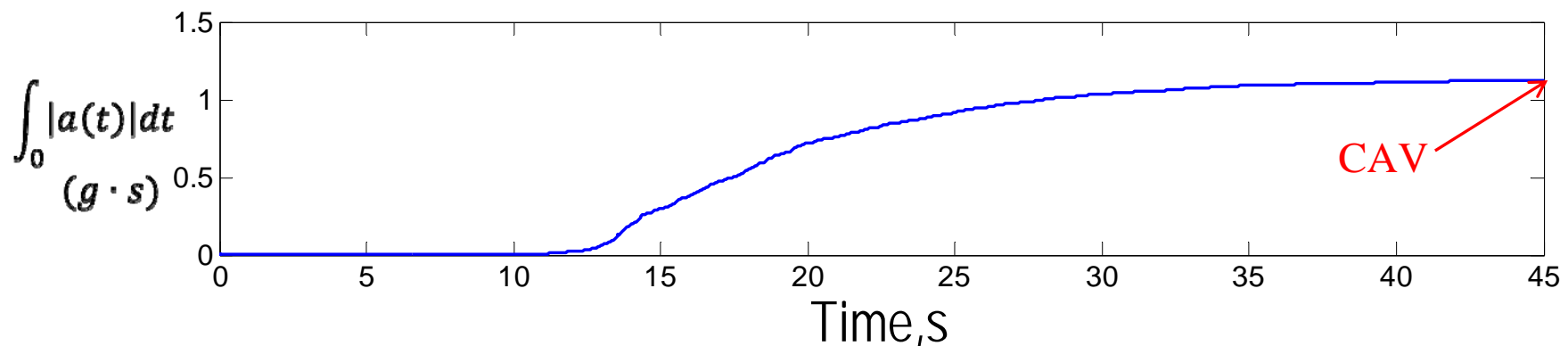
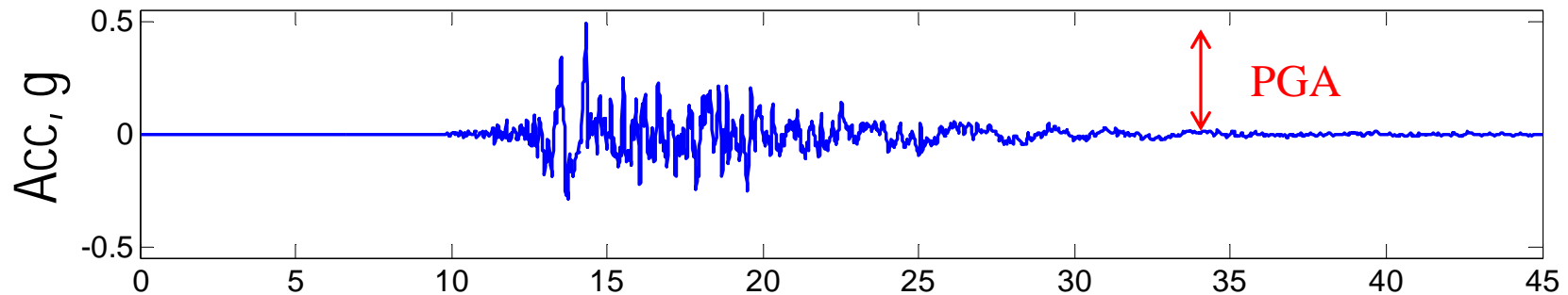
# Introduction

- Ground Motion Characterization

PGA: Peak Ground Acceleration

CAV: Cumulative absolute velocity

$$CAV = \int_0^{T_d} |a(t)| dt$$



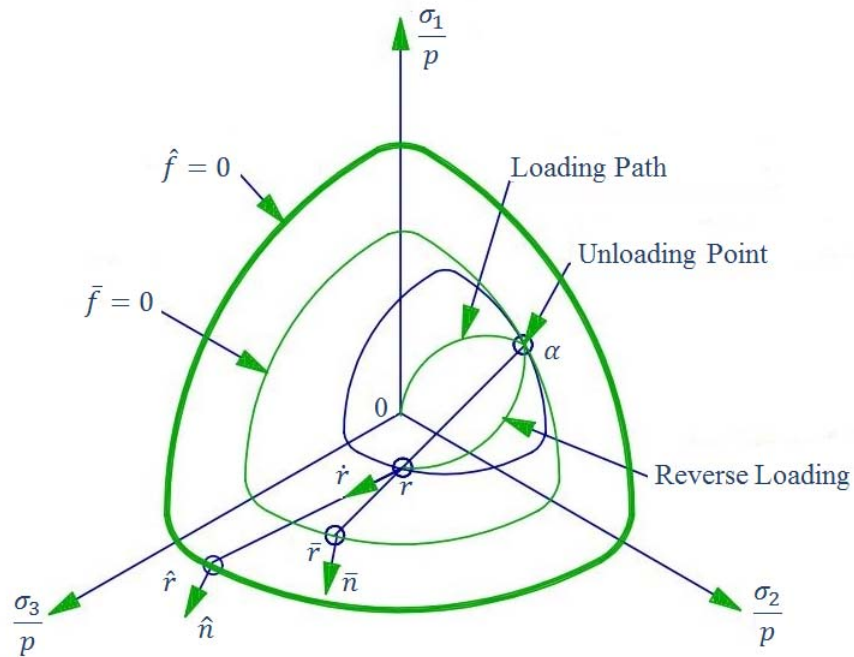
# Introduction

- Ground Motion IM  $\leftrightarrow$  PWP generation ?

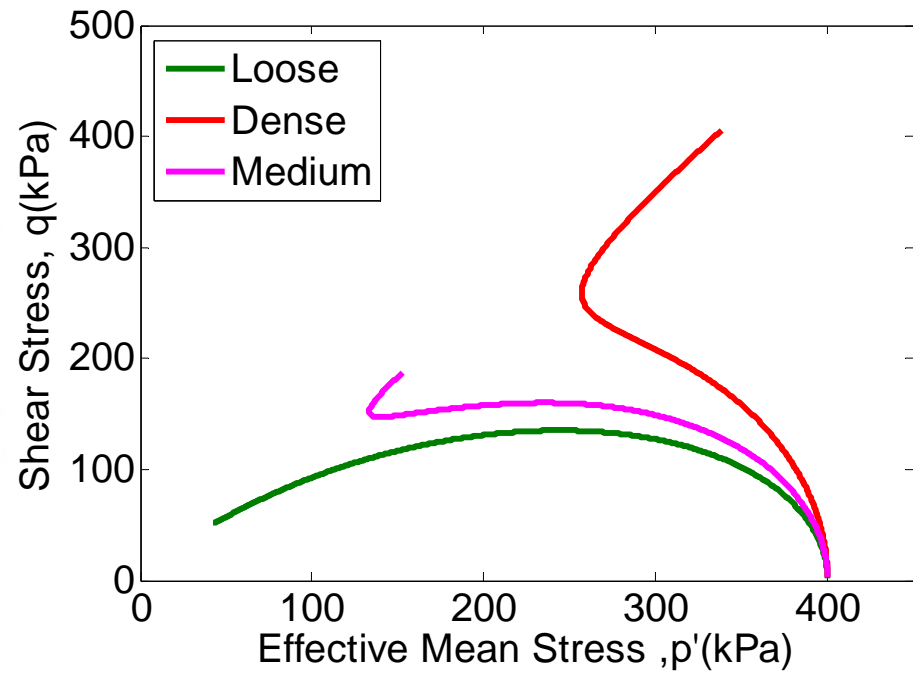
PGA  $\leftrightarrow$  PWP generation

CAV  $\leftrightarrow$  PWP generation

# Bounding Surface Model



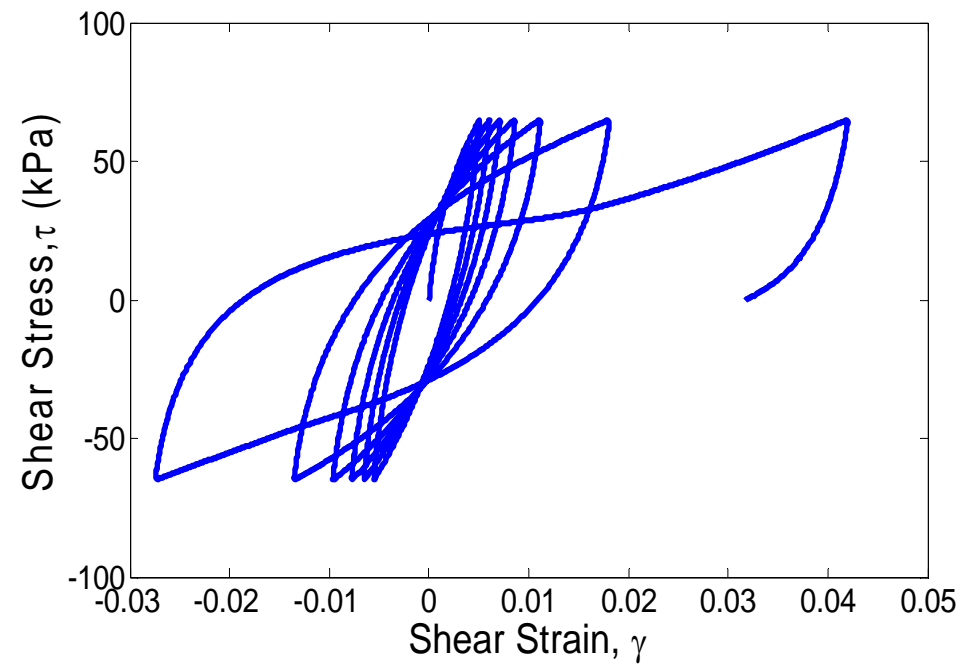
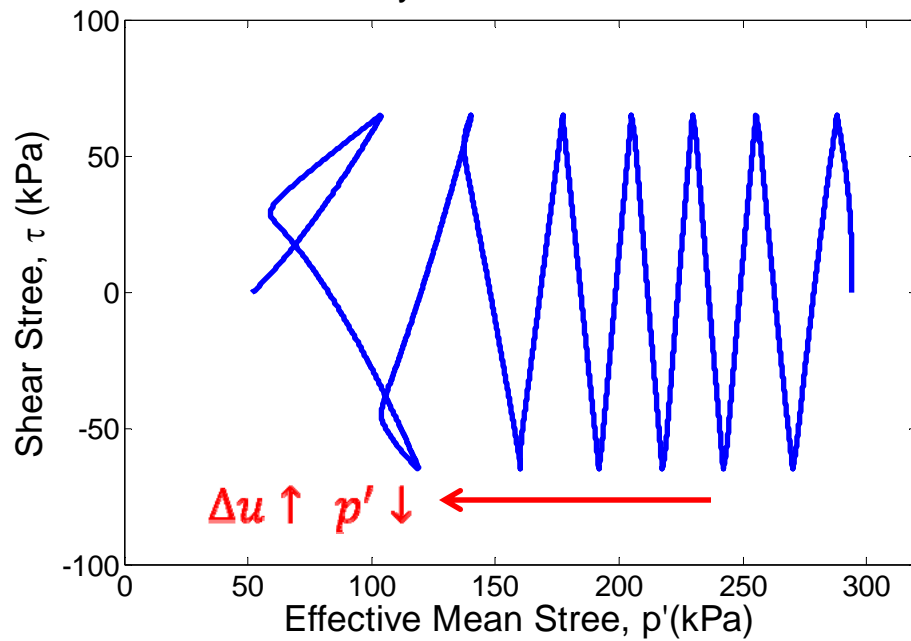
(After Wang *et al*, 1990)



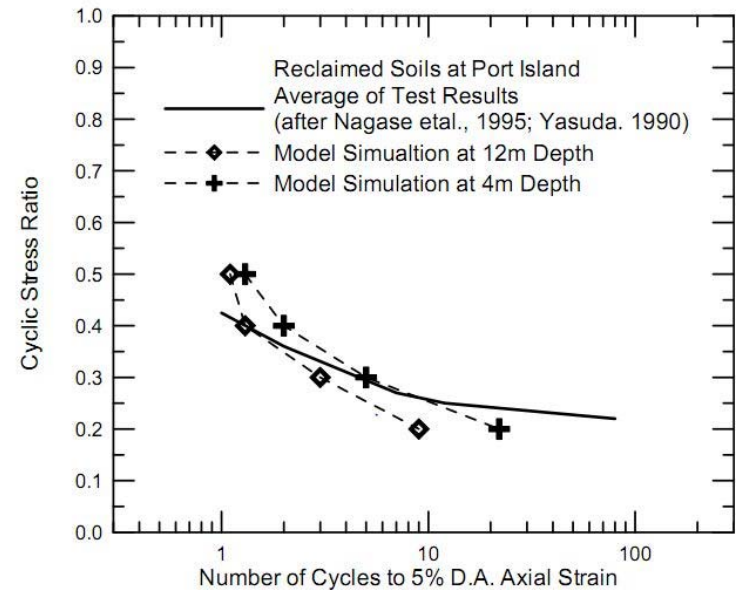
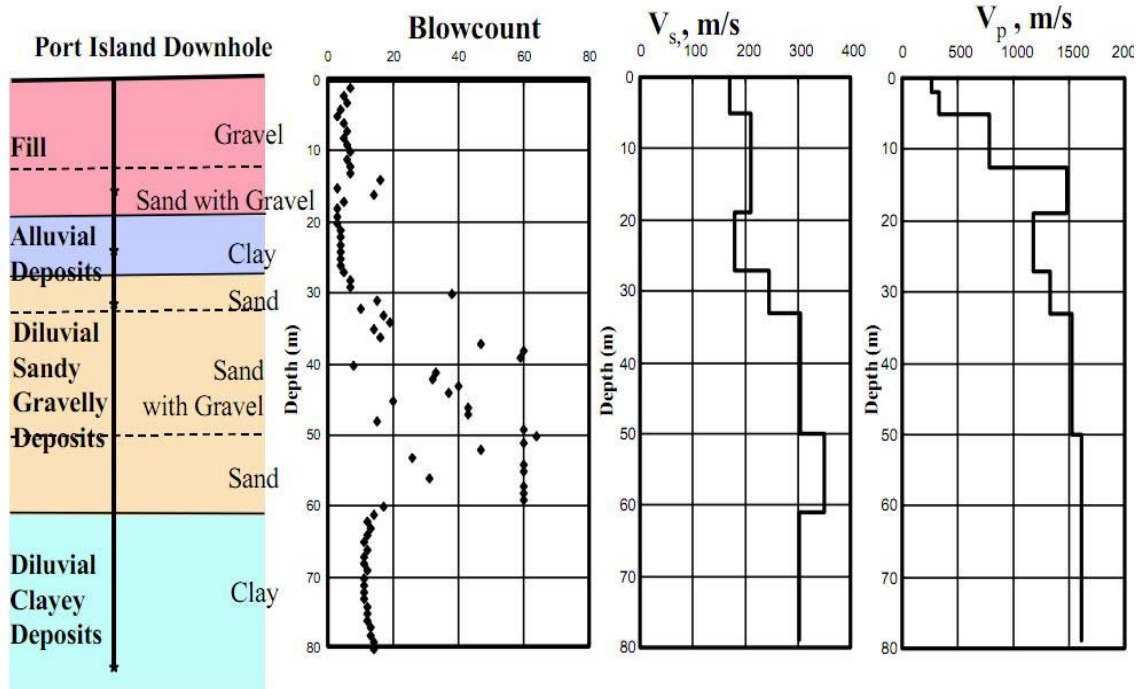
Monotonic Loading

# Bounding Surface Model

Cyclic Stress Path



# Port Island Simulation

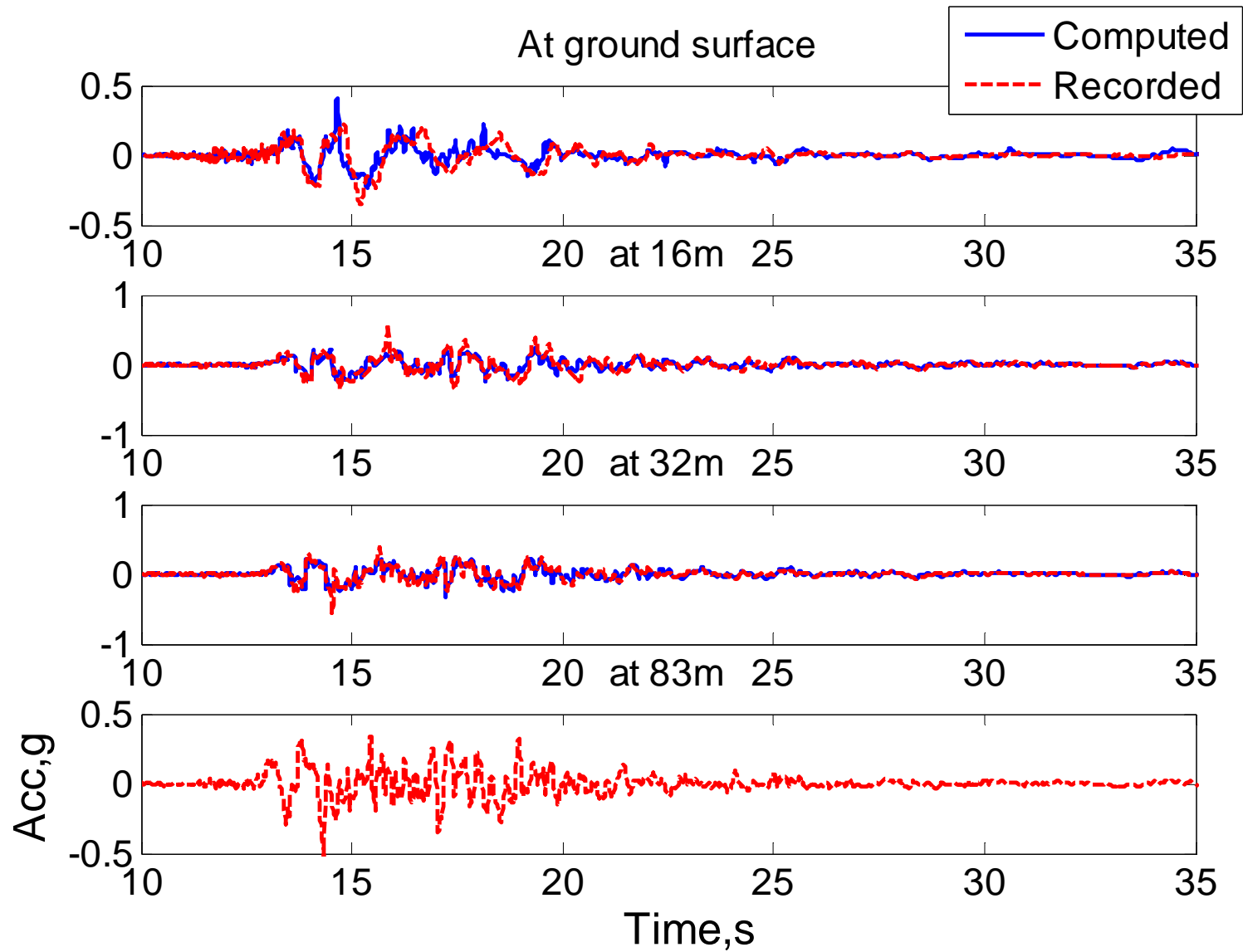


(After Wang, 2001)

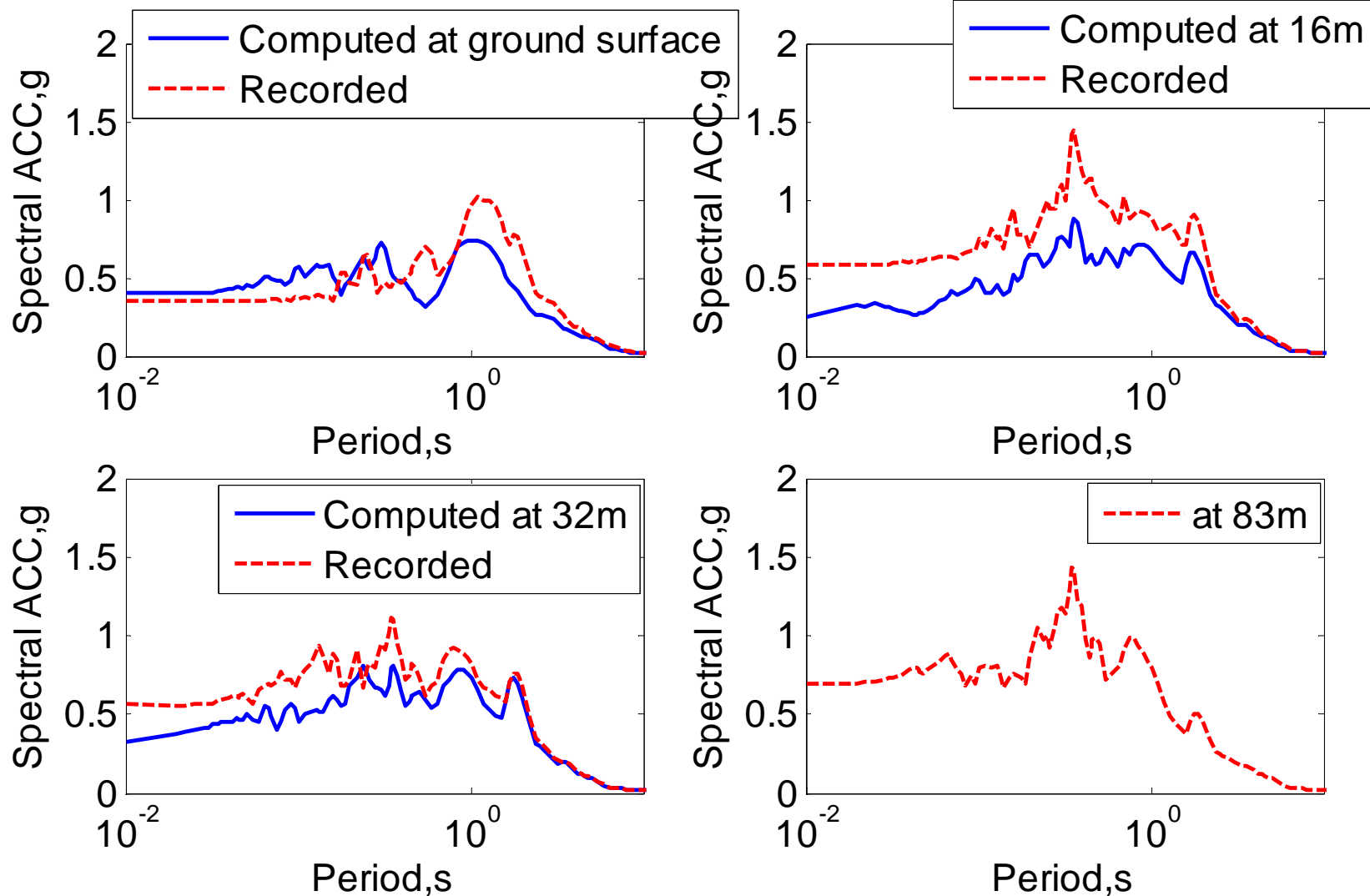
\* Location of Downhole Instruments (at depths of 0, 16, 23, 32, and 83 m)



# Port Island Simulation

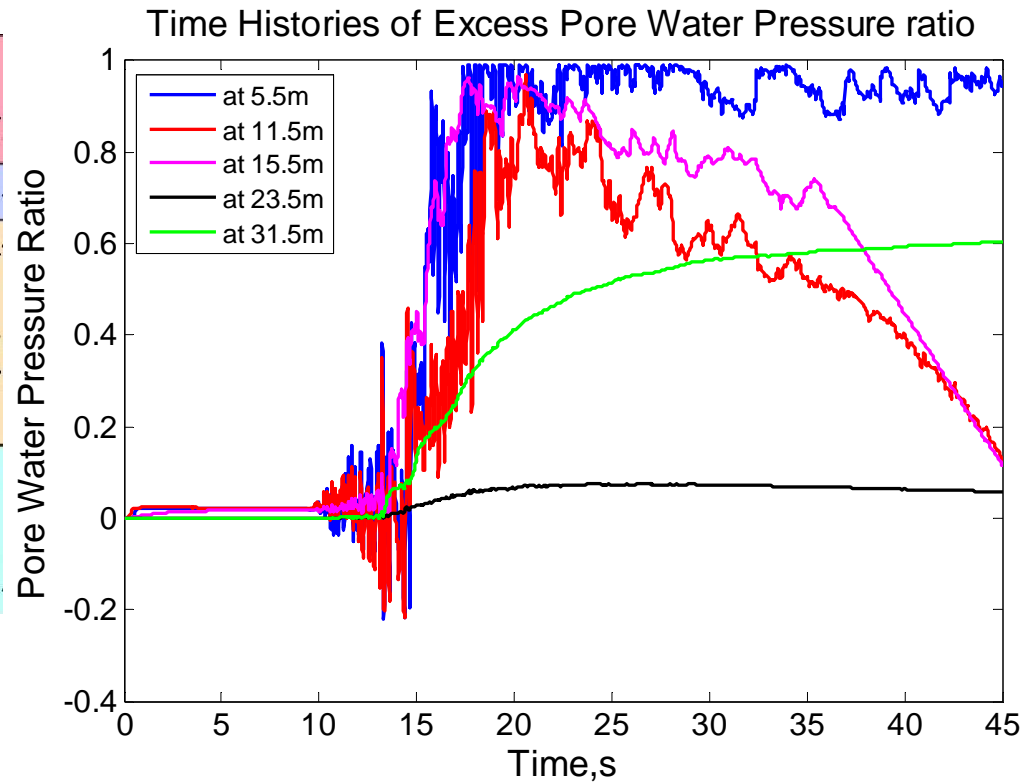
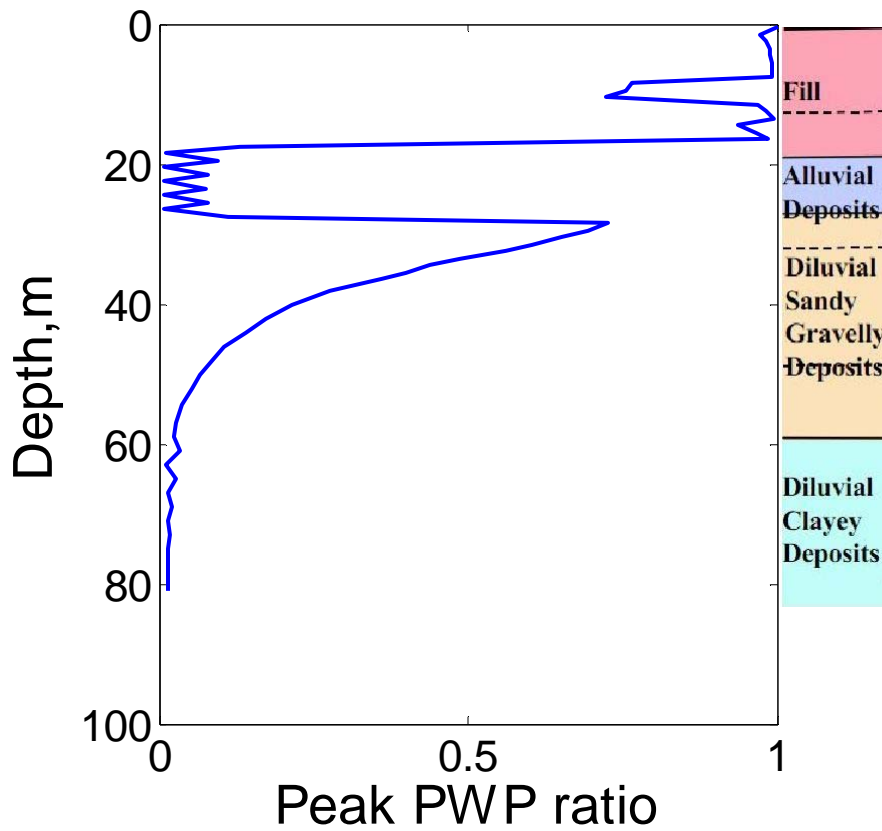


# Port Island Simulation



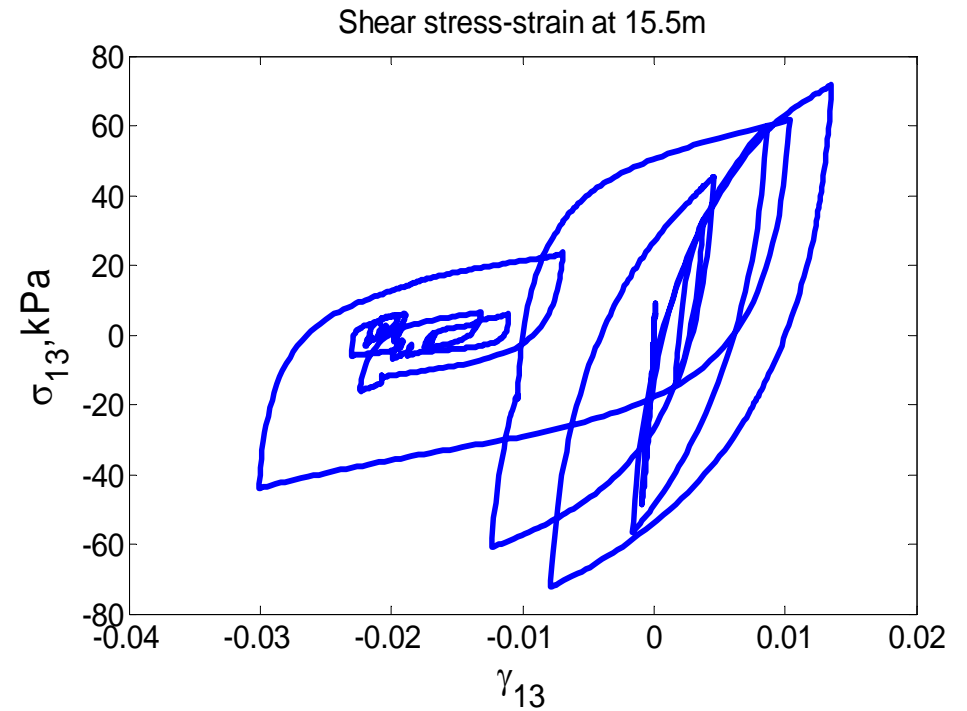
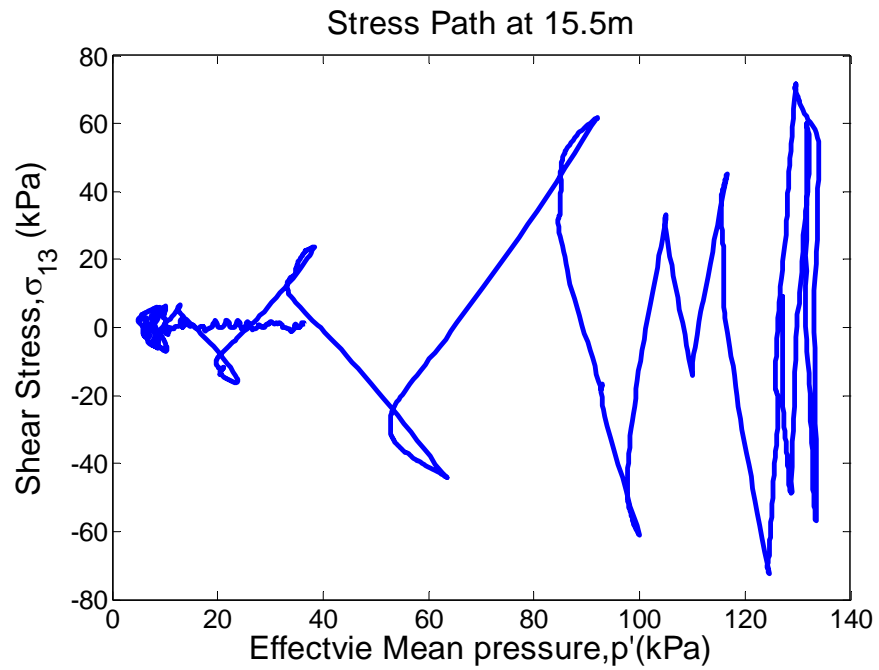
Spectral Acceleration (PGA at different periods)

# Port Island Simulation

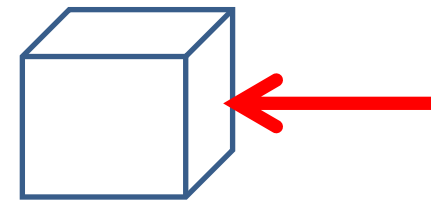
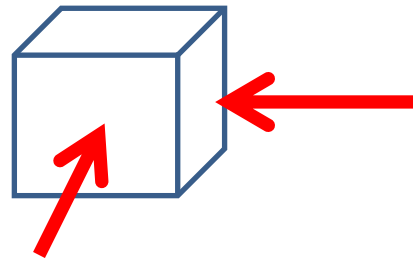
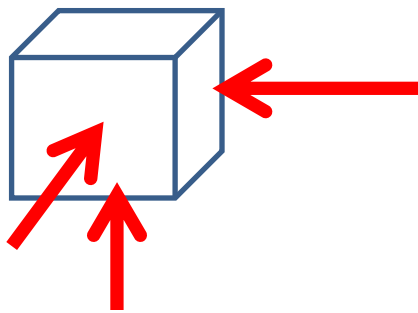
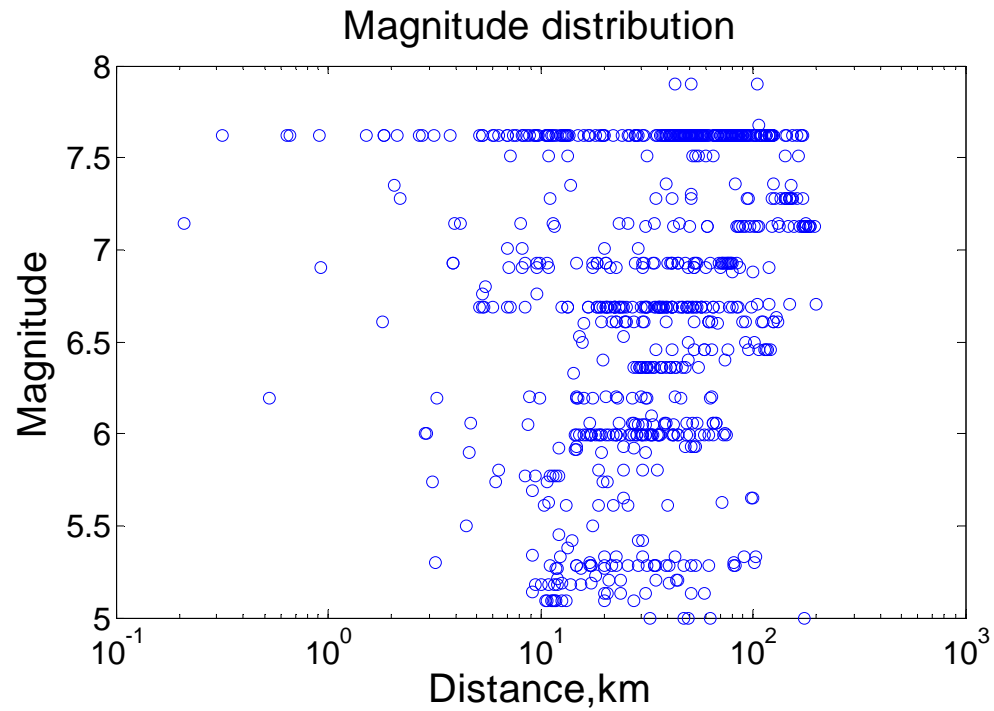


*Pore pressure ratio  $r_u \rightarrow 1$ : liquefaction*

# Port Island Simulation

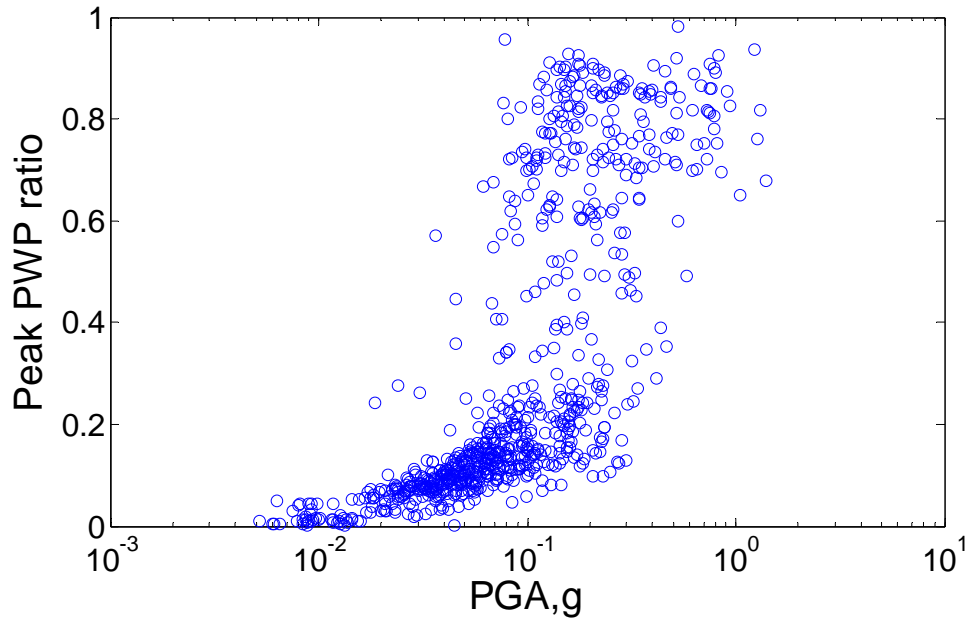


# GM IM and PWP Generation

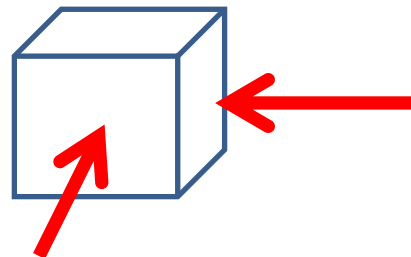
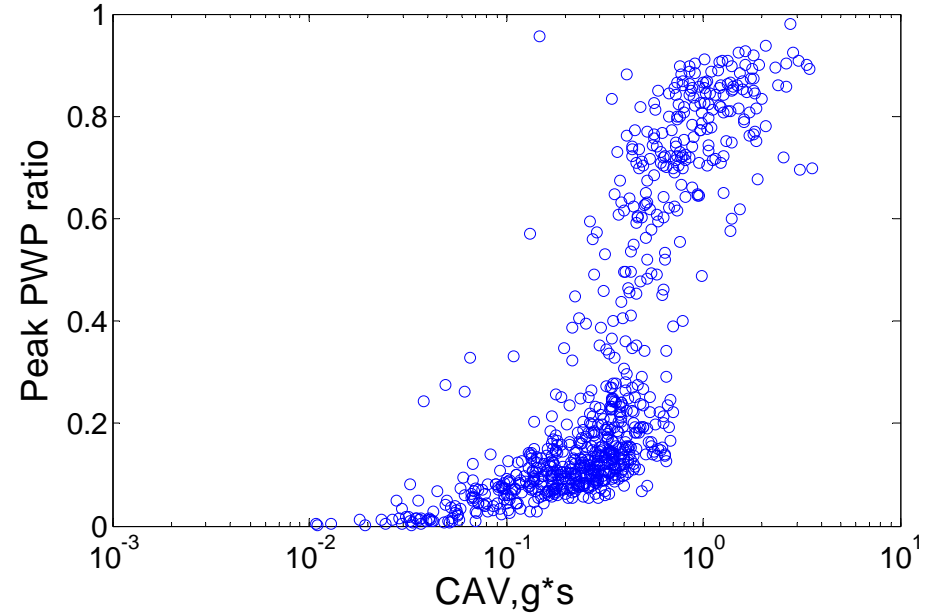


# GM IM and PWP Generation

PGA - Peak PWP ratio

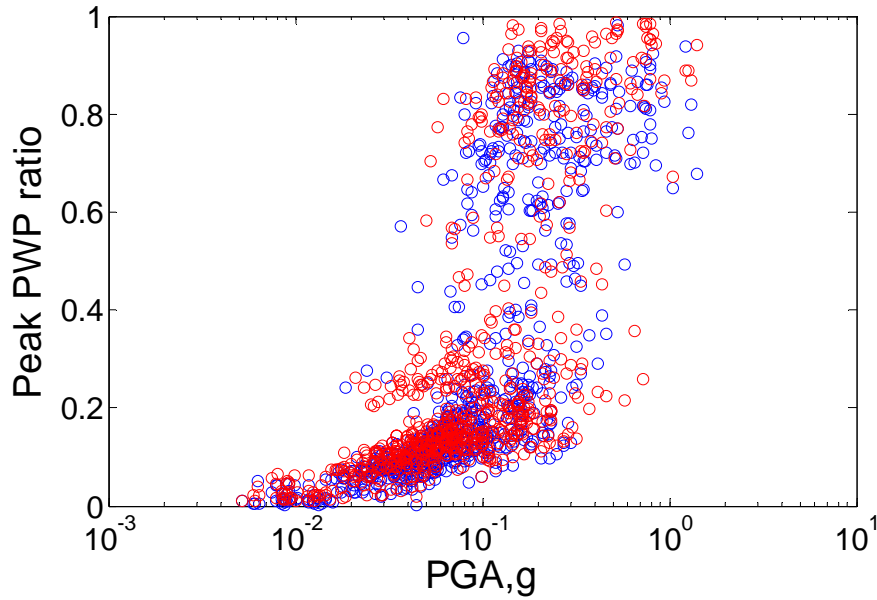


CAV - Peak PWP ratio

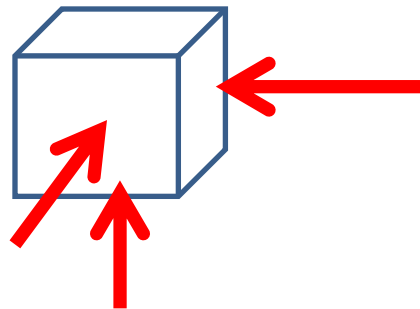
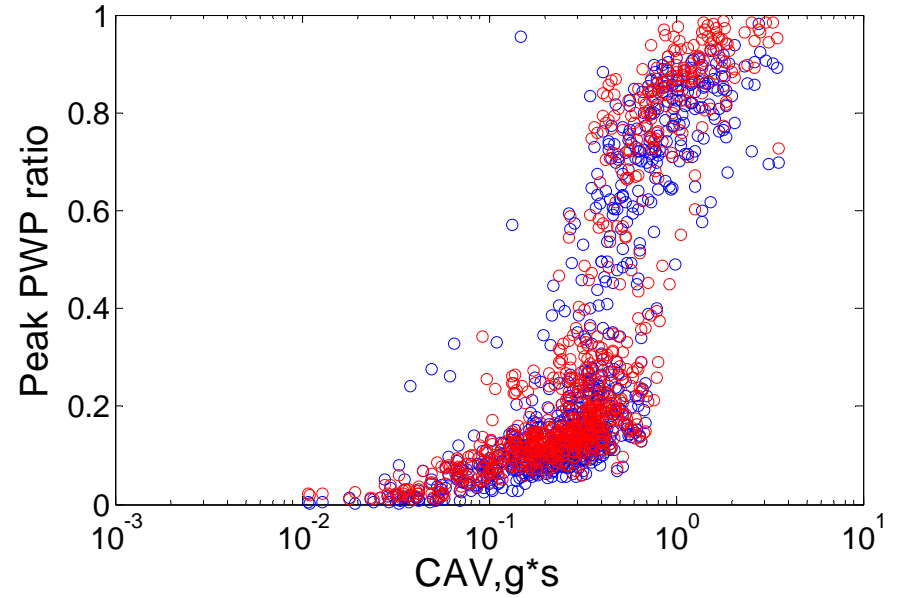


# GM IM and PWP Generation

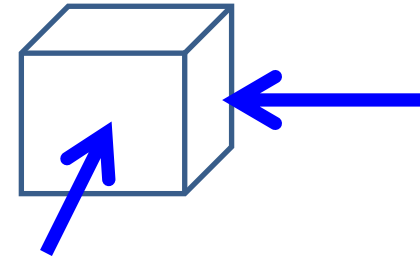
PGA - Peak PWP ratio Correlation



CAV - Peak PWP ratio

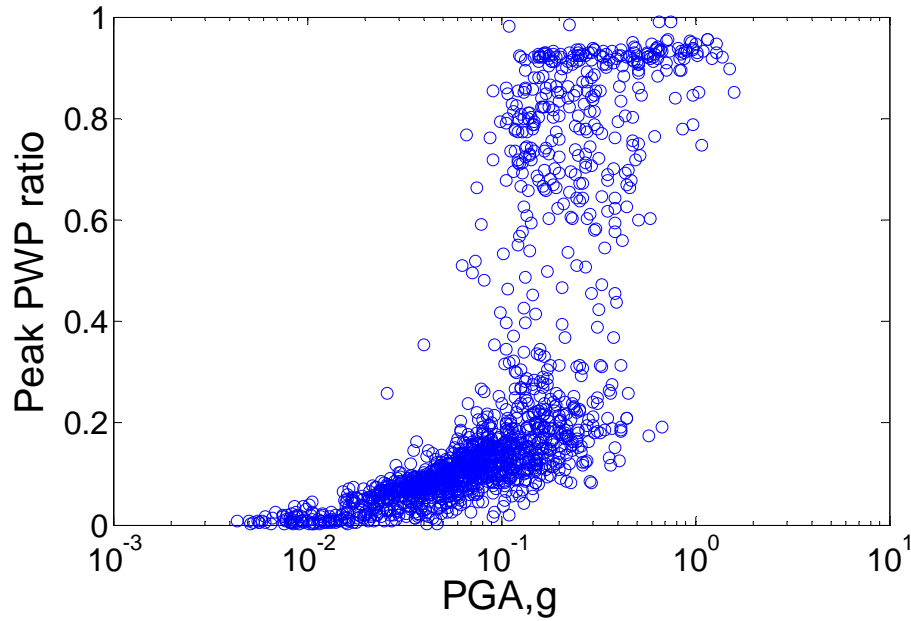


Comparison

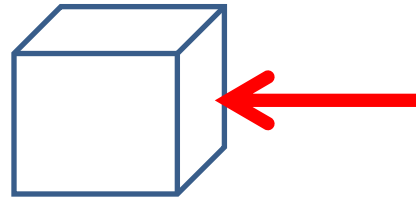
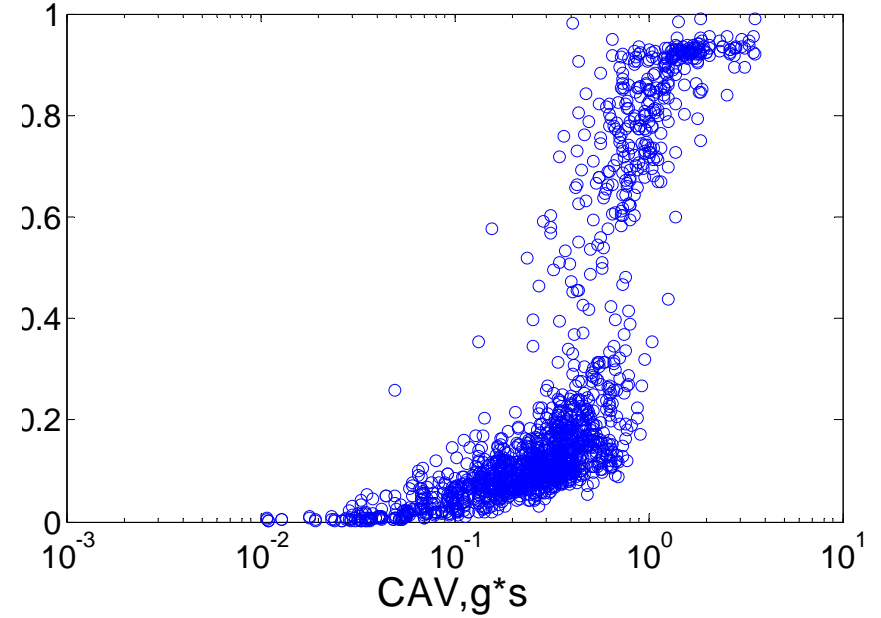


# GM IM and PWP Generation

PGA - Peak PWP ratio Correlation



CAV - Peak PWP ratio





# Conclusion

- Bounding Surface Hypo-plasticity is capable of capturing the features of complex soil behaviors
- Statistically, the vertical component of the ground motion has little effect on the soil's liquefaction behavior
- CAV seems to be a better ground motion IM in predicting the PWP generation
- Other IM may be considered for the ground motion characterization in the future, like soil resistance, soil thickness, and duration etc.



**Thank you!**