Application of PM4Sand and PM4Silt Models to Study Effect of Spatial Variability in Liquefiable Soil

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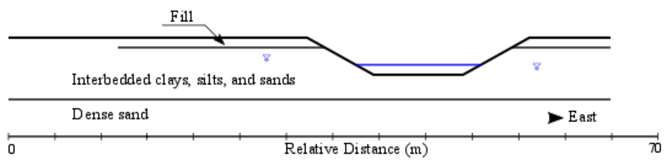
Introduction:

PM4Sand and PM4Silt are two constitutive models for earthquake engineering applications proposed by Boulanger and Ziotopoulou (2017, 2018) to represent sand-like and clay(silt)-like soil behaviors (Boulanger and Idriss, 2006), respectively. The models are originally implemented in FLAC and have been implemented in OpenSees by the authors. In this study, these two models were used to study a zero-displacement lateral spread case, Çark Canal site, located at Adapazari, Turkey. After the 1999 Kocaeli earthquake, no surface evidence of ground displacement near the canal was observed, despite multiple linear regression procedures predicted 0.0 to 2.6 m of lateral displacements (Youd et al. 2009). The over-estimation is thought to be related to interbedded deposits of sand, silt, and clay encountered at this site. This site has been studied by Boulanger et al. (2019) using FLAC. This study tried to take a different approach to investigate the effect of spatial variability within the interbedded layer using OpenSees. Uncertainty in input motions and sensitivity in hydraulic conductivity were also investigated.

Site Conditions:

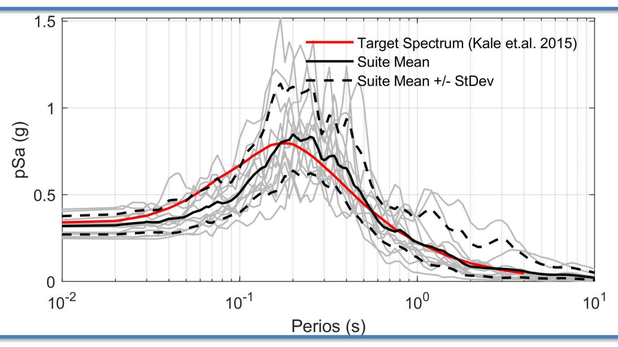
The surficial fill (~1 m) is underlain by a layer of interbedded sands, silts, and clays (~6 m). Beneath this layer is a stratum of dense sands. The ground water table depth likely was between 2.6 and 3.3 m (Youd et al. 2009).



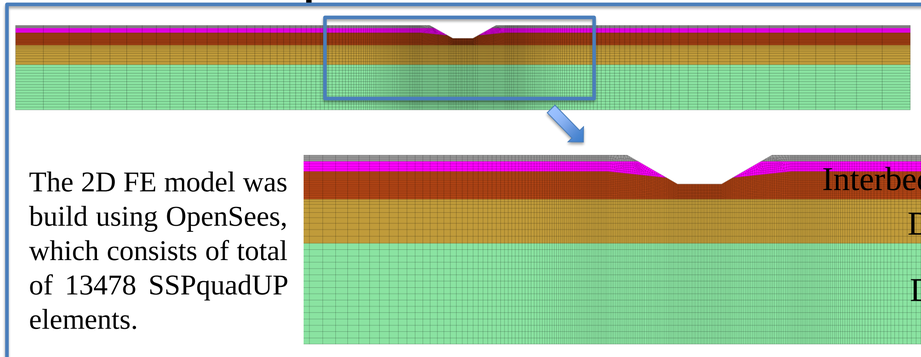
Cross section of Çark Canal site (data from Youd et al. 2009)

Input Motions:

During Kocaeli Earthquake, a motion was recorded at the Sakarya station located 4 km away from the site. In this study, this motion was complemented with additional ten motions selected based on a local ground motion predictive model for Turkey developed by Kale et al. (2015).



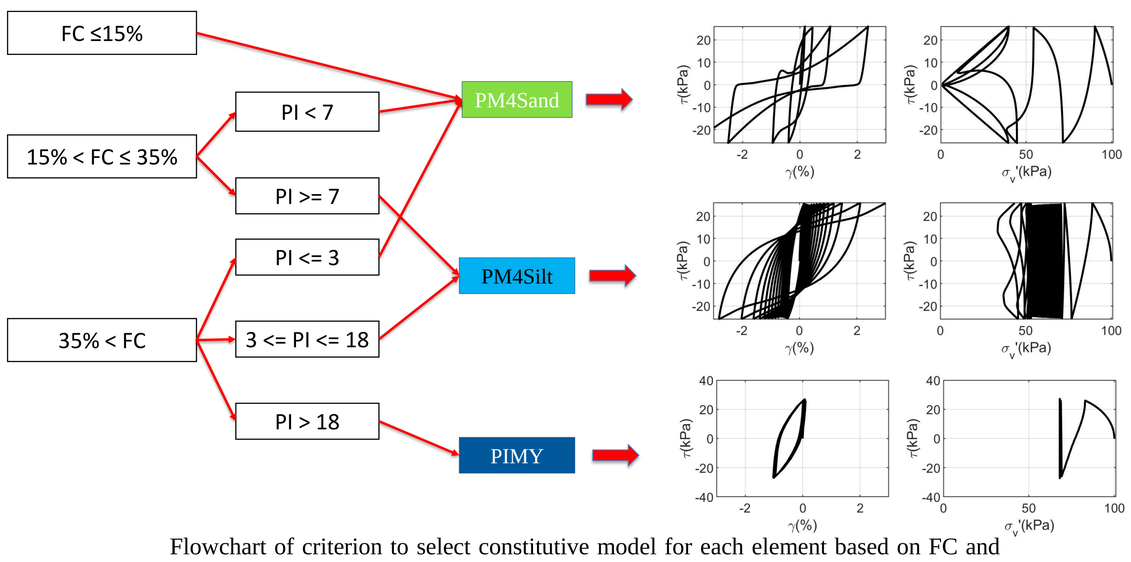
FE Model Development:



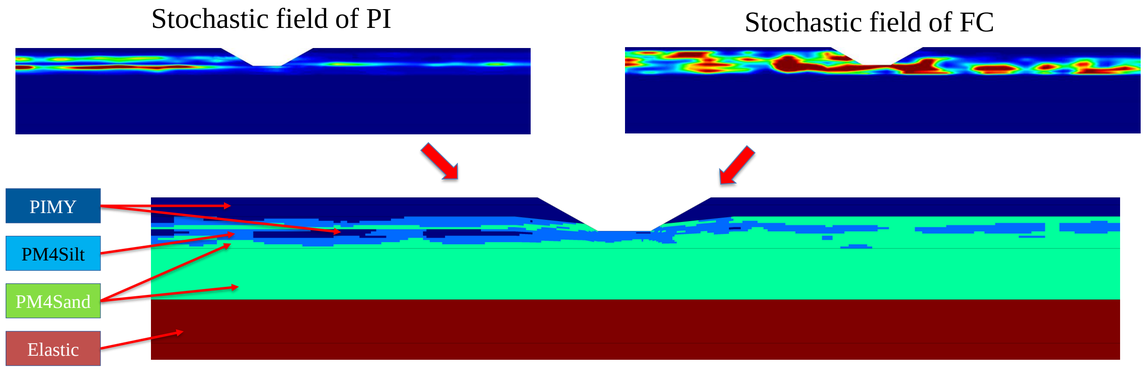
The 2D FE model was build using OpenSees, which consists of total of 13478 SSPquadUP elements.

Constitutive Models:

The layers above ground water table were modeled using PressureIndependentMultiYield (PIMY) model. The interbedded layer was modeled using PM4Sand, PM4Silt and PIMY models based on randomly generated Fines Content (FC) and Plastic Index (PI) stochastic fields. The mean value of these fields were interpreted from available SPT data. The criterion that defines the type of soil model is presented below:

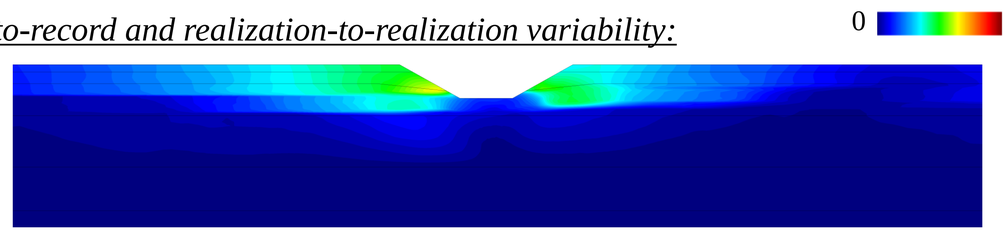


Flowchart of criterion to select constitutive model for each element based on FC and PI; and typical behavior of each model under undrained cyclic simple shear test.

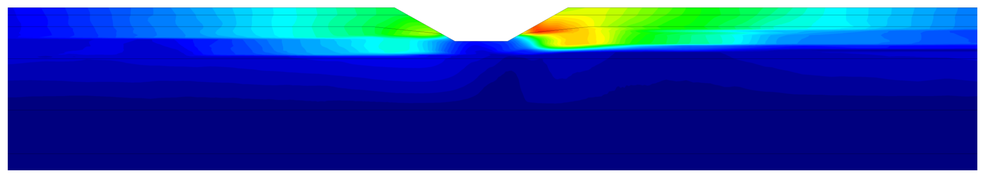


Preliminary Results:

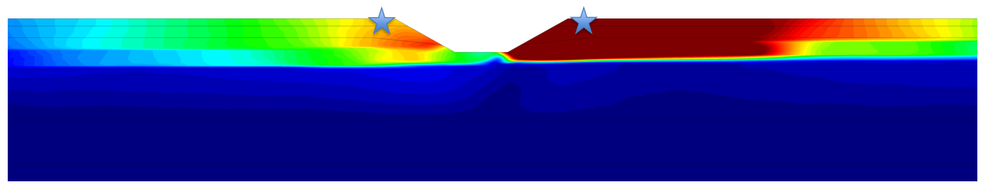
Record-to-record and realization-to-realization variability:



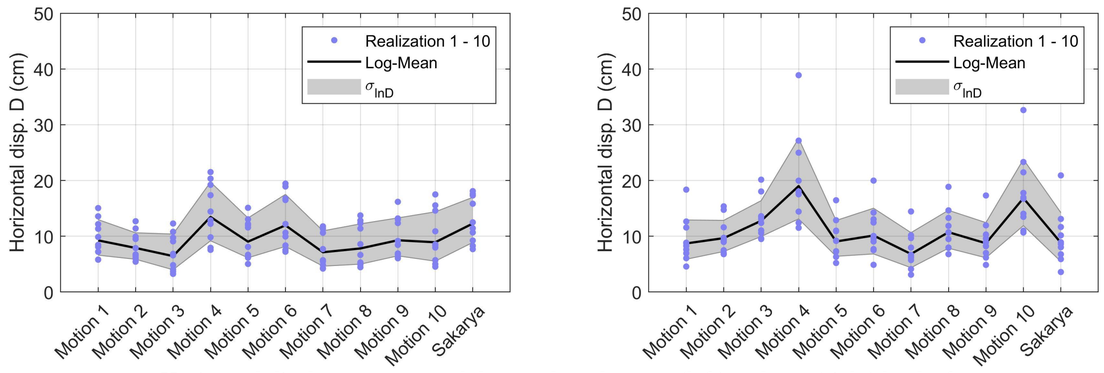
Contours of nodal displacement for **realization 1** with **Sakarya motion**



Contours of nodal displacement for **realization 1** with **motion 4**



Contour of nodal displacement for **realization 7** with **motion 4**



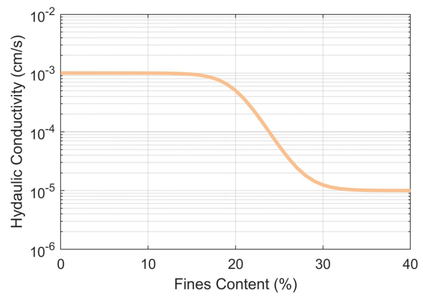
Horizontal displacement toward the canal on the west (left) and east (right) banks from all realizations (lines) and motions (x axis).

Sensitivity Study on Hydraulic Conductivity:

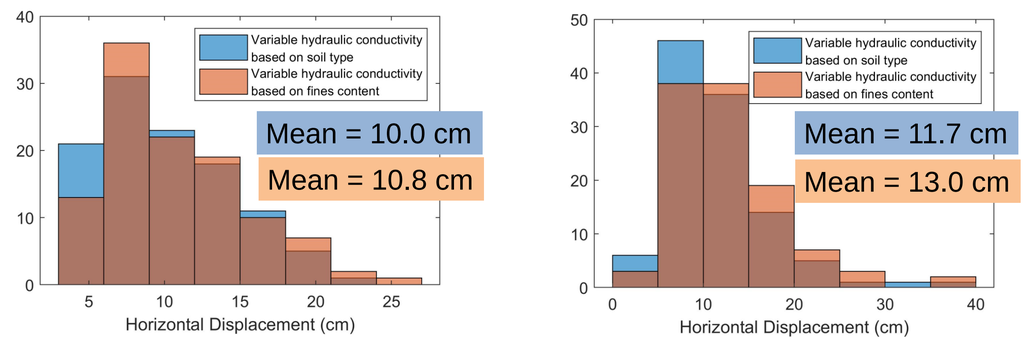
1. **Variable hydraulic conductivity based on soil type**
2. **Variable hydraulic conductivity based on fines content**

Change of hydraulic conductivity based on soil type.

Material Model	Hydraulic Conductivity (cm/s)
PM4Sand	10^{-3}
PM4Silt	10^{-4}
PIMY	10^{-5}



Change of hydraulic conductivity based on fines content. This relationship was based on a study conducted by Gomez et al. (2014) on effects of fines content on hydraulic conductivity of granular structural backfill.



Comparison of horizontal displacement of west (left) and east (right) banks obtained from simulations using variable hydraulic conductivity based on soil type (blue) and fines content (orange).

References:

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