Numerical Modeling of Liquefaction Effects

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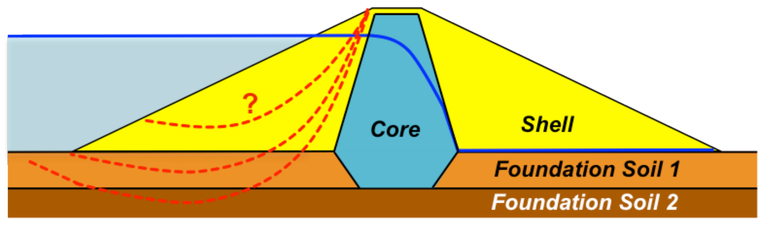
Motivation

The seismic deformation analysis of a geotechnical structure like an earth dam may need to account for strata or zones of sand ranging from very loose to dense states, under a wide range of confining stresses, initial static shear stresses, drainage conditions, and loading conditions.



The engineering effort is significantly reduced if the constitutive model utilized can reasonably approximate the predicted stress-strain behaviors under all these different conditions.

PM4Sand (Boulanger & Ziotopoulou 2012)

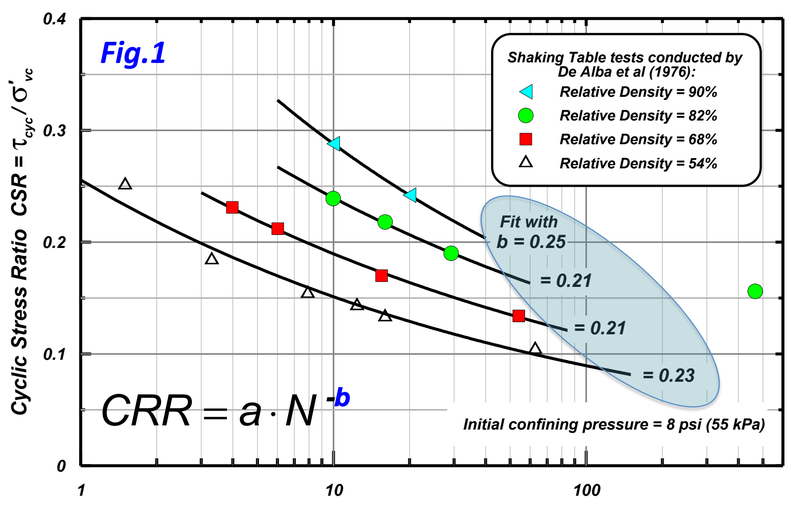
It follows the basic framework of the critical-state compatible, stress-ratio controlled, bounding surface plasticity model of Dafalias & Manzari (2004). It was developed aiming at having the ability to:

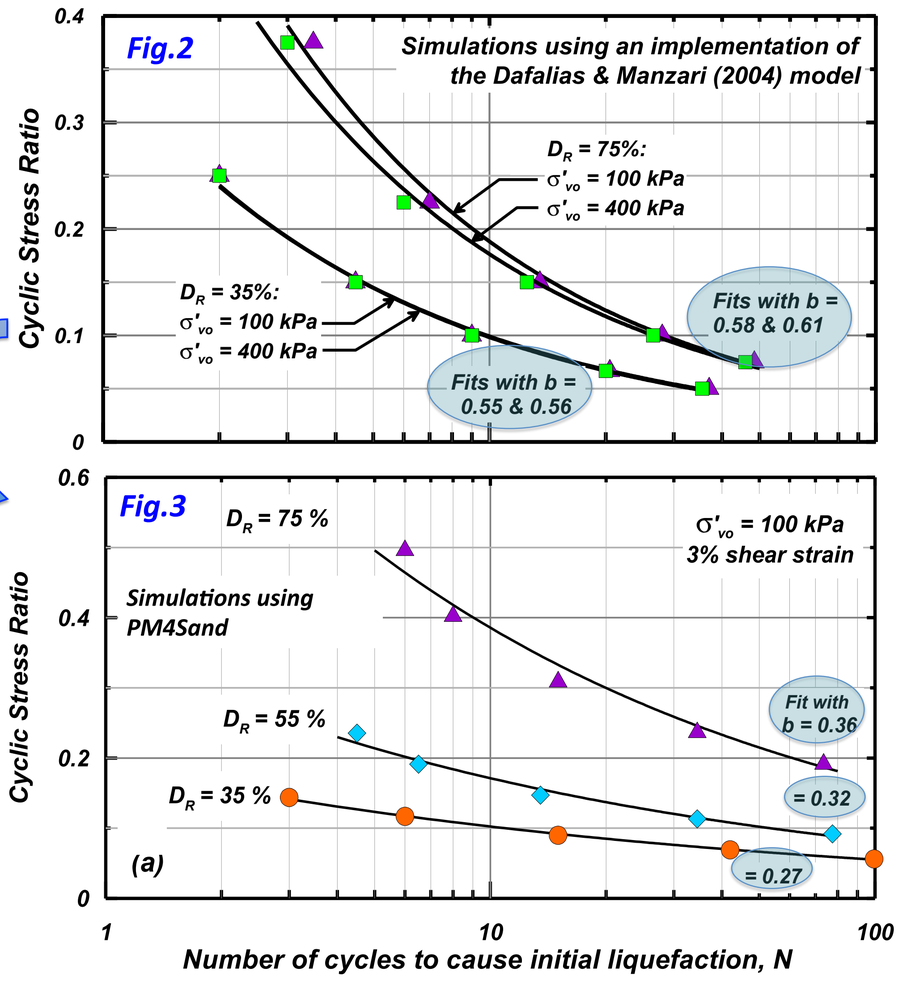
(1) Reasonably approximate the empirical correlations commonly used in U.S. practice, which reflects large bodies of experimental data;
(2) Calibrate the model with a reasonable amount of effort.

This poster illustrates changes relative to the D&M (2004) model to improve its ability to simulate the experimentally-observed effects of: **(a)** cyclic loading duration, and **(b)** overburden stress. Other factors and effects examined in Boulanger & Ziotopoulou (2012).

Cyclic Resistance Ratio vs. Number of Cycles

Numerous tests on sands show cyclic resistance ratio (CRR) vs. Number of Cycles plots can be fit with a power relationship, with the exponent b typically ranging from 0.2 to 0.35.

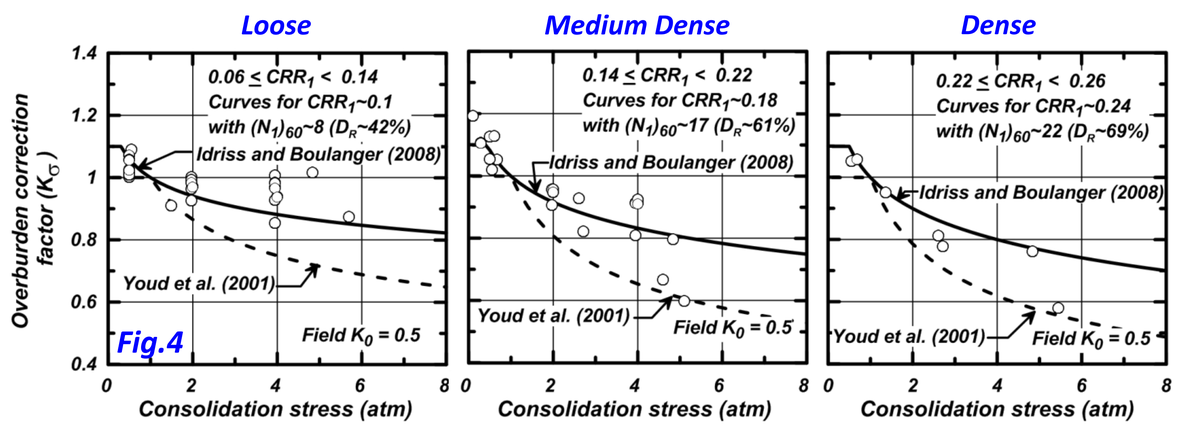




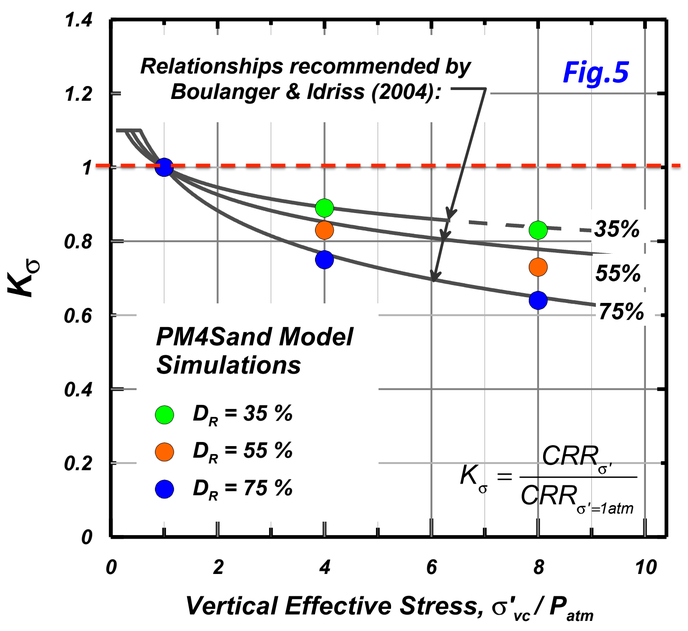
Slope **b** is controlled by equations for **D** (dilatancy) and $\mathbf{K_p}$ (plastic modulus)

Overburden Effects

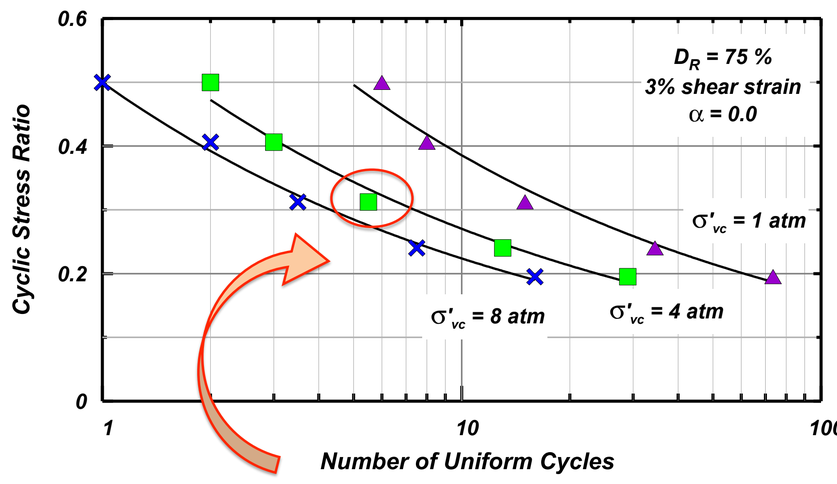
Compiled data for clean sands show how CRR decreases with overburden stress, with the effect being stronger as relative density increases:

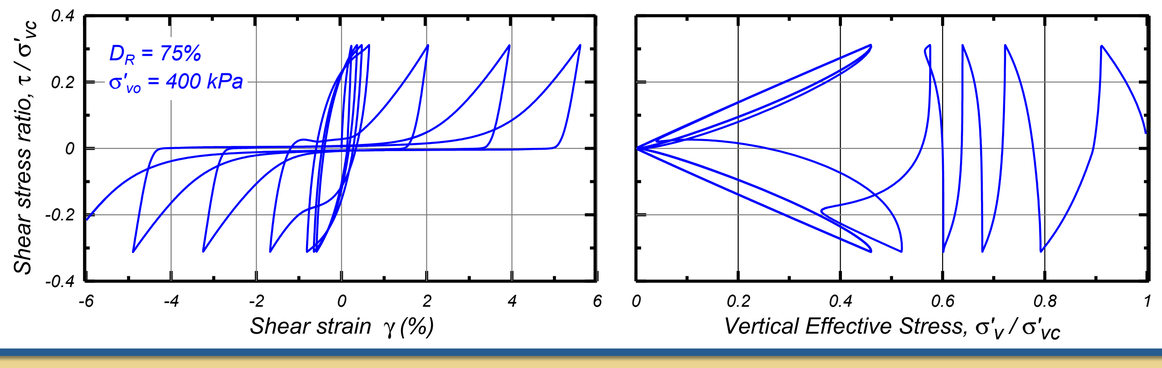


(Montgomery et al. 2013)



The original D&M (2004) model (Fig.2) yielded a $K_\sigma \approx 1$. In PM4Sand, this was captured through modification of the functional form of the D relationship for contractive conditions: it was recast in terms of the relative state parameter such that by increasing the confinement, the relative state is increased and the material becomes more contractive.





Summary

- Components of PM4Sand were modified to improve the ability to simulate the experimentally-observed effects of cyclic loading duration and effective overburden stress on CRR. Examples of simulation results were presented to illustrate the improvements in simulated responses. The complete model can be found in Boulanger & Ziotopoulou (2012).
- Currently working with Monika Maharjan and Professor A. Takahashi from Tokyo Tech as part of a CUEE-PEER effort to evaluate the response of various constitutive models under a static shear stress ratio α.

Acknowledgements

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