Research Project Highlight

Implementation and Validation of PM4Sand in OpenSees

Project #1133-NCTRAP

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Start-End Dates:
12/15/2017-12/16/2018

Abstract
Soil liquefaction is a major cause of damage during earthquakes. To predict the behavior of liquefiable soils, advanced constitutive models are necessary. Over the last decade several advanced models for liquefiable soils have been proposed. Among them PM4Sand is a sand plasticity model for earthquake engineering applications recently proposed by Boulanger and Ziotopoulou [2015]. This 2D plane-strain model follows the plasticity framework proposed by Dafalias and Manzari [2004] and is based on bounding surface plasticity and critical state soil mechanics concepts. The model has been calibrated at an element level to approximately simulate general trends observed in the field and empirical correlations commonly used in geotechnical earthquake engineering practice. By changing three primary input parameters, the user can achieve reasonable approximations of desired behavior including pore pressure generation and dissipation, limiting strains, and cyclic mobility. Using secondary parameters (18 in total and optional) the user can further fine-tune the response, although this is not necessary. Since its introduction, the PM4Sand model has drawn wide attention of geotechnical engineers and researchers due to its relatively easy calibration process and good agreement with field observations. The UW Computational Geomechanics group has implemented this model at an element level using a "container" constitutive driver specially designed to test constitutive models. Preliminary results using conventional stress paths are very promising. However, challenges related to model stability and efficiency and implementation into OpenSees require further work. The goal of this proposal is to implement PM4Sand in OpenSees and validate it using existing experimental results for 2D and 3D boundary value problems.

Deliverables
The project tasks include:

1. Implementing PM4Sand V3 in OpenSees: This would make PM4Sand model available in OpenSees and produce comparable results to the model's current implementation in the commercial tool FLAC.

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2. With the implemented model, we propose to validate it using experimental results, including soil elements tests and centrifuge tests. Finally we expect to provide validated and improved design recommendations related to the use of the model in practice.

A PEER report, a conference paper, and a journal paper are expected as part of this project.

Research Impact

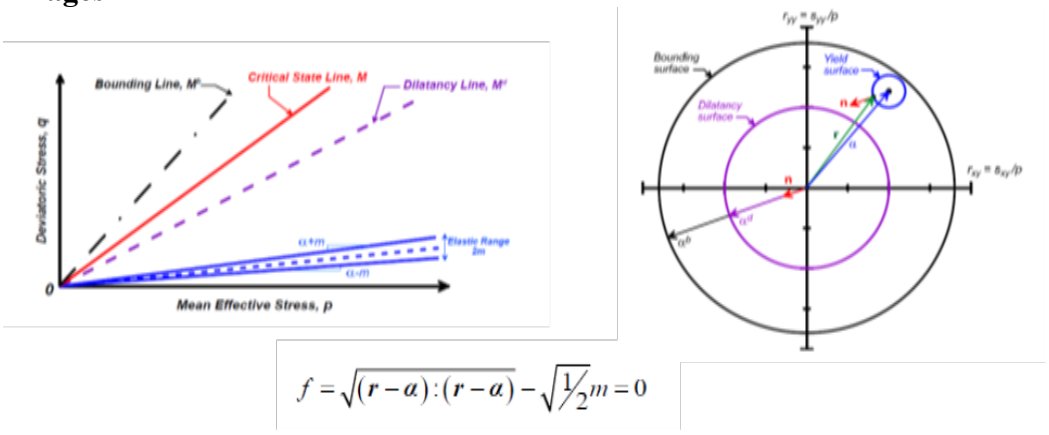
Prediction of the behavior of liquefiable soils is important for design. Key to accomplish this goal is to have an advanced model. Existing models usually require many input parameters and those parameters usually require a great effort to calibrate. The PM4Sand model was introduced to provide relatively good approximation and easy calibration process. An implemented PM4Sand model in OpenSees would provide a reliable and free tool to simulate behavior of liquefiable soils. This tool can be both used by researchers and engineers in practice.

References

Dafalias Y.F., Manzari M.T. (2004). Simple plasticity sand model accounting for fabric change effects, ASCE, *J. Eng. Mech*., 130(6), doi.org/10.1061/(ASCE)0733-9399(2004)130:6(622).

Boulanger R.W., Ziotopoulou K. (2015). PM4Sand (Version 3): A sand plasticity model for earthquake engineering applications, *Report No. UCD/CGM-15/01*, Center for Geotechnical Modeling, Department of Civil and Environmental Engineering, University of California, Davis, CA, 112 pgs.

Project Images



PM4Sand model definition: bounding, dilatancy, and yield surfaces in (a) *qp* space and (b) deviatoric space.

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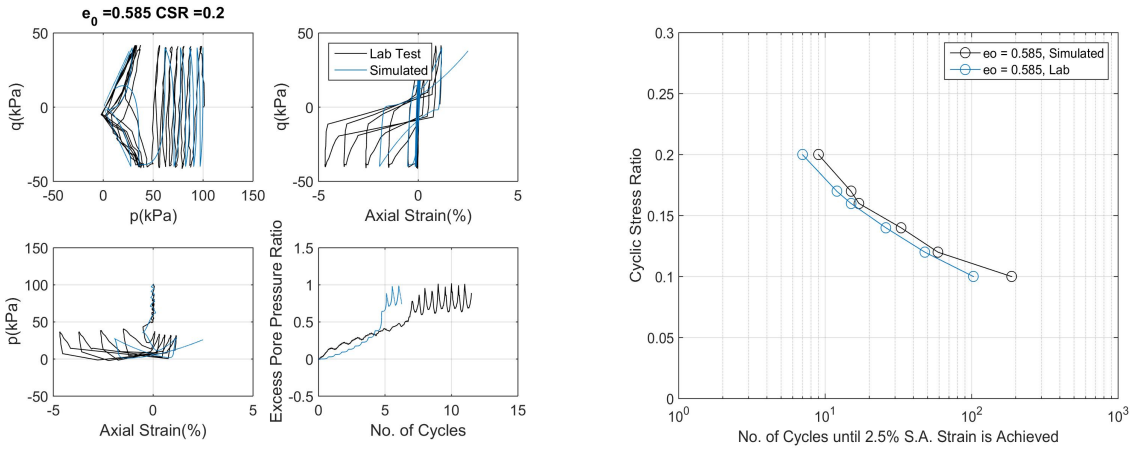

(a) (b)

PM4Sand model calibration: (a) stress path, stress strain, mean stress, and pore water pressure and (b) cyclic stress ratio versus # of cycles to liquefaction

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