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Simulation of Nonlinear Seismic Response of Soft Clays at Medium Strains

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Introduction

Site response analysis predicts the response of a soil profile to ground motions originating from the bedrock. Such analysis is necessary for seismic hazard analysis.

Site Response Analysis Methods:
1. Equivalent Linear Method (ELM)
2. Nonlinear Effective Stress Method (NESM)

In high intensity excitations that lead to shear strains over 1% the ELM cannot be used and only the NESM can properly model the nonlinear response of the soil.

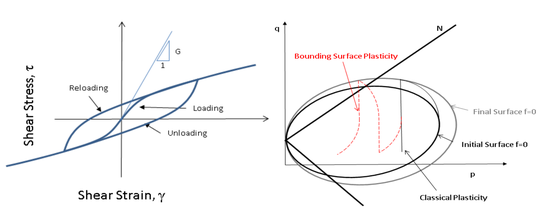
Research Objective

In this work the nonlinear seismic response of soft clay in medium strains is modeled using an advanced elastoplastic constitutive model. The model is formulated in the framework of bounding surface plasticity and uses a Ramberg-Osgood type formulation to capture the small strain response of clays during cyclic loading. The proposed model is validated against the results of a centrifuge experiment.

SANICLAY-SSBS

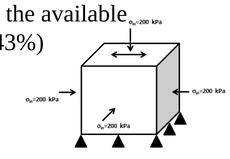
SANICLAY-SSBS is a plasticity model based on the original SANICLAY model which was developed to capture the behavior of anisotropic clayey soils in monotonic loading conditions.

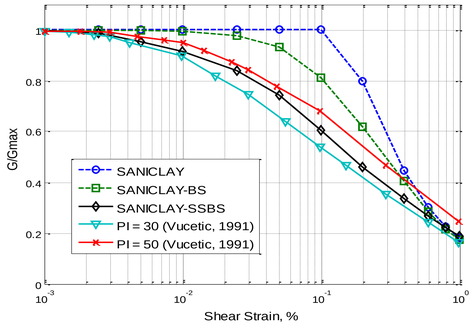
Key Features:
1. Small strain response is modeled by introducing nonlinearity in the elastic response.
2. Radial mapping bounding surface plasticity is used to capture the cyclic behavior of clay.
3. A damage parameter is introduced to model the reduction in material strength as a function of the plastic deviatoric strain.



Model Calibration

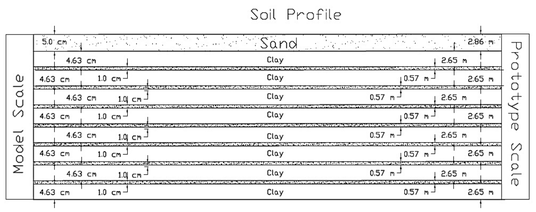
The constitutive model parameters are usually calibrated by using the results of laboratory-scale element tests. For the clayey soil used in this work (Bay Mud), the experimental data available in literature were used as supplemental information. Some key aspects of the calibration effort are as follows:
- Direct Simple Shear Tests were used in the calibration.
- All tests were strain controlled.
- The simulations were compared with the available experimental data on Bay-Mud (PI=43%)

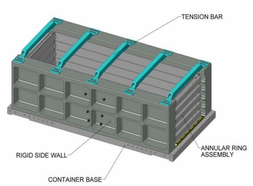




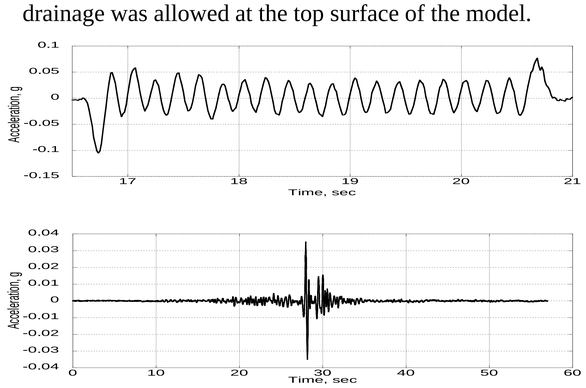
Site Response Analysis

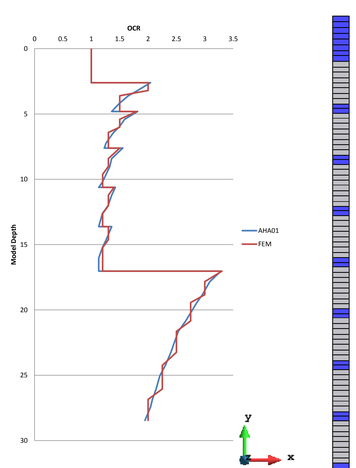
Centrifuge Experiment:
- A series of centrifuge experiments were conducted at UC Davis to model the site response of soft clay over a wide range of shear strains. (Afacan et al., 2013).
- The centrifuge model consisted of lightly over-consolidated layers of San Francisco Bay Mud.
- Centrifuge was Spun to 57.2 g before the shaking phase.
- Hinge-plate model container (HPC) was used to model free-field conditions





Finite Element Modeling:
Fully coupled dynamic effective stress analyses were performed. Some key elements of the analysis are as follows:
- Brick-UP Elements were used.
- The finite element model was constrained in the direction perpendicular to the plane of shaking.
- The lateral boundaries were tied in the horizontal direction to simulate the free-field condition
- The nodes on the bottom boundary were constrained and free drainage was allowed at the top surface of the model.

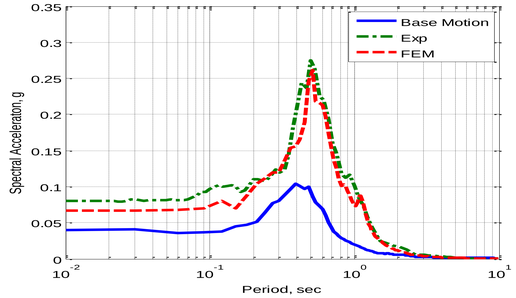




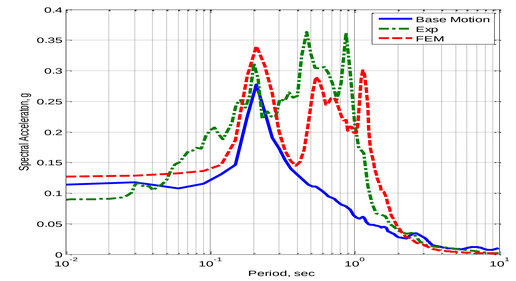
Simulation Results

The response spectra of the horizontal accelerations at the top surface were computed to assess the ability of the model to capture strain softening of the soil.

Input Motion 1:



Input Motion 2:



Concluding Remarks

- An elastoplastic constitutive model was implemented in a public domain research finite element code for earthquake engineering simulations (OpenSEES)
- A series of centrifuge experiments on lightly over-consolidated soft clays are simulated. The preliminary results are promising.
- Further simulations are ongoing to further validate the model and examine its capabilities.

Acknowledgement

The work presented here was supported by the National Science Foundation Geomechanics and Geohazard programs.

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