Research Project Highlight

Prediction of Seismic Compression of Unsaturated Backfills

TSRP Topic - Geotechnical Engineering, Estimation of Permanent Deformations – G2

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Start-End Dates:
2/15/2021-2/14/2022

Abstract

This study will develop, implement and validate a new effective stress-based elasto-plastic constitutive model to predict the evolution in seismic compression of unsaturated backfill soils in transportation systems (e.g., highway embankments, bridge abutments, earth retention systems, etc.). This study seeks to depart from commonly-used semi-empirical approaches for seismic compression prediction by developing an effective stress-based elasto-plastic constitutive model that can capture the impacts of initial degree of saturation and density on the deformation response. Although the model development will build upon concepts from established elasto-plastic constitutive models (e.g., UBCSand), new developments will include a poro-mechanics approach to consider the generation in pore air and pore water pressures during cyclic shearing, an approach to consider changes in the shape of the soil-water retention curve (SWRC) on the effective stress state, and an approach to consider the coupled evolution in soil dynamic properties with effective stress and volumetric contraction. Interaction between each of these new developments is also expected in the model. Data from cyclic simple shear tests on unsaturated sands under different densities will be used to calibrate the new constitutive model in terms of the evolution in volumetric strain, degree of saturation, pore air and pore water pressures, matric suction, effective stress, and dynamic soil properties with cycles of shearing. This study will focus on unsaturated granular backfill soils in the funicular saturation regime (i.e., initial degrees of saturation between 20% and 60%), where the largest volumetric contractions are expected during earthquake loading but liquefaction is not expected.

Deliverables

A PEER report and several conference and journal papers describing the model theory, validation of the model against results from cyclic simple shear tests on sands having different initial densities and

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degrees of saturation, and model assessment by prediction of the seismic compression of a soil layer in a transportation application.

Research Impact

Seismic compression is defined as the accrual of permanent contractive volumetric strains in soils during earthquakes and has been recognized as a major cause of seismically-induced damage in earth structures. Although backfill soils are typically in an initially dense state and are expected to have minimal settlement under static or traffic loading, they may still experience volumetric contraction during earthquakes. Even small backfill settlements can have a negative impact on the functionality of transportation systems and can lead to high repair costs. Most approaches for seismic compression prediction are semi-empirical, which have been shown to result in variable predictions, and do not necessarily consider the impacts of unsaturated conditions. Accurate predictions are challenging for unsaturated soils, as the degree of saturation and matric suction (the difference between pore air and water pressures) will change during volumetric contraction and will affect the effective stress and dynamic soil properties (e.g., the shear modulus, damping ratio). Generation of pore air and water pressures depend on the bulk fluid modulus and on the initial degree of saturation in the soil.

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Project Images

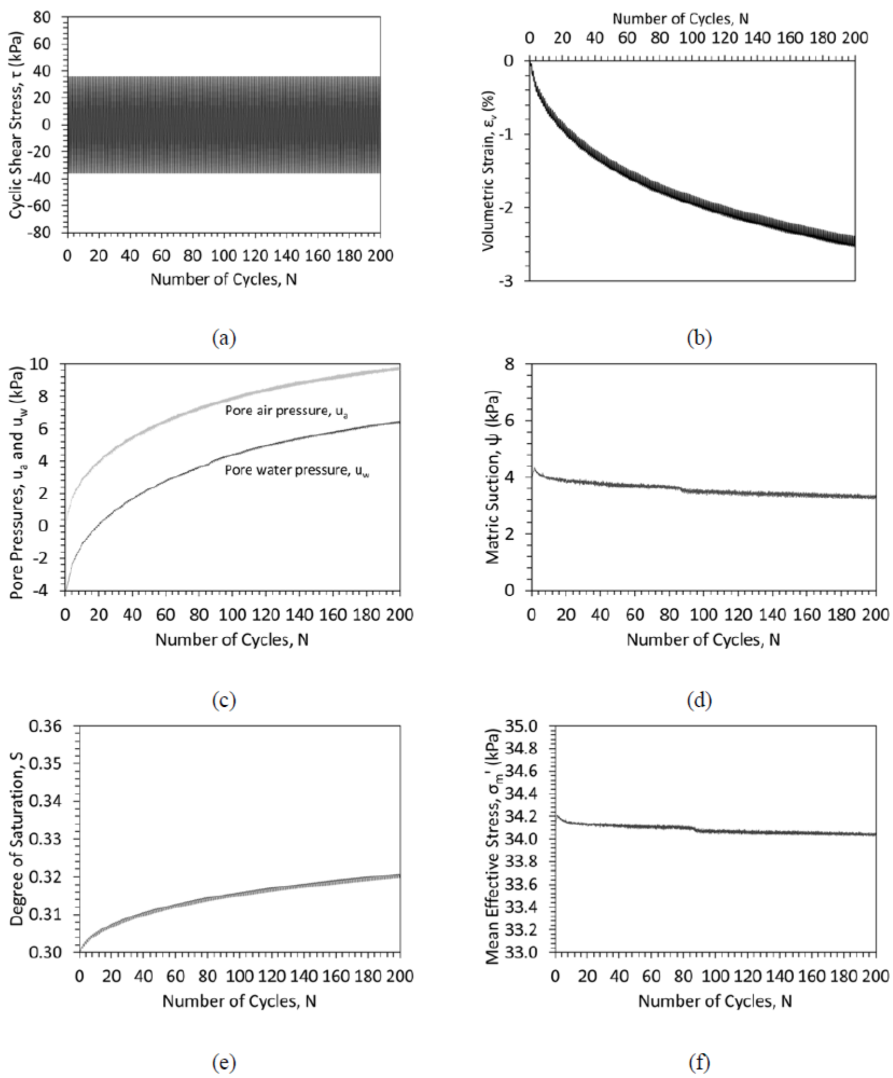

Figure 1: Preliminary simulations of seismic compression of unsaturated sand having an initial degree of saturation of 0.4 highlighting evaluation in key hydro-mechanical variables: (a) Applied sinusoidal cyclic shear stresses; (b) Calculated volumetric strain; (c) Calculated pore air and water pressure; (d) Calculated matric suction; (e) Calculated degree of saturation; (f) Calculated mean effective stress

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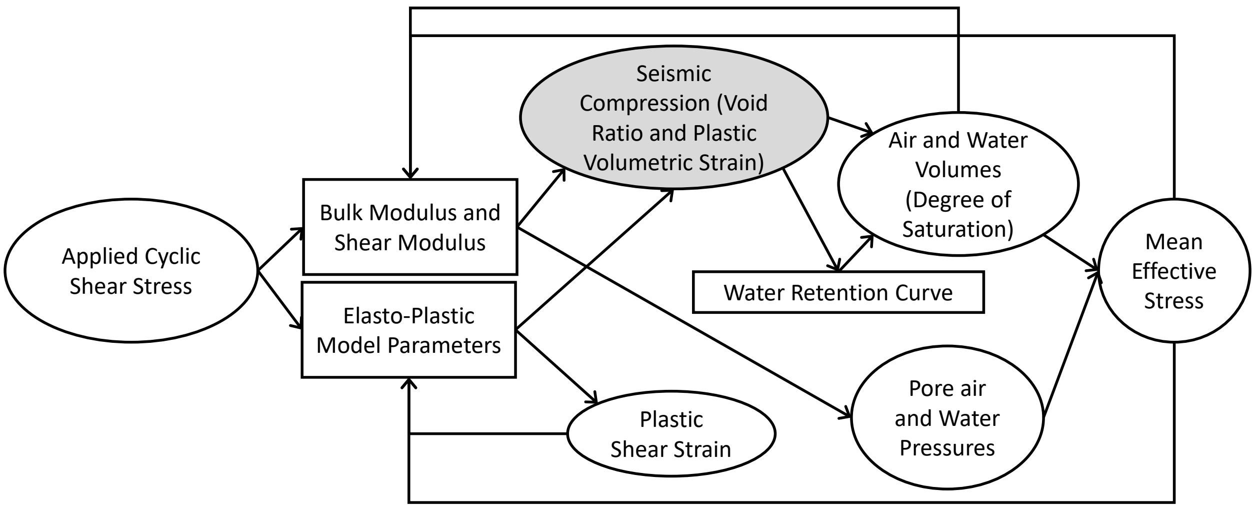

Figure 2: Coupling between hydro-mechanical parameters in prediction of the seismic compression of unsaturated soils