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Liquefaction Assessment and Mitigation in Interbedded and Variable Deposits

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Abstract:

The existing engineering methodologies for mitigation of seismic liquefaction rely on free-field triggering in uniformly layered granular soil deposits. These methods do not evaluate performance, and they routinely ignore cross-layer interactions in realistically stratified deposits as well as soil-structure interaction (SSI). In this presentation, through an experimental-numerical-statistical study, we show that these methods are unreliable, jeopardizing our ability to assess and mitigate liquefaction vulnerability of our sites and structures. We performed more than 19,000 and 4,000 fully-coupled, 3D, dynamic finite element analyses of free-field site response and seismic SSI, respectively, in OpenSees. These simulations were calibrated and validated with element and centrifuge experiments. The datasets were designed using quasi-Monte Carlo sampling, to capture a wide range of critical parameters, including stratigraphic variability, soil types and properties, foundation and structure properties, mitigation mechanisms and geometry using dense granular columns (DGCs), and ground motion characteristics. The influence of stratigraphic variability on mitigation efficacy is shown to be significant in terms of foundation settlement, tilt, spectral accelerations, and flexural drift. Physics-informed, random forest, machine learning (ML) is subsequently used to identify the key predictors and models for free-field ejecta potential in highly nonlinear and stratified soil profiles, as well as mitigated/non-mitigated ratios of foundation's vertical and lateral displacement and foundation and roof peak accelerations. The models show strong predictive performance on independent test sets, significantly reducing uncertainty and outperforming traditional regression techniques. Combining advanced numerical simulations and machine learning enables a new approach to liquefaction mitigation, one that accounts for seismic soil-structure interaction in realistic sites and structures.