Research Project Highlight

A System-Level Study to Evaluate the Role of Soil Gradation on Seismically Induced Embankment Deformations

TSRP Topic – Estimation of Permanent Deformations – G2

Principal Investigator
Jason T. DeJong, Professor, UC Davis

Start-End Dates:
1/15/21-1/14/22

Abstract
The overarching goal is to realize a step-change in the prediction accuracy of earthquake induced embankment deformations that will result in increased societal safety and significant reductions in economic impacts. More specifically, the project objectives are to (1) evaluate how and why the seismic deformations of embankments constructed of well graded soils, as is typical in practice, can be significantly less than for embankments constructed of poorly graded soils, which is the basis for industry standard analyses, and (2) develop guidance on how to incorporate the project results into nonlinear deformation analyses (NDA) so that excessive and unknown conservatism does not continue to be incorporated into engineering analyses of earthen embankments. The project is planned around a 9m radius centrifuge test comprised of two side-by-side embankments constructed with a soil representative of field embankment conditions and prepared at relative densities of 40% and 65%. High speed cameras (HSC) using Particle Image Velocimetry (PIV), LiDAR, and accelerometers will be used for detailed deformation analysis. All methods, data, and personnel capabilities that have been developed for an ongoing NSF project (CMMI #1916152) will be leveraged to accelerate productivity, magnify impact, and bridge the knowledge generated from the NSF project to conditions routinely present in constructed embankments.

Deliverables
A PEER report, archived dataset, and conference and journal papers describing the testing program, data analyzed, project results, results from prediction exercise and workshop, and guidance for practitioners on how the effects of soil gradation can be considered.

Research Impact
Industry NDA analyses to predict the seismic induced deformations are based, at its origin, on constitutive models developed for and calibrated to poorly graded sands. Knowledge on how soil properties and behaviors change with gradation is severely limited (even though gradation is always known), and hence routine practice defaults to the (incorrect) assumption that well graded soils behave

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similarly to poorly graded sands. The NSF leveraged results (in Project Image below) show that embankment deformations comprised of well graded soils can be 20% of poorly graded sands when subject to the same loading conditions. This implies that current industry practice may be excessively conservative. Large embankment dams routinely undergo re-evaluation, and due to recent increases in seismic hazard estimates, it often leads to remediation measures, typically at the cost of $50-$500M per embankment. If the project hypothesis is true, and well-graded soils deform only a fraction of poorly graded soils, retrofit measures may not be necessary or could be more modest in many cases, which could lead to significant savings for dam owners (and rate payers).

Project Image

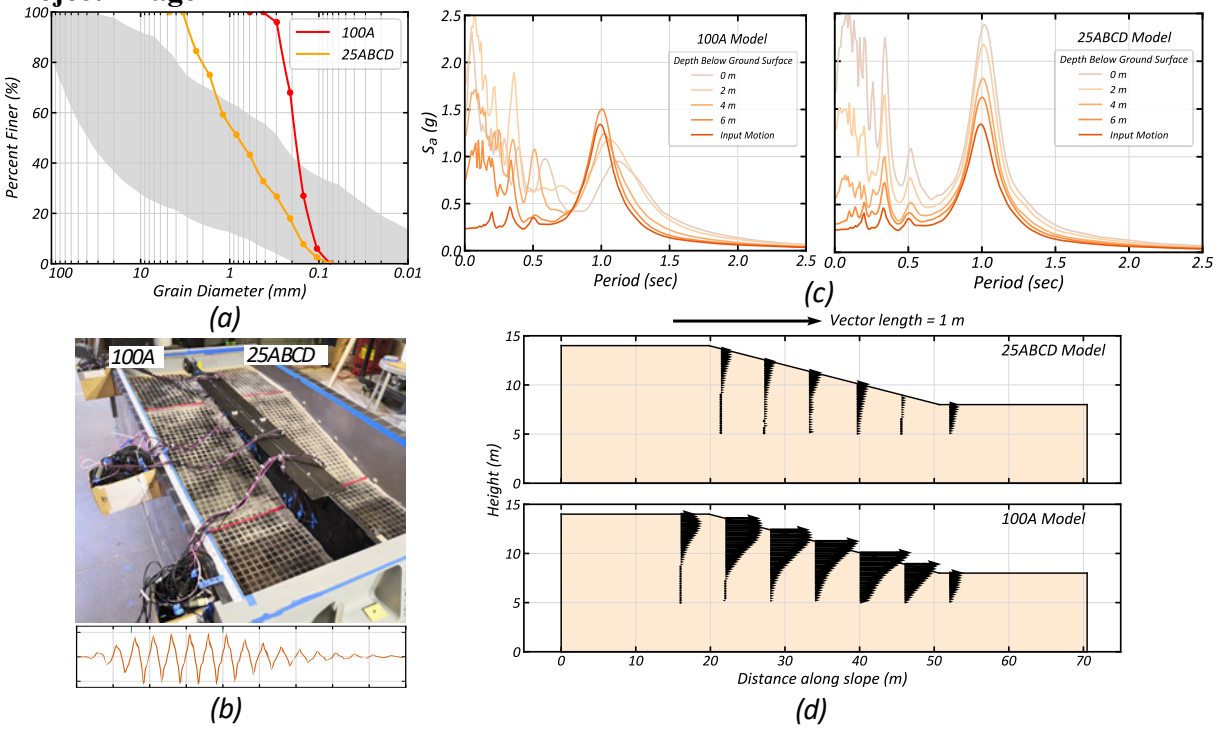

Figure: (a) Grain size distribution of tested soils (colored lines) and typical gradations in constructed embankments (gray zone); (b) photo of divided centrifuge model and input motion; (c) response spectrum of accelerometer data; (d) permanent deformations of slopes following shaking from HSC-PIV analysis.

PEER Center – 325 Davis Hall, UC Berkeley, CA 94720 | peer_center@berkeley.edu