Computational fluid dynamics-based modeling of liquefied soils

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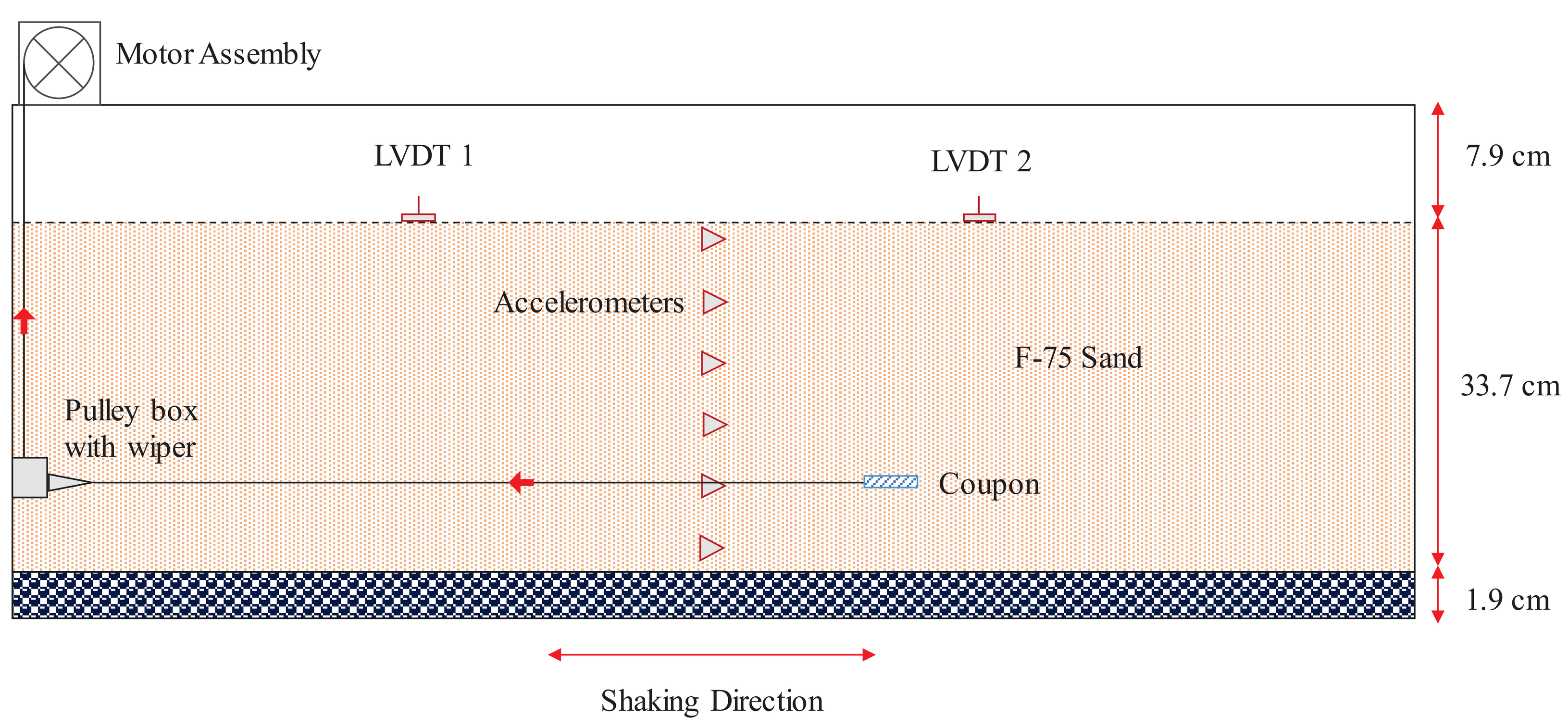
Abstract

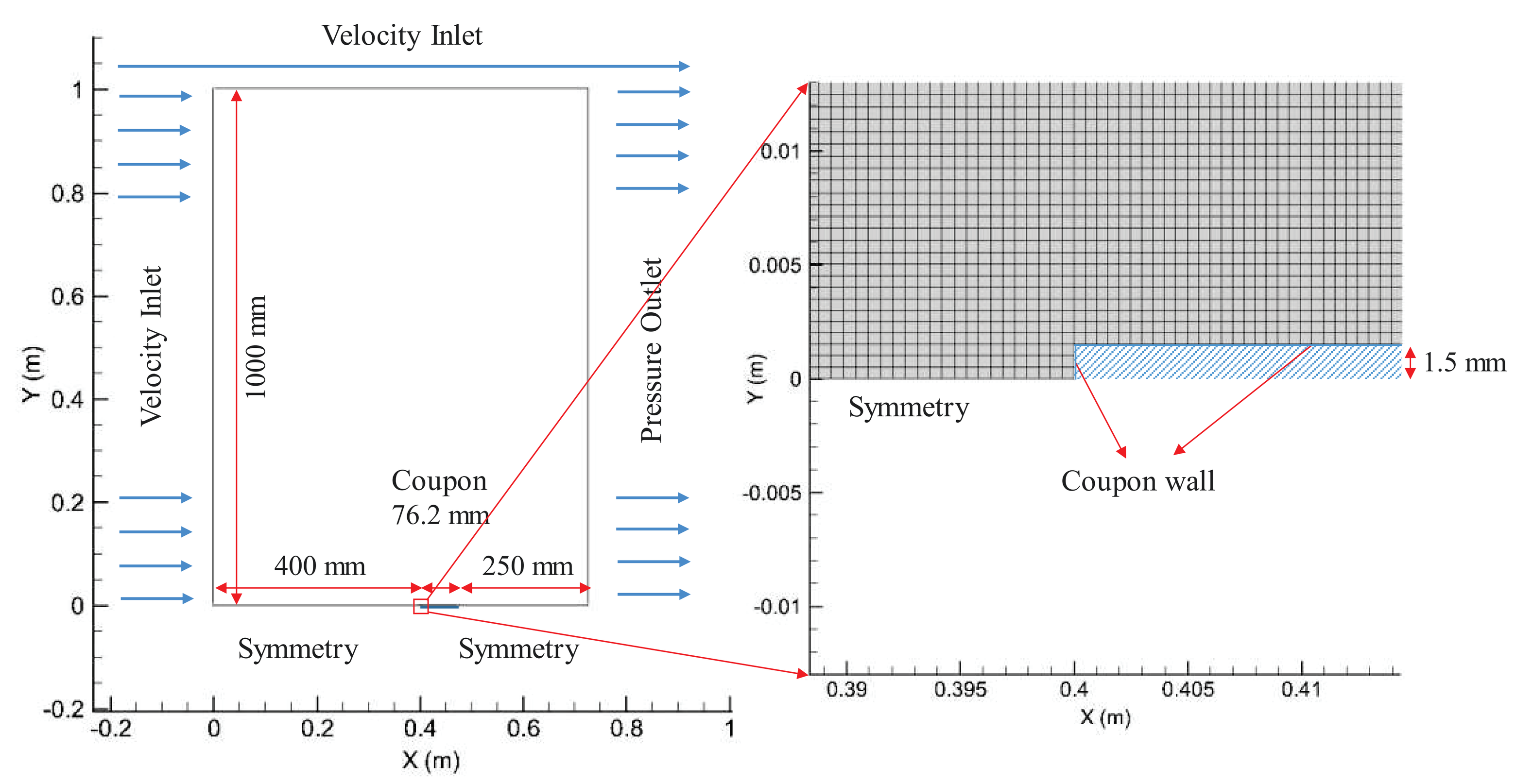
The residual shear strength of liquefied soil is a key parameter in evaluating liquefaction flow failures. Results from a series of dynamic centrifuge experiments where the shear strength of liquefied soil was inferred by measuring the force required to pull a thin metal plate (coupon) horizontally through the liquefied soil are assessed here using a computational fluid dynamics (CFD) based model. Viscosity is a key parameter for the Newtonian fluid constitutive model used in the simulations, and apparent viscosities of liquefied soil in the range of about 5,800 – 13,300 Pa·s were obtained when the CFD model was calibrated against coupons pulled through liquefied soil in dynamic centrifuge tests. These computational values agree reasonably with apparent viscosities of liquefied soil reported in the literature when the Reynolds numbers (Re) exceeded 1.0. Importantly, the CFD simulations illustrated that in cases where Reynolds numbers are < 1.0, apparent viscosities of liquefied soil back-calculated using simplistic closed-form solutions commonly applied in geotechnical literature are several orders of magnitude too large; and therefore, such closed-form solutions should not be used for these cases.

1. Physical model



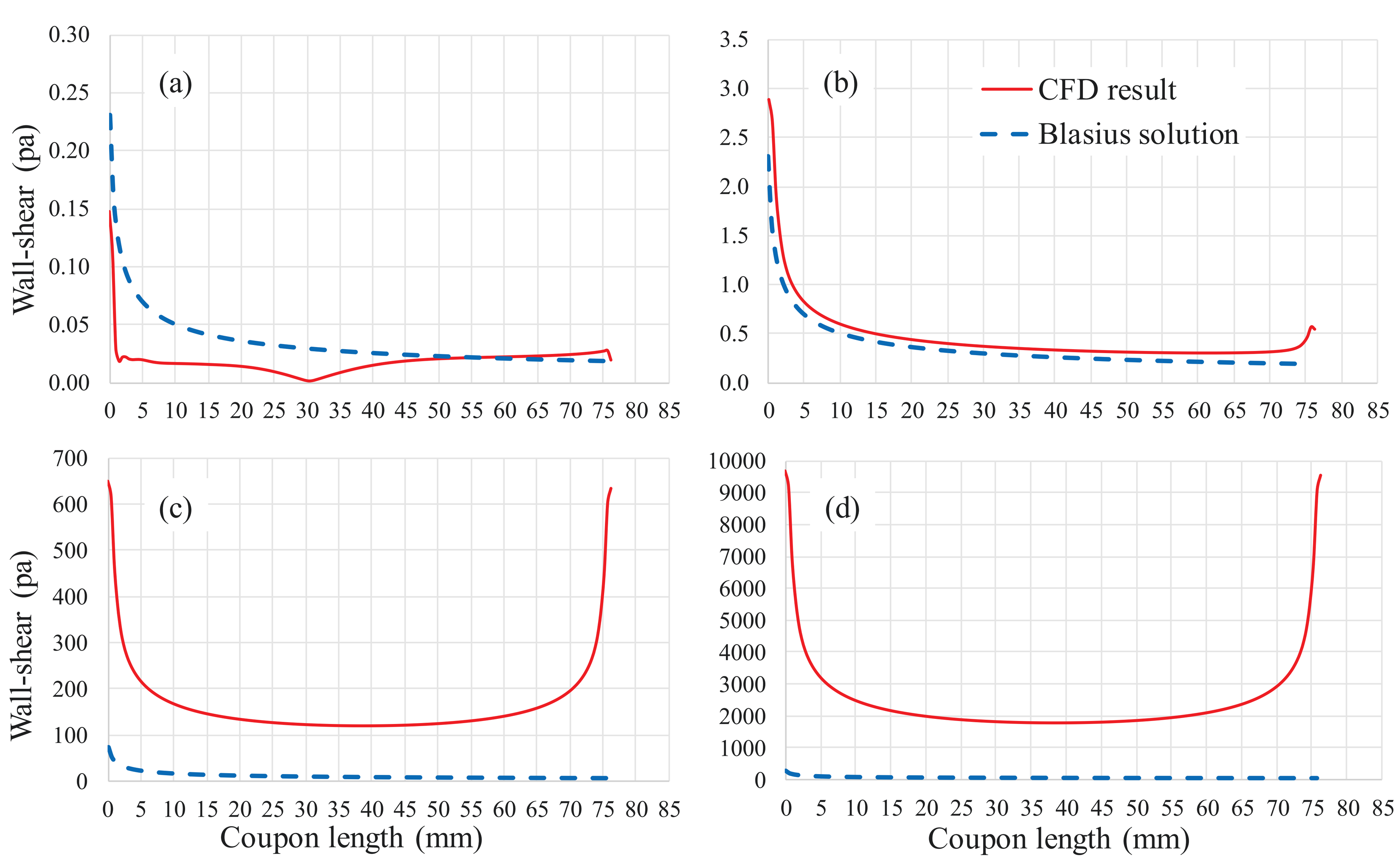
Cross-sectional view of the dynamic centrifuge model where the motor assembly mounted on top of the container was used to pull a coupon through liquefied soil to measure soil resistance. The measured soil resistance was used to infer the residual shear strength of liquefied soil (from Dewoolkar et al. 2015).

2. Computational model



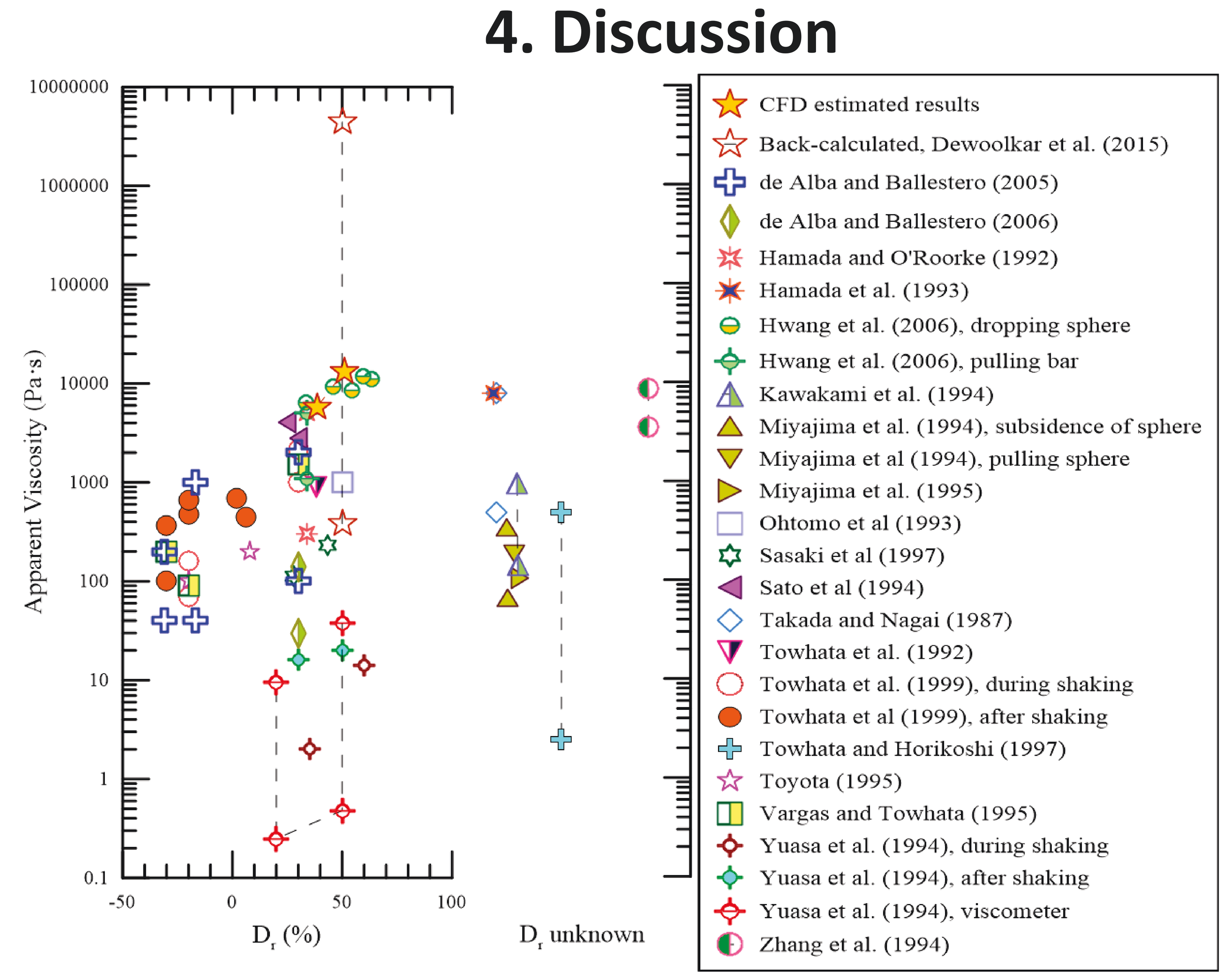
Computational domain used to model flow past the coupon. The inlet velocity equaled the coupon velocity in the centrifuge tests. The upper boundary was defined with a flow velocity equal and parallel to the inlet velocity to model an infinite domain above. The coupon wall is a no slip wall. The domain size and number of elements were modified until we observed a consistent flow field.

3. Results



Comparison between simulations and closed-form Blasius solution for flow over a flat plate: (a) μ = 0.001 Pa·s; (b) μ = 0.1 Pa·s; (c) μ = 100 Pa·s; and (d) μ = 1500 Pa·s. At low viscosity (μ), the simulations and closed-form solutions reasonably agree; however, they differ by several orders of magnitude when the viscosity increases (Re < 1). These results illustrate that closed-form solutions are limited, cannot be used to back-calculate apparent viscosity of liquefied soil from physical experiments.

4. Discussion



*References listed above are provided in the conference paper.

A wide range of apparent viscosities have been reported for liquefied soils when closed-form solutions are used for physical experiments with low Reynolds numbers (Re < 1), such as with the Dewoolkar et al. (2015) tests. When these tests were simulated using CFD, the apparent viscosities narrowed to 5,800-13,300 Pa·s. Additional comparisons using CFD-based simulations are needed to better define this range. Furthermore, non-Newtonian models may better model liquefied soil.

Acknowledgement

Funding: National Science Foundation

Award Numbers: 1728172 and 1728199

Project: Collaborative Research: Novel Measurement of Shear Strength Evolution in Liquefied Soil and Calibration of a Fluid Dynamics-based Constitutive Model for Flow Liquefaction