Numerical Study of Stone Columns in Liquefiable Silty Soil

PEER Transportation Systems Research Program

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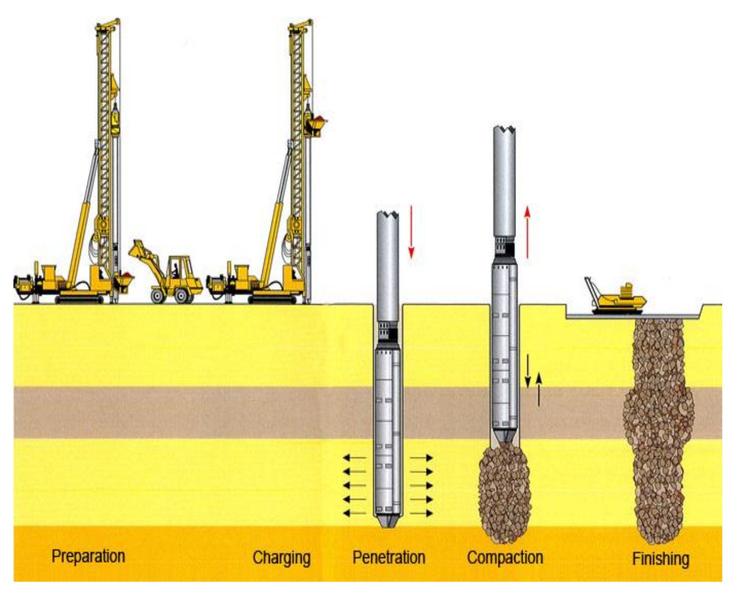
1. Introduction



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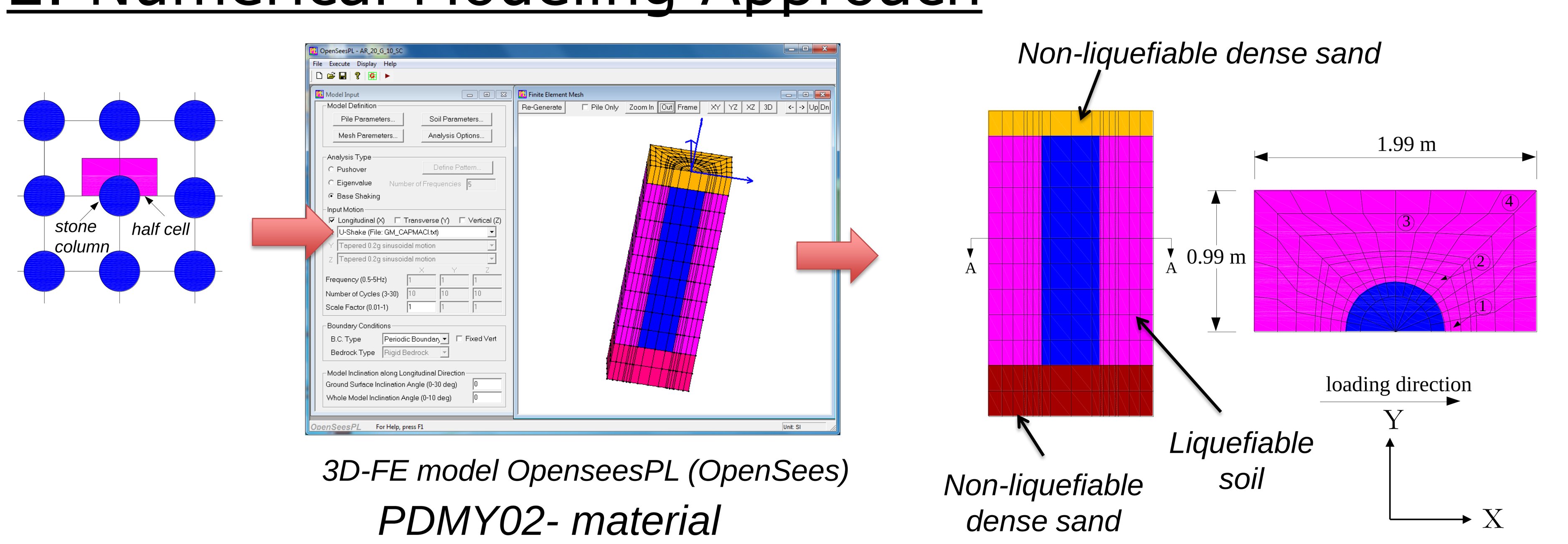
Stone columns (SC) are often used to improve the liquefaction resistance of loose saturated cohesionless soil (e.g., sand, silt). Particularly for silty soil, it is assumed that SC acts as shear reinforcement, where SC being relatively stiffer takes higher stress and helps to reduce shear stress in surrounding soil (Baez 1995). Pure shear beam deformation and shear strain compatibility between SC and surrounding soil are the main assumptions for SC design in current engineering practice.

Alternatively, Goughnour and Pestana (1998) , Green *et al.* (2008) and Olgun and Martin (2008) argued that SC can have flexural deformation as well, and shear strain compatibility between SC and surrounding soil may not be the correct assumption.

Objective

- Investigate shear stress and strain distribution between SC and surrounding soil
- Conduct parametric analysis to understand behavior of stone columns under shaking
- Develop a design chart for SC in silty soil based on shear reinforcement effect

2. Numerical Modeling Approach



3D-FE model OpenseesPL (OpenSees)

PDMY02- material

3. Linear Elastic Analysis

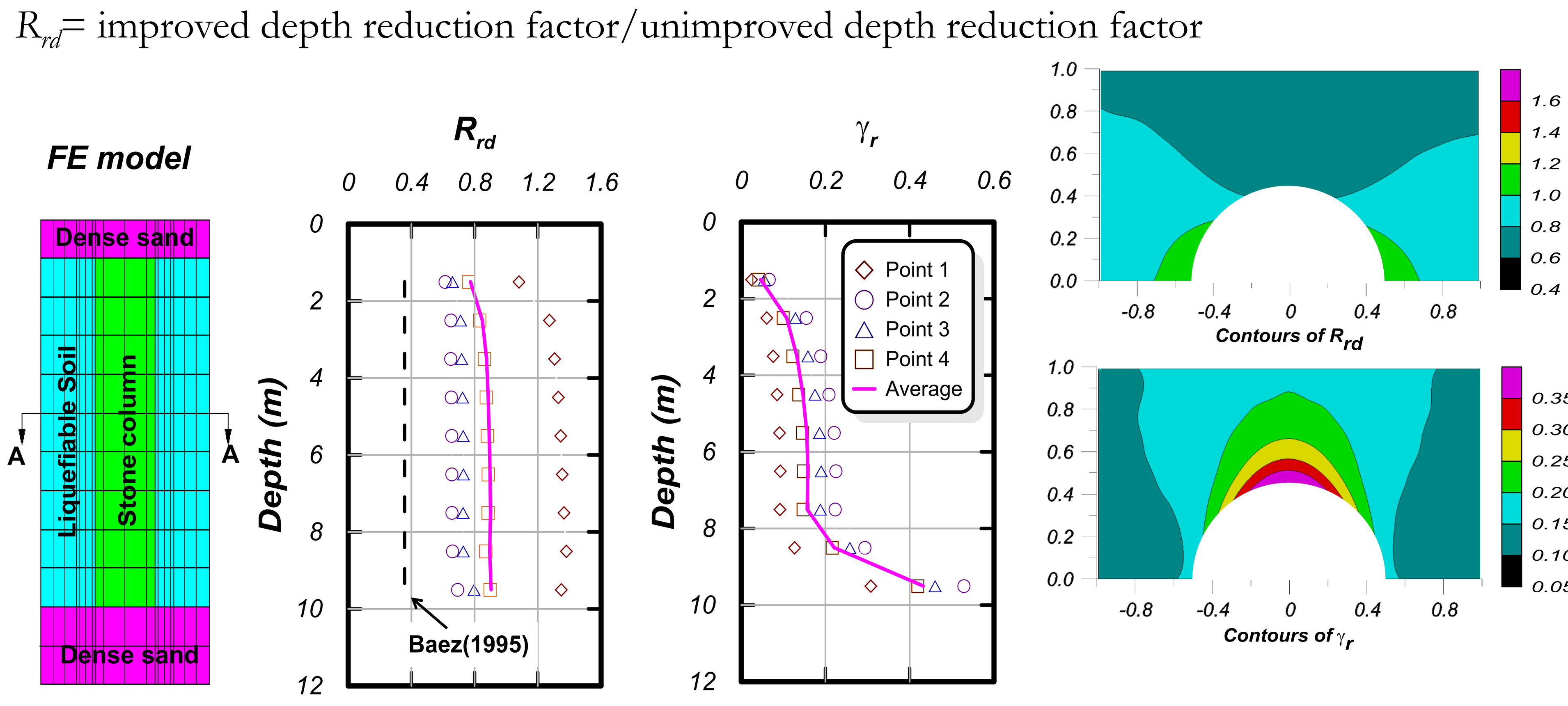
Interpretation Framework

Based on Seed and Idriss (1971), shear stress reduction factor is estimated as

$$R_{CSR} = \frac{CSR_I}{CSR_U} = \frac{(a_{max} r_d)_I}{(a_{max} r_d)_U} = R_{a\max} R_{rd} \qquad \text{and} \qquad \gamma_r = \frac{\gamma_{stone-column}}{\gamma_{soil}}$$

R_{amax}= improved surface acceleration/ unimproved surface acceleration

R_{rd}= improved depth reduction factor/unimproved depth reduction factor

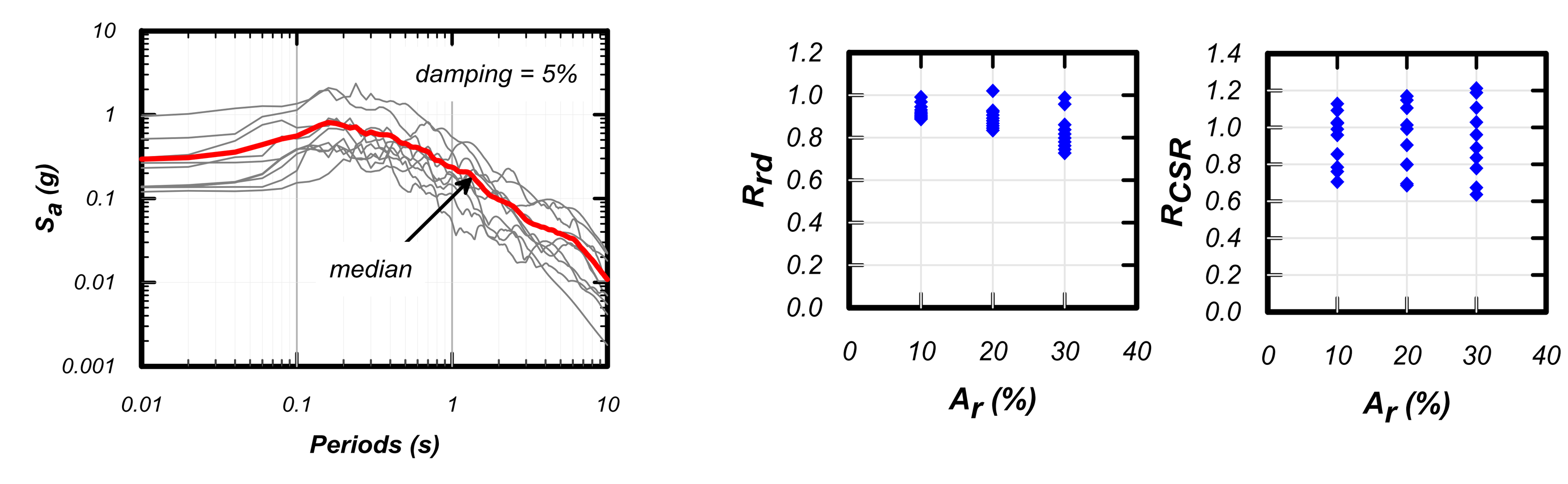


R_{rd} contours at section A-A

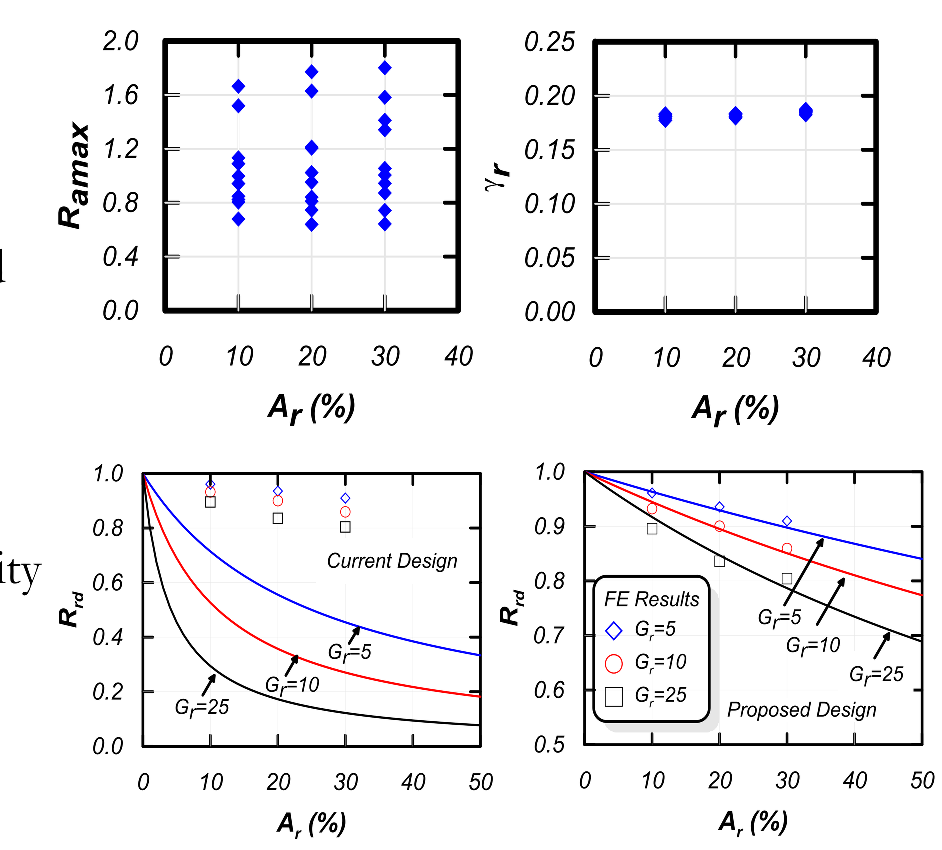
dry case- pseudo-static motion (A_r=20%, G_r=10)

- No shear strain compatibility between SC and surrounding soil
- R_{rd} and γ_r varies spatially
- Shear stress reduction is lower than predicted by strain compatibility assumption

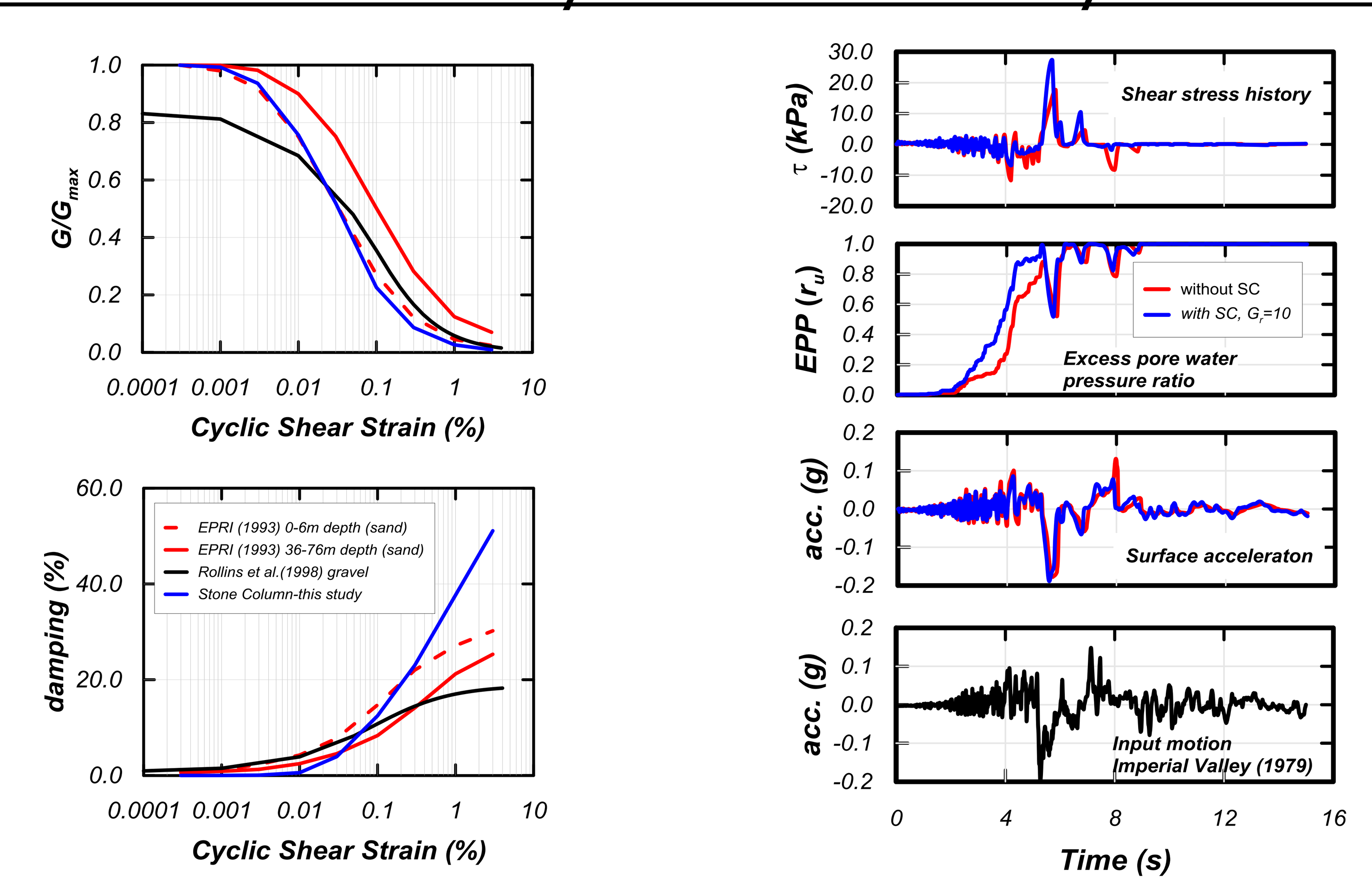
4. Parametric Study and Design Chart



- Ground motions- Baker *et al.* (2011) for rock site condition
- R_{CSR} and R_{amax} varies quite significantly with input ground motions
- Proposed design relationship gives better estimate of the shear stress reduction as compared to strain compatibility design assumption



5. Nonlinear Analysis: Preliminary Results



- Drainage is restricted by providing low permeability to SC (k=10^{-6} m/s)
- No significant reduction in shear stresses in this particular motion
- Stiffer response and relatively fast EPP generation than without SC case

6.0 Progress and Future Work

- Parametric study based on nonlinear soil modeling
- Conduct centrifuge experimental test to validate the shear strain compatibility assumption and numerical analysis results
- Update design chart for SC based on new results

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