Lateral Spreading Analysis for Single Piles

PEER Transportation Systems Research Program

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Objective:

- Create a simplified design procedure for piles subjected to lateral spreading which recognizes the shortcomings of current methodologies and provides more realistic pile bending demands.

Procedure:

- Develop a 3D finite element (FE) model for lateral spreading case in OpenSees.
- Include nonlinear soil behavior through the use of a Drucker-Prager constitutive model and include three distinct pile designs which are modeled using beam elements and fiber section models. Beam-solid contact elements model the soil-pile interface.
- A parametric study using the 3D model is computationally expensive and inefficient.
- In contrast, a 1D beam-spring model is more efficient in a parametric study, however, it is crucial that the proper *p-y* curves are defined for all depths.

Progress to date:

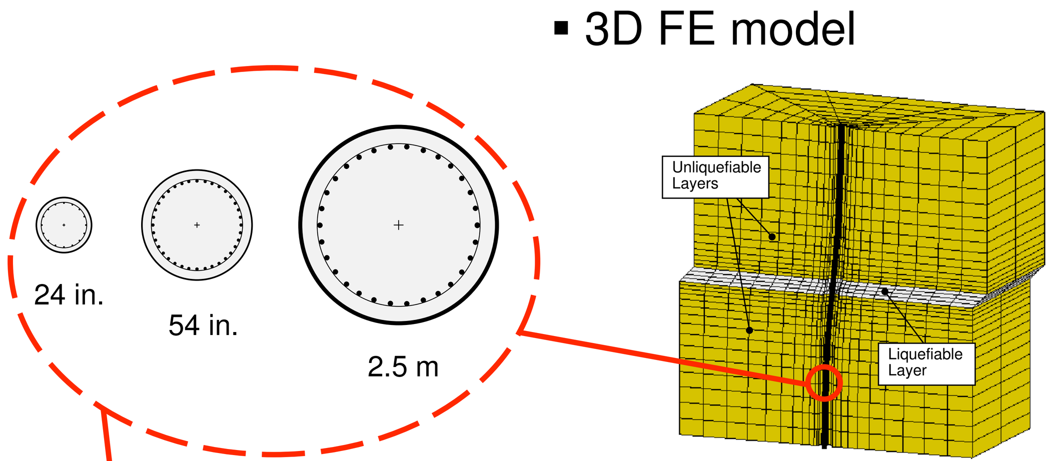
- Have a working 3D finite element model of lateral spreading problem and can extract suitable *p-y* curves for all depths for a given soil profile from this model.
- Have identified problems with the use of conventional *p-y* curves in context of lateral spreading.
- Have verified that 1D simulations produce results which are reasonably similar to 3D modeling effort.

Future Work:

- Use 3D model to obtain a set of suitable *p-y* curves for various soil profiles.
- Perform a parametric study of the lateral spreading case in 1D to determine maximum pile bending demands for a variety of soil/pile combinations.
- Use results of 1D parametric study to establish a simple lateral spreading design procedure which can return realistic pile bending demands applicable to most practical applications.

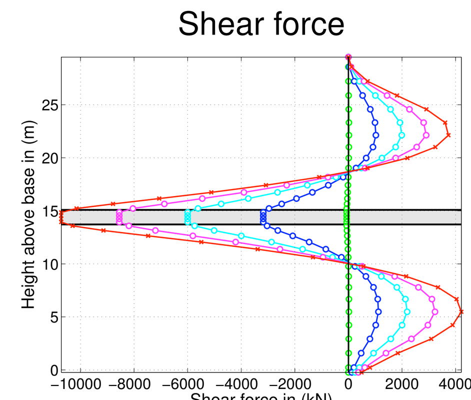
Modeling Approach:

- 3D FE model

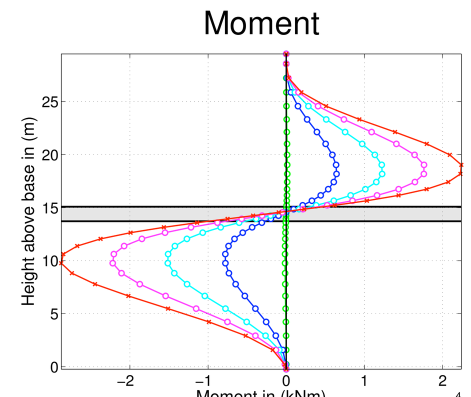


- Three reinf. concrete pile designs are considered.
- Both produce similar pile bending demands

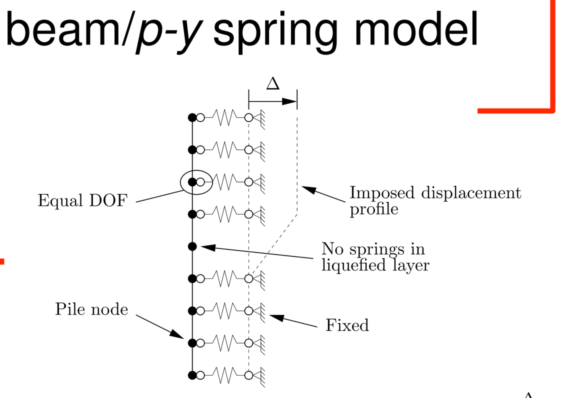
Shear force



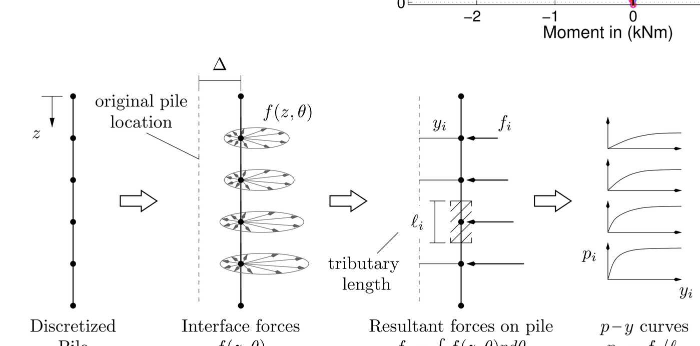
Moment



- 1D beam/*p-y* spring model



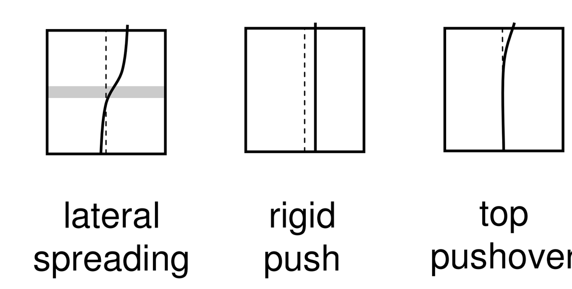
- Suitable p-y curves must be defined for all depths in order to use the 1D approach.



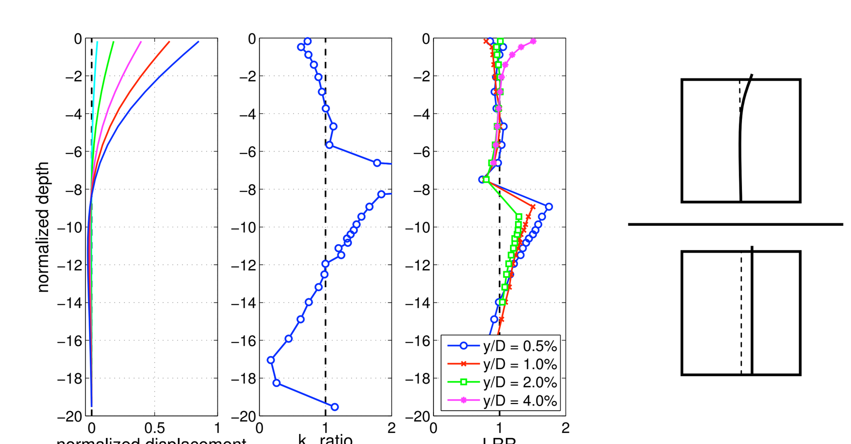
Extraction of *p-y* curves from 3D FE model

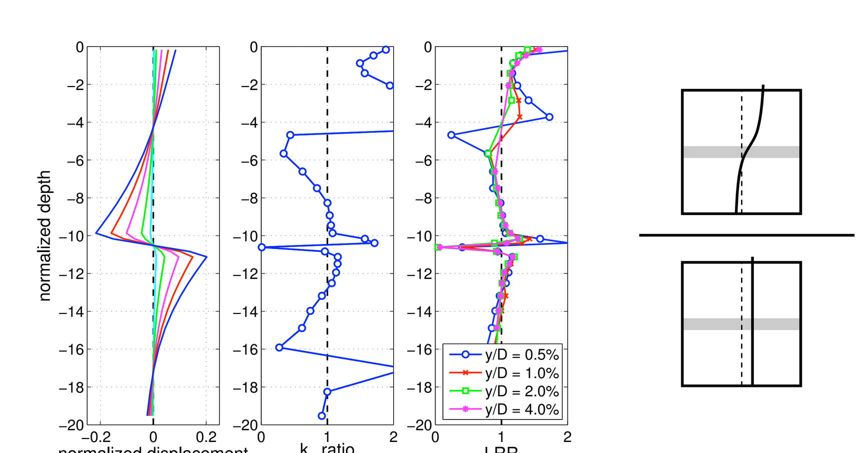
Kinematic Effects:

- Three kinematic cases are analyzed.

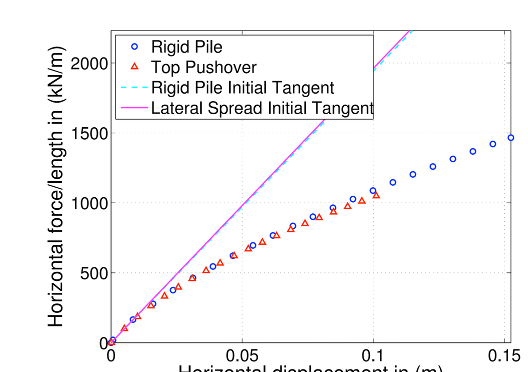


- The extracted *p-y* curves are not independent of pile kinematics.
- Comparison of *p-y* curves using ratios of initial stiffness (k_t) and lateral resistance:

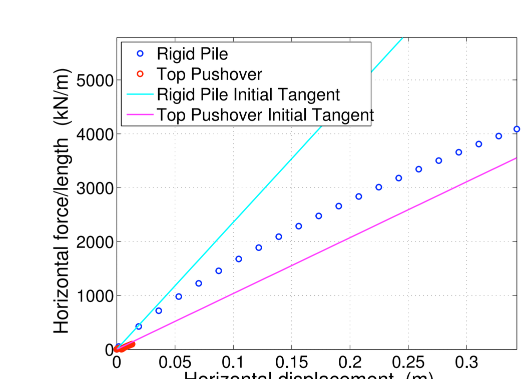




- The curves match well where displacements are large:

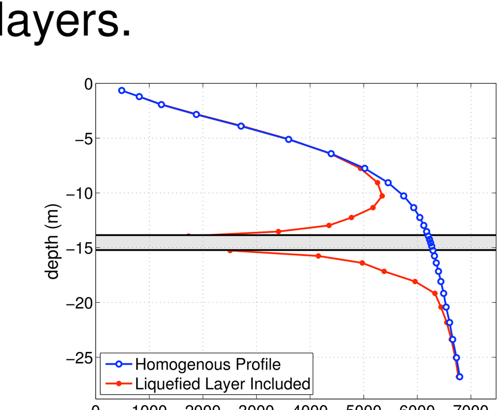


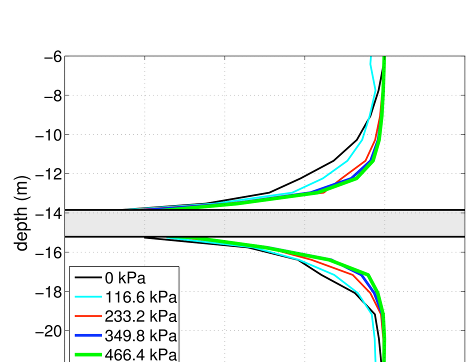
- The curves match poorly where displacements are small:



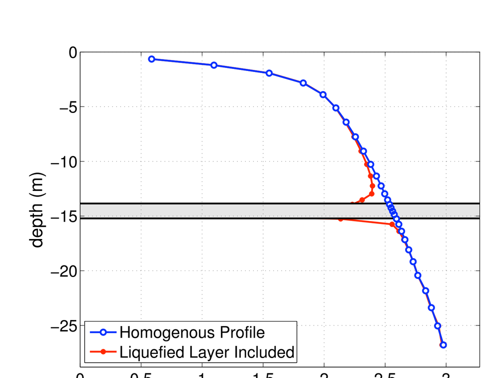
Liquefied Layer Effects:

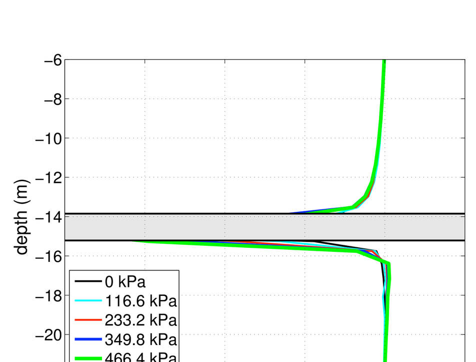
- The extracted *p-y* curves are not independent of the soil layers.
- The ultimate lateral resistance p_u in the unliquefied layers is reduced significantly due to the presence of the liquefied layer.





- The reduction in p_u for the unliquefied layers becomes less significant as the depth to the liquefied layer increases.
- The initial stiffness k_t in the unliquefied layers is reduced only slightly.

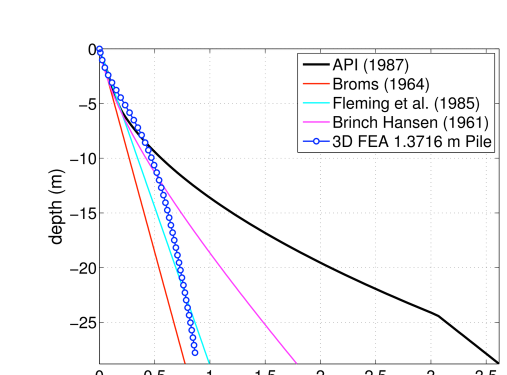


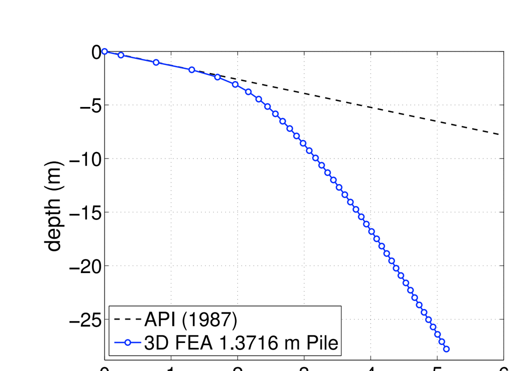


- The stiffness reduction remains relatively constant for all liquefied layer depths.

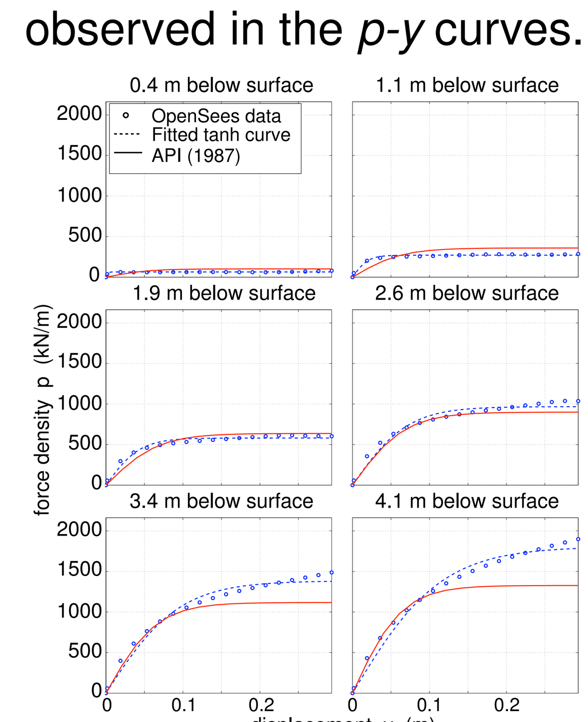
Conventional vs. Extracted *p-y* Curves:

- For the extracted *p-y* curves, the distributions of ultimate lateral resistance and initial stiffness deviate from conventionally defined distributions.
- At shallow depths, there is generally good agreement.
- At increased depths, there are significant differences.

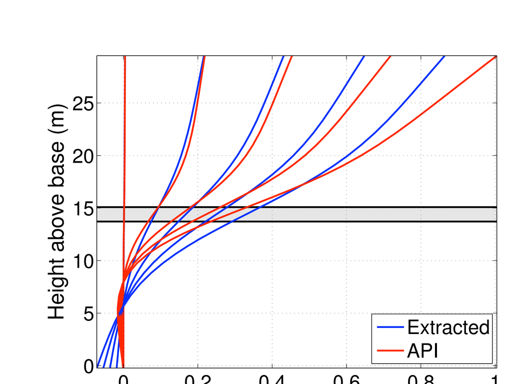


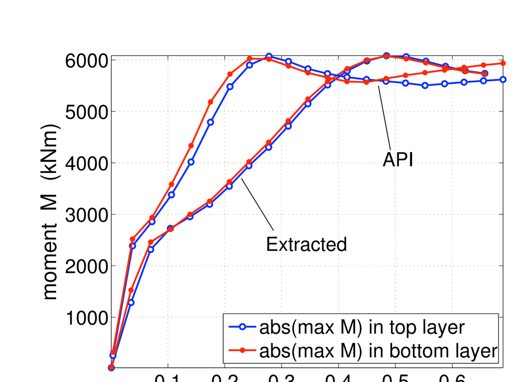


- The differences can be observed in the *p-y* curves.



- The differences can also be observed in the pile bending demands and deformations resulting from using each set of curves in the 1D lateral spreading model.





This project was made possible with support from: