ENGINEERING HONORS PROGRAM
UNIVERSITY OF MICHIGAN

Investigating the Behavior of Foundation Piles Experiencing Downdrag

Ries Plescher, Roman Hryciw
Department of Civil and Environmental Engineering, University of Michigan, Ann Arbor

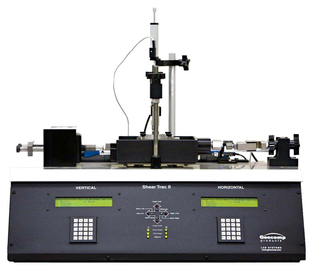
Background

Predicting the downward displacement of a pile foundation is essential to ensure that buildings are not at risk of settling and cracking. This is generally done by assuming the load is resisted by the friction between the pile and the soil. The phenomenon of downdrag occurs when extra weight is applied directly onto the soil **after pile loading**, such that the soil is compressed and the friction between the soil and the pile now pulls **downward** on the pile, causing additional settlement. The purpose of this research project is to develop a model to accurately predict the frictional downdrag forces so that pile displacement can be predicted more accurately and avoided.

Methods

An existing hyperbolic model for friction force was modified algebraically to predict the friction forces in a pile under downdrag.

Direct shear tests were performed between a sandy soil and various pile materials shown below. The direct shear machine recorded this data for both upward and downdrag cases.



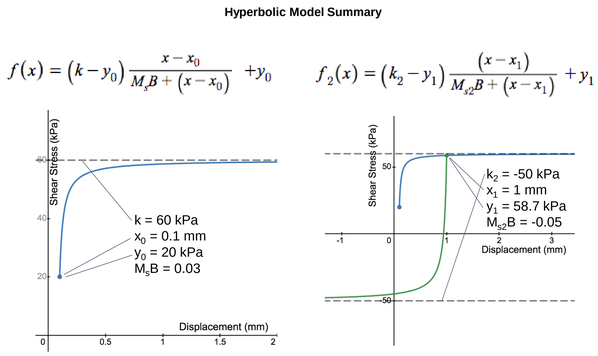
Direct Shear Apparatus

rough concrete | wood (against/along grain) | wood (normal to grain)

smooth concrete | rough steel | smooth steel

MATLAB was then used to fit parameters to the models. These experimental parameters were analyzed to search for relationships between pile behavior and the materials' properties.

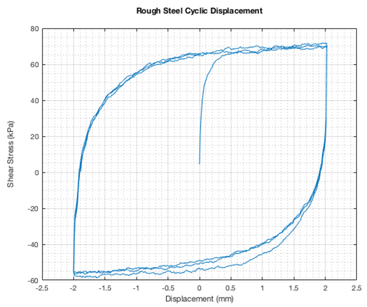
Results and Discussion

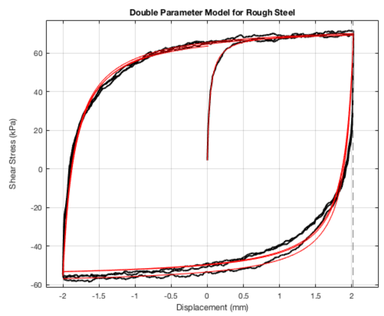


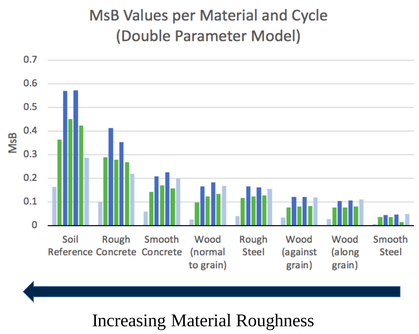
The traditional hyperbolic model is shown on the left, and the model on the right is the model used to predict shear forces in the reverse direction in the case of downdrag.

In the models, the value of M_SB indicates the overall shape of the curve (a high value indicates a steeper curve), and k indicates the value that the graph will asymptotically approach.

MATLAB is used to fit the data to this model. The program finds the best-fitting M_SB and k values for each forward and backward cycle.



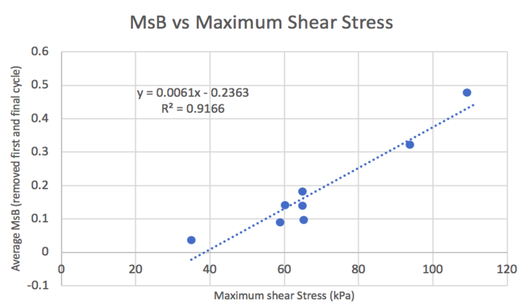




M_SB values for each material and cycle tested are compared in the following graph. The first and last cycles move a smaller amount of displacement in the apparatus, so are identified as outliers using faded colors. This graph shows:

1. M_SB increases with the qualitative roughness of the material
2. There is a difference in shape between the cycles under positive vs. negative displacement.

Using the maximum shear stress k as a quantitative measure of roughness, the relationship between k and M_SB is graphed, and a relatively linear relationship is observed.



Conclusions

If the relationship between M_SB and k can be demonstrated with more data, then the behavior of a pile under both normal loading and downdrag can be predicted by a single empirical constant that could be tabulated for each type of pile material.

The implementation of this model would allow a more accurate prediction of the pile settlement expected both during construction and during the life of the structure.

Future Directions

- Investigating the difference in M_SB and k values between the forward cycles and backward cycles.
- The current data was all collected under a normal (towards the surface) pressure of 100 kPa. Observation of behavior under other normal pressures will be important.
- Modification of the hyperbolic model to account for discrepancies in the first and last loading cycle.
- Creation of a user-friendly interface for real world application would translate this research into a practical engineering tool.

Acknowledgements

Thanks to Roman Hryciw and Andrea Ventola for their continued help and guidance through the course of the project.

I also want to give a huge thanks to Jan Pantolin, the Technical Services Supervisor, for his expertise with the Direct Shear Apparatus and the manufacturing of the materials.

Finally, thanks to the Engineering Honors Program for the opportunity to present this research.