Calculating Pile Downdrag: Experimental and Numerical Investigations

Developing a simple and effective method to quantify and calculate pile downdrag

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20GTLSU10

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$90,042

Downdrag is in the design of transportation foundations subjected to ground settlement. There are currently conflicts on how downdrag and drag load are incorporated into the pile design, partly due to the differences of design methods in the design codes (e.g., AASHTO LRFD Bridge Design Specifications and FHWA Driven Pile Manual). State DOTs are facing a challenge about the inconsistency of design codes (i.e., AASHTO LRFD Bridge Design Specifications and FHWA Driven Pile Manual) to predict drag load and downdrag. A preliminary analysis of a hypothetical pile showed that pile design could be considerably more conservative and costly when using AASHTO LRFD Bridge Design Specifications. Therefore, there is an urgent need to investigate the fundamental behavior of piles subject to downdrag to update the design specifications. Furthermore, though several field monitoring programs in the literature were successfully conducted on piles under downdrag, fully instrumented lab-scale pile tests focusing on the responses at the soil-pile interface remains elusive.

Problem Statement

Deep foundation axial resistance falls into two categories: shaft resistance and tip resistance. The direction of the shaft resistance depends on the relative movement between the deep foundation and the adjacent soil. If the pile moves downward relative to the soil, the positive shaft resistance is developed (i.e., shaft resistance acting upward). Conversely, If the soil flows downward relative to the pile, the negative shaft resistance (drag load) is developed (i.e., shaft resistance acting downward). The drag load is defined as the axial compressive load induced along the length of the pile due to the accumulated negative skin friction. Downdrag is characterized by downward movement of a pile that results from the ground settlement. The neutral plane location is where the transition from negative to positive shear direction occurs. The neutral plane location is where the transition from negative to positive shear direction occurs.

Objectives

The goal of this project is to explore pile downdrag in consolidating ground using fully instrumented lab-scale pile tests and finite element numerical modeling. To achieve this, the following tasks will be performed:

(1) Conduct literature review related to the calculation of pile downdrag.

(2) Explore force-displacement relationships at the soil-pile interface using the interface direct shear tests.

(3) Investigate the drag load and downdag along the pile length using fully instrumented lab-scale tests with advanced sensors

(4) Analyze the test results and compare with the available design methods of downdrag.

(5) develop a numerical modeling tool and perform parametric analysis to accurately predict pile downdrag and drag load.

Intended Implementation of Research

Workforce Development and Outreach: The final report will be written for state DOTs within Tran-SET and industry professionals. The research team will start preparing professional engineers using the short course, webinars, technical publications, and conference presentations. Also, a video including the procedures and results of laboratory model tests and the implementation of the provided numerical modeling tool will be created and disseminated to the DOT geotechnical engineers/staff, private consultants, and pile installation contractors. Furthermore, the results of this research will be incorporated into the LSU online Master of Sciences program in Civil Engineering which attracts many state DOT engineers and industry professionals.

Education: The project will train two graduate students and several undergraduate students interested in graduate studies. One graduate student will focus on the experimental study of the proposed research. The other graduate student will handle the numerical modeling of downdrag. The graduate and undergraduate students are to perform research as listed in the research plan, collect and analyze research data, write research papers to high-impact journals and conferences, and help PI and Co-PI prepare outreach activities.

Anticipated Impacts/Benefits of Implementation

The PI will write an updated literature review on downdrag and an updated document that summarizes a database of case histories relating to downdrag. This database can be a reference for downdrag design and a teaching tool to help students and engineers understand what downdrag is and how to estimate and reduce it. The main deliverables from this study are:

(1) A final report detailing how to design and estimate downdrag with the provided modeling tools.

(2) A webinar and presentation to disseminate the findings of this study to a broad audience.

(3) presentations to be given at annual, national conferences.

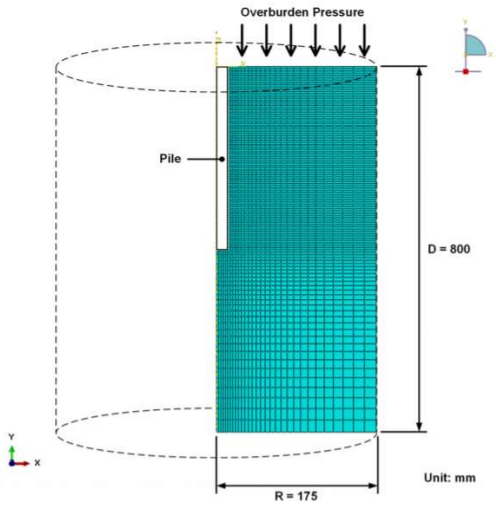

Figure 1: Finite element meshing for pile downdrag laboratory test

Web links

- Tran-SET's website https://transet.lsu.edu/research-in-progress/

Tran-SET

Tran-SET is Region 6's University Transportation Center. It is a collaborative partnership between 11 institutions (see below) across 5 states (AR, LA, NM, OK, and TX). Tran-SET is led by Louisiana State University. It was established in late November

Learn More

For more information about Tran-SET, please visit our website, LinkedIn, Twitter, Facebook, and YouTube pages. Also, please feel free to contact Dr. Momen Mousa (Tran-SET Program Manager) directly at transet@lsu.edu.