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Research Results

Evaluation of Soil Plug Geotechnical Resistance in the Design of CISS Piles

This research will evaluate various soil plug thicknesses and assess their impact on the geotechnical resistance of the pile and how it correlates with the API design procedure.

Geotechnical/ Structures

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Project Title: Evaluation of Soil Plug Geotechnical Resistance in the Design of CISS Piles

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WHAT WAS THE NEED?

The California Amendments to the American Association of State Highway and Transportation Officials (AASHTO) LRFD Bridge Design Specifications require the use of the American Petroleum Institute (API, 2000) design procedure for Cast-In-Steel Shell (CISS) concrete piles larger than 18 inches in diameter. However, the API procedure assumes that a soil plug remains inside the pile, which does not align well with current Caltrans practice. Caltrans typically removes the soil from inside the pile and then fills it with concrete and steel reinforcement.

WHAT WAS OUR GOAL?

The objectives of this research are as follow:

- Evaluate the soil plug contribution to the geotechnical resistance of the pile for variable thicknesses of soil plug.
- Evaluate the Caltrans practice of placing concrete and steel reinforcement on top of the soil plug and its effect on the geotechnical resistance of the pile.
- Evaluate the API design procedure in predicting the geotechnical capacity of the CISS pile.

WHAT DID WE DO?

Four nominally identical open-ended steel shells (3 ft diameter, 40 ft embedment) were driven and cleaned out to target plug lengths of 0, 6 ft, 12 ft, and 18 ft, and were tested in two series of top-down compression load tests to 600 kips and 1,150 kips. Distributed fiber optic sensing (DFOS) installed in four configurations survived impact driving and provided high-

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resolution axial strain profiles, from which layerwise t-z and q-z relationships were back-calculated by inverse analysis. Finite-element simulations were performed to interpret the pile-soil interaction mechanisms.

WHAT WAS THE OUTCOME?

None of the tests reached geotechnical failure, and the piles continued to carry increasing loads with relatively little change in displacement. The measured shaft resistance was about 2.8 times higher than predicted by Model 3 and about 5.7 times higher than predicted by the American Petroleum Institute (API) method. This indicates that both design methods are conservative for estimating shaft resistance under the soil conditions tested.

The computer simulations also showed that pile driving significantly increased the stiffness and strength of the surrounding soil. The soil stiffness needed to match the test results was 15 to 29 times higher than the values estimated from cone penetration testing (CPT).

Because the actual soil resistance was much higher than predicted, the test loads were carried primarily by the pile shaft, with only small pile movements. As a result, the soil plug and the pile tip contributed relatively little to the measured resistance. Within the range of loads tested, changing the remaining soil plug length from 0 to 18 feet did not measurably affect pile movement or shaft resistance. Therefore, the test results could not be used to separately determine the contributions of end bearing and the soil plug.

WHAT IS THE BENEFIT?

This research will reduce uncertainty in the design of CISS piles and help lower geotechnical risks during construction. CISS piles are among the most expensive foundation systems used by Caltrans because they consist of a thick steel shell that is driven into the ground and then filled with concrete and steel reinforcement. They are commonly used when a foundation must provide high lateral capacity to resist earthquake forces.

On several Caltrans projects, the actual geotechnical resistance of CISS piles during construction has been lower than predicted by the design, resulting in costly change orders. This research will improve the ability to predict the geotechnical resistance provided by the soil plug inside the pile. The results will help engineers develop more cost-effective CISS pile designs while reducing the risk of unexpected performance and construction costs.

IMAGES



Image 1: Example of pile load test configuration during testing.

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