DRISI

Caltrans Division of Research, Innovation and System Information

Research Results

Calibration of LRFD Geotechnical Axial (Tension and Compression) Resistance Factors for Driven Piles and Drilled Shafts

The project was separated into two components: a driven pile assessment and a drilled shaft database construction and assessment.

Geotechnical/ Structures

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Project Title: Improved LRFD Specifications for California Bridge Design

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WHAT WAS THE NEED?

In 2008, as part of FHWA's mandated adoption of LRFD design practices, Caltrans began designing driven piles and drilled shafts using LRFD. At that time Caltrans rejected AASHTO recommended resistance factors since their adoption would have resulted in substantially increased foundation sizes. Since pre-LRFD design practice hadn't generated any foundation failures, adding additional conservatism to Caltrans design practice seemed wasteful. Instead of using the recommended AASHTO factors, Caltrans chose to simply back-calculate factors that would reflect pre-LRFD practice.

In 2013, as part of a FHWA review of Geotechnical Services, FHWA pointed out that while this back-calculation of resistance factors was suitable for a transition period to LRFD, it is inconsistent with LRFD's intended goal of achieving a uniformly reliable design. FHWA then requested that Caltrans perform a California specific calibration of its resistance factors, based on Caltrans design and construction practices.

WHAT WAS OUR GOAL?

The goal of both teams was to accurately characterize existing foundation design practice and assess the reliability of these practices. LRFD calibration procedures were employed to provide resistance factors that correspond to target reliability goals.

WHAT DID WE DO?

Since Caltrans Division of Research, Innovation and System Information (DRISI) already maintains a driven pile load-test database, the project was separated into two components: a driven pile assessment led by DRISI and a drilled shaft database construction and assessment led by Xinbao Yu at University of Texas at Arlington (UTA). The DRISI team found that pile capacity prediction methods typically used for pile design didn't work very well in sandy soils and for large diameter piles. The team expanded their scope to include the development of an improved design procedure.

WHAT WAS THE OUTCOME?

The drilled shaft team assembled a load-test database consisting tests from 79 drilled shafts, 41 from Mississippi, 30 from Louisiana, and 8 from western states (2 CA, 3 AZ, and 3 WA). A major obstacle for the drilled shaft team was the lack of suitable load-tests in California. While California had many tests, only a couple were carried to failure (or near failure). The results of the reliability analysis were generally consistent with AASHTO recommendations. The team also compared two different design methods: the 1999 and the 2010 FHWA procedures. They found both methods had nearly identical predictive power. The 1999 method was more conservative than the 2010 method.

The driven pile team, using an all California database of 94 load-tests, developed a new design method for piles in sand. The method, named Model 3, uses SPT blow count as the primary predictor of capacity along with three adjustment factors to account for direction of loading (uplift or compression), distance from the pile tip, and reduced radial stresses in open-end piles. Applying Model 3 reduced the prediction error from a COV of about 0.50 to a COV of 0.28 reflecting a substantial increase in design efficiency.

Since driven piles often have their capacity verified in the field using a pile dynamic analyzer (PDA), the LRFD reliability assessment was modified to account for the combined impact of both the office based capacity prediction and PDA verification. Consideration of both the initial design and verification in an integrated reliability calculation results in 10 to 20% larger resistance factors than if calculated using traditional calibration procedures. The new verification based LRFD framework was also extended to consider use of the energy formula and static load testing for verification. It was found that using PDA for verification instead of the energy formula (Caltrans' current practice for standard plan piles) will increase resistance factors about 15%. The new LRFD framework also incentivizes use of static load testing to reduce foundation costs whereas current Caltrans procedures provide no incentive.

Caltrans is in the process of adopting Model 3 and the verification based LRFD resistance factors as California Amendments to the 8th Edition of AASHTO LRFD Bridge Design Specification. These amendments are targeted for July 1, 2018 adoption.

WHAT IS THE BENEFIT?

For drilled shafts, the primary benefit of this research is an approximate confirmation of current AASHTO recommendations. The study will also be used by Caltrans to determine whether or not to adopt the FHWA 2010 Drilled Shaft design procedures or continue with the 1999 procedures. The lack of high quality drilled shaft load-test data hampered efforts to develop California specific resistance factors. A renewed focus on load-testing and adoption of cutting edge instrumentation technologies should remedy the situation in future.

For driven piles, the primary benefit is reduced foundation costs. Using the new Model 3 pile design method and the verification based LRFD framework, resistance factors are roughly 20% larger than previous factors. A 20% larger resistance factor corresponds to a 20% reduction in design load, thus leading to shorter, less expensive piles.

IMAGES

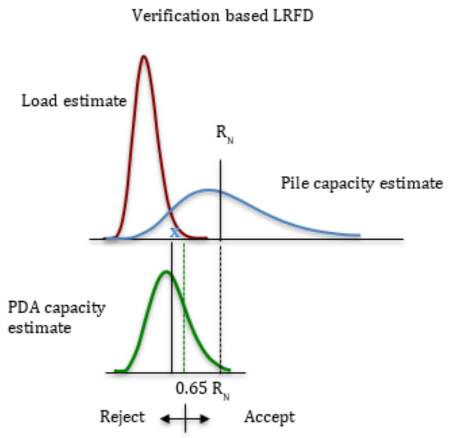

Image 1

Image 2