RESEARCH
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TECHNOLOGY TRANSFER PROGRAM

Calibration of Resistance Factors for Drilled Shafts for the New FHWA Design Method

JUST THE FACTS:

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SPR

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POINTS OF INTEREST:

Problem Addressed / Objective of Research / Mehodology Used Implementation Potential

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PROBLEM

The Federal Highway Administration (FHWA) and American Association of State Highway and Transportation Officials (AASHTO) require that all federally funded bridges including substructures be designed using the load and resistance factor design (LRFD) method after October 1, 2007. In compliance with this mandate, the Louisiana Transportation Research Center (LTRC) completed a research project to calibrate the resistance factors for driven piles and drilled shafts based on load tests available in engineering archives of the Louisiana Department of Transportation and Development (LADOTD). In this calibration, the FHWA (1999) design method recommended by AASHTO (2007) was used for drilled shaft design. Through searching the LADOTD load test database, only 16 cases of drilled shaft load tests were available at that time, among which only 11 tests were able to be used for the calibration. This number of load tests was not sufficient to perform calibration of resistance factors for LRFD. Therefore, another 15 drilled shaft tests, with subsurface soil conditions closer to Louisiana soils, were collected from Mississippi to supplement the Louisiana load test database for statistical reliability analysis. A resistance factor of $\Phi = 0.5$ was recommended for the drilled shaft design in Louisiana.

In 2010, a new design manual (Brown et al., 2010) published by the FHWA introduced a new design methodology in calculating the side resistance of drilled shafts and load settlements. The new design manual is referred to as FHWA (2010). For cohesionless soils, the side resistance is calculated using the β-method in AASHTO (2007), which was back-calculated from field test data. A more rational approach proposed by Chen and Kulhawy (2002) was adopted in the new design manual to evaluate the β value directly from K and δ values, taking into consideration the change in soil strength and in-situ state of stress with a depth below the ground surface. K can be approximated to the at-rest lateral earth pressure coefficient, K_o, which depends on the soil's effective internal friction angle and overconsolidation ratio (OCR), and can be calculated using a Mayne and Kulhawy (1982) relationship. The O'Neill and Reese normalized load transfer curves for axial load-deformation responses are no longer included in the new manual. Instead, a simple method by Chen and Kulhawy (2002) in which the normalized total axial load is compared to normalized shaft top settlement curves is proposed.

To accommodate the changes of the new design methodology plus the availability of additional new drilled shaft test cases, it becomes necessary to perform a new calibration of resistance factors to provide LADOTD engineers with the latest information on drilled shaft design with more accurate information on local soil conditions. In this research, drilled shafts' load-settlement curves will be calculated using the new FHWA design methodology to investigate its effect on calibrated resistance factors.

OBJECTIVE

The purpose of this research study is to calibrate the resistance factors for a drilled shaft design using the new FHWA design methodology based on the Louisiana experience and subsurface soil conditions. For comparison purposes, the resistance factors for both the old FHWA (1999) and the new FHWA (2010) design methods used by LADOTD will be developed at the target reliability, $\beta_T = 3$. Procedures for the implementation of the LRFD design will be recommended as well.

METHODOLOGY

The new available drilled shaft load tests in Louisiana will be collected and compiled following the same data management framework developed in a previous research study. A search in LADOTD files will be conducted to identify, collect, and analyze all drilled shaft load test reports with soil properties and in-situ testing adjacent to test shafts. The measured resistance of each drilled shaft will be determined according to the FHWA failure criterion, i.e., the shaft load at the settlement of 5 percent shaft diameter or plunge load, whichever occurs first. The predicted resistance of each shaft will be determined from the calculated load-settlement curves obtained using the FHWA (1999) and FHWA (2010) design methods used by LADOTD for drilled shaft design and analyses. A statistical analysis will be conducted to obtain the statistical parameters such as bias factors, coefficients of variation, and distribution of resistances for the different design methods. Current reliability theories such as the First Order Reliability Method (FORM) and Monte Carlo Simulation (MCS) method will be utilized to perform the calibration at different target reliability indices to determine the resistance factors for the different design methods. The knowledge presented in the Transportation Research Board Circular number E-C079 (Allen et. al., 2005) will be used in the development of load and resistance factors in this study. Recommendations of the target reliability indices and the corresponding resistance factors for both methods will be provided. Procedures for the implementation of the LRFD design will be recommended as well. All these materials will be documented to facilitate the implementation of the LRFD design for the substructures and future LRFD calibration when more local experience is available.

IMPLEMENTATION POTENTIAL

By the end of the proposed research, the total and separated resistance factors for both the new and old FHWA design methods used in LADOTD will be recommended. These recommendations will be used in at least one state project for drilled shafts. The cost/benefit analysis will compare the design results obtained by the related indices and resistance factors in this research and those recommended by the AASHTO LRFD Bridge Design Specifications (2004 ,2006).