Design of Drilled Shafts in Iowa – Validation and Design Recommendations

tech transfer summary

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RESEARCH PROJECT TITLE
Design of Drilled Shafts in Iowa – Validation and Design Recommendations

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The Bridge Engineering Center (BEC) is part of the Institute for Transportation (InTrans) at Iowa State University. The mission of the BEC is to conduct research on bridge technologies to help bridge designers/owners design, build, and maintain long-lasting bridges.

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A regional database of high-quality load test data is important for developing resistance factors for the design and construction of drilled shafts in Iowa-specific conditions.

Goal and Objectives

The goal of this project was to provide recommendations for the design and construction of drilled shafts in Iowa in accordance with the load and resistance factor design (LRFD) framework using load test data. Specific objectives were as follows:

- Expand the Drilled SHAft Foundation Testing (DSHAFT) database developed in previous research
- Conduct regression analyses on the data to develop local design methods
- Monitor and analyze settlement of production shafts
- Formulate design recommendations
- Develop design examples to illustrate applications of the design recommendations

Background and Problem Statement

The use of drilled shafts to support highway bridges in Iowa has significantly increased in recent years. Drilled shafts are more efficient and cost-effective than the commonly used driven piles for certain ground and construction site conditions.

Completed construction of drilled shafts

Drilled shafts after placement of pier caps and girders

Current design guidelines in the Iowa *Bridge Design Manual* (2024) for the LRFD design and construction of drilled shafts rely primarily on Brown et al. (2018) and the American Association of State Highway and Transportation Officials (AASHTO) *LRFD Bridge Design Specifications* (2017). These specifications have allowed the Iowa Department of Transportation (DOT) Bridges and Structures Bureau to design bridges in accordance with the Federal Highway Administration (FHWA) mandate to use the LRFD approach on all federally funded bridges.

However, the recommended resistance factors for drilled shaft design, specifically for axial loading, have several limitations. These factors were developed primarily by fitting to previously used allowable strength design (ASD) factors of safety (Brown et al. 2018) and were evaluated against the resistance factors calculated by Allen (2005) based on a national database before final values were adopted.

Additionally, the recommended factors were not specifically developed for Iowa and may not accurately reflect local geological conditions and construction practices. It is therefore important to establish resistance factors at regional levels utilizing a local high-quality load test database.

To improve design efficiency at the state level, a series of research projects was conducted to develop the DSHAFT database—a regional database facilitating the collection, storage, and efficient access of load test data from Iowa and other states—and to utilize the collected data to establish regional resistance factors that reflect the uncertainties associated with predicting drilled shaft capacity under Iowa's specific geological conditions and construction practices.

Research Description

To achieve the objectives of this research, the following tasks were carried out:

1. The previously developed DSHAFT database was expanded using test data collected from Iowa, Illinois, and Nebraska.

2. Regression analyses were conducted on data from tests performed in Iowa only to investigate the correlation between soil parameters and measured unit side resistance and develop local equations to predict resistance more accurately.

3. Production shafts at Iowa DOT bridge replacement projects were instrumented, and settlement data were collected via surveying and analyzed to gain insight into the performance of drilled shafts designed in accordance with current Iowa DOT design procedures.

4. The findings from these analyses were utilized to develop final design recommendations as well as design examples illustrating implementation of the recommendations

Key Findings

- The results from the regression analyses of Iowa data indicate that a linear correlation between soil parameters and measured unit side resistance is the best fit for most soil types.

- The resistance factors recommended for implementation generally show significant improvements over those recommended by the AASHTO *LRFD Bridge Design Specifications* (2017).

- The collection of settlement data from production shafts during bridge construction using surveying methods proved to be challenging, as evidenced by some inconsistencies in the collected data.

- Design recommendations were formulated based on the findings, and design examples were developed to illustrate application of the design recommendations.

Recommendations for Future Development

To continuously refine the resistance factors developed in this and previous research and to improve the efficiency of drilled shaft design in Iowa, the following recommendations are made:

- Continuously update the regional drilled shaft test data in the DSHAFT database as additional data become available.
- Conduct detailed soil and rock investigations at demonstration shafts beyond the typical standard penetration testing.
- Verify the recommended resistance factors by performing controlled O-cell load tests in Iowa and making appropriate revisions.
- Ensure that any future load tests are conducted until large displacements or complete geotechnical failure are achieved.
- Develop and recommend regional resistance factors for end bearings in cohesive and cohesionless soils as additional data become available.
- Using additional data from load tests performed in Iowa, conduct further regression analyses to improve correlations between soil parameters and measured resistance in order to increase the accuracy of drilled shaft capacity predictions in Iowa geological conditions.

Implementation Readiness and Benefits

Design recommendations based on the findings of this research are presented in Chapter 5 of the final report, and design examples illustrating application of these recommendations are presented in the appendix.

The design recommendations developed in this research provide the Iowa DOT with a design methodology to more accurately predict the capacity of drilled shafts during bridge design.

References

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