Resistance Factors for Drilled Shafts with Minor Defects

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Abstract

Drilled shafts are among the most common, and favorable type of deep foundation solutions for heavy structures and bridges. Their main role is to transfer vertical, and or combined loading from superstructures through weak, near surface to deeper soil or rock. Their cost effectiveness, and relative ease of construction gained them more ground in the deep foundation market. Yet due to their nature of construction and the environment in which they operate, minor and/or major anomalies do occur. Thorough, and well-performed quality assurance techniques including Non-Destructive Evaluation (NDE) methods are believed to reveal major anomalies. Studies have shown that minor defects can comprise up to 15 percent of the cross section and go undetected. Consequently, drilled shafts still suffer from minor anomalies that go undetected by the regular NDE methods. Hence, this study aims at finding structural resistance factors that take these minor anomalies into consideration when designing a drilled shaft. Nevertheless, the construction and thorough assessment of a structurally sound drilled shaft is a goal yet to be achieved by contractors, and owners respectively.

1. Introduction

Current design codes (AASHTO, FHWA Design Manual) treat drilled shafts structurally the same way as structural beam-columns. No study has been directed towards identifying and dealing with their differences from the phase of construction to their assessment to the environment in which they operate. Besides identifying these differences, this study ultimately aims at finding resistance factors taking these factors into consideration. The study is based on field tests, scaled down structural lab tests, full-scale structural tests as well as finite element, and computer modeling analysis.

2. Testing Program

Field Tests: Six full-scale drilled shafts of 0.76 m diameter and 7.62 m length were constructed at the University of Houston NGES site. One reference, and five with pre-installed minor defects. These tests served to determine the maximum size of anomaly that can go undetected by various NDE methods. And estimation of the percent reduction in lateral load capacity due to the presence of these anomalies. Other studies confirmed these findings, Baker et al (1993), Samman and O'Neill (1997), and Amir (1997). All have found that the maximum size of anomaly that can go undetected could be up to 15 percent of the cross section. According to the load test results the reduction in ultimate load was 10 percent. This result was based on lateral load-deformation relationship drawn from the tests. Reanalysis of the results using a numerical computer model, and based on uniform soil conditions and ideal shaft dimensions revealed a reduction of 24 percent in the ultimate lateral load capacity.

Lab. Testing (Scaled Down): Nineteen scaled concrete shaft specimens were tested in the structural lab at the University of Houston. Three different loading conditions were considered, namely pure bending, pure axial load, and combined loading. The specimens had a diameter of 0.305 m and were tested in a closed loop, servo-controlled MTS machine with a capacity of 11,125 kN. Several variations in anomalies were considered, such as size, position of anomaly. Also corrosion of rebars, and cage offset, and spiral spacing were investigated. The main conclusion drawn from that study was that the reduction in ultimate moment was about 22 percent for an anomalous specimen with 15 percent reduction in cross section.

Full-Scale Lab. Tests: Two full-scale concrete shafts were tested at the FHWA Turner-Fairbanks Research Lab. in McLean, Virginia. The first was a reference having a uniform cylindrical cross section, while the second shaft had a 15 percent reduction in cross section at the point of maximum moment. The results obtained from these full-scale tests showed a decrease of 27 percent in the ultimate bending capacity.

3. Computer Modeling

Simple computer programs as well as rigorous FEM codes are employed to analyze and calibrate these models to the results obtained from the tests. Hence making possible extrapolation into various conditions and superposition of anomalies. This calibration is currently underway.

4. Conclusions

According to the test results, and considering a worst-case scenario, minor anomalies affect the structural bending capacity by 24 percent. Combinations of anomalies could produce more reduction in capacity. New interaction diagrams with new resistance factors are currently being developed using reliability-based methods.

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6. References

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