CENTER FOR TRANSPORTATION RESEARCH

PROJECT SUMMARY

Texas Department of Transportation

0-6953: Strut-and-Tie Modeling and Design of Drilled Shaft Footings

Background

The strut-and-tie method (STM) is a design method intended to provide realistic strength and detailing requirements for deep structural members subjected to non-linear distribution of strain by considering idealized flow of internal forces. Axially loaded concrete struts and ties are used to represent the compression and tension fields in structural members, and it forms three-dimensional (3D) structure of strut-and-tie models in drilled shaft footings. However, current STM provisions were formulated based on research into deep structural members (such as deep beams) designed with two-dimensional (2D) strut-and-tie models, and there are no experimentally verified design guidelines for designing the deep structural members with 3D strut-and-tie models.

The lack of guidance for even the legacy design methods (sectional models for flexure, one- and two-way shear) results in a variation of the geometric proportions and reinforcement details used in drilled shaft footings in the field. Additional complications arise from the application of current 2D-based STM design provisions to the design of drilled shaft footings. This design approach results in overly conservative detailing of the reinforcement cages on drilled shaft footings, making them highly difficult and expensive to fabricate. A full transition to strut-and-tie modeling can achieve uniform design and detailing of drilled shaft footings; therefore, this project identified experimental research needs regarding the application of 3D strut-and-tie models to the design of drilled shaft footings.

What the Researchers Did

To clarify the current state of research and the limitations of applying 3D STM to the design of drilled shaft footings, a series of international provisions and literature were reviewed. A database of 147 drilled shaft footing tests was established from the review. Furthermore, 35 drilled shaft footings designed and constructed by TxDOT were also reviewed to determine design parameters for the experimental program of this study.

The experimental program was planned with large-scale structural testing of drilled shaft footings subjected to various loading scenarios. The designed test specimens were almost half-scale of the actual size of drilled shaft footings and the largest drilled shaft footings ever tested in the history of drilled shaft footing research. Nineteen test specimens were fabricated during the three test phases comprising the experimental program, and tested with selected design parameters to investigate the behavior of drilled shaft footings and fill the knowledge gap in the application of the 3D STM in drilled shaft footings.

To supplement the test results, additional parametric studies were conducted with a series of numerical analyses. The design parameters that

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could not be covered in the experimental program could be investigated through parametric studies.

Lastly, 3D STM guidelines for designing drilled shaft footings was proposed by refining the 2D STM guidelines proposed by TxDOT Project 0-5253 and the drilled shaft footing design example proposed by TxDOT Project 5-5253-01, based on the results and insights obtained from the experimental program and parametric studies. A design example of a drilled shaft footing was also provided to remove ambiguities in the application of the proposed 3D STM guidelines in designing drilled shaft footings.

What They Found

The research team clarified the effect of each design parameter on the behavior of drilled shaft footings using both experiments and numerical analyses. On the basis of the results, the research team proposed 3D STM design guidelines for drilled shaft footings.

The proposed guidelines contain recommendations for a 3D nodal geometry of the nodes at the bearing faces of a drilled shaft footing, modifications of factors, and the configuration of bottom mat reinforcement, as well as identification of critical sections for anchorage requirements in the column and drilled shaft reinforcement. Implementation of these proposed recommendations increases the accuracy of predicting the ultimate capacities of previous drilled shaft footing tests included in the database, improving on the accuracy achieved using the recommendations of TxDOT Project 5-5253-01. Furthermore, the proposed recommendations did not generate any unconservative predictions, and the strength ratios predicted from the proposed recommendations were consistent with the other design methods (modified compression field theory and 2D STM) employed in the current AASHTO Load and Resistance Factor Design (LRFD) manual.

The research team also drafted a set of revisions to the most recent edition of the AASHTO LRFD based on the recommendations made for the 3D STM of drilled shaft footings.

What This Means

This research provides an extensive experimental database of large-scale drilled shaft footings subjected to various loading scenarios. The database is a valuable reference for future research conducted on drilled shaft footings.

Furthermore, the proposed 3D STM guidelines based on the comprehensive research work can provide a uniform and consistent design for drilled shaft footings designed using 3D STM. The recommendations comprising the guidelines resolved existing uncertainties and ambiguities in the application of the 3D STM to designing drilled shaft footings. The recommendations could be employed when designing other structural members with the 3D STM.

The provided design example of a drilled shaft footing covers design procedures of various loading conditions applied to drilled shaft footings. It will help designers to understand the proposed 3D STM guidelines. Implementation of the proposed 3D STM guidelines by designers will lead to safe, consistent design and detailing of drilled shaft footings throughout Texas.

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