CENTER FOR TRANSPORTATION RESEARCH

PROJECT SUMMARY

Texas Department of Transportation

0-6953-01: Strut-and-Tie Modeling and Design of Drilled Shaft Footings under Biaxial Eccentric Loading

Background

Strut-and-tie method (STM) is a practical design tool for deep structural members that simplifies their internal force flow into idealized struts and ties. Typically, the configuration of the strut-and-tie models developed in drilled shaft footings forms three-dimensional (3D) shapes. TxDOT Project 0-6953: 3D Strut-and-Tie Modeling for Design of Drilled Shaft Footings established a series of design recommendations for drilled shaft footings using the 3D STM based on large-scale tests and numerical analyses. However, this comprehensive research was limited to uniaxial loading scenarios, and the design example proposed by the research was also primarily based on the recommendations for drilled shaft footings subjected to uniaxial loads. The design example also includes some biaxial eccentric loading cases, but they were designed with the simplest 3D strut-and-tie model, similar to that of uniaxial compression-only loading.

On the other hand, in-practice drilled shaft footings are also designed for biaxial eccentric loading cases that induce tension at one corner of the column or one of four drilled shafts. Due to the complexity of these loading conditions and the lack of research on 3D strut-and-tie models of drilled shaft footings under them, the recommendations proposed by Project 0-6953 cannot be directly applied when designing the footings under biaxial eccentric loading. These limitations hinder the application of the 3D STM for a consistent design of drilled shaft footings subjected to various loading conditions. The research team therefore set out to refine the 3D STM design recommendations for drilled shaft footings to cover the biaxial loading scenarios.

What the Researchers Did

The research team reviewed the load cases of several constructed drilled shaft footings in bridge projects designed by TxDOT and their consultants to clarify the proportion of biaxial eccentric load cases to total load cases. They conservatively refined the design recommendations for drilled shaft foundations proposed in Project 0-6953 to allow the application of the 3D STM for biaxial eccentric loading. The refined features are summarized below.

First, the team used an equivalent force system with a single strut and single tie to minimize the calculation effort required to establish the system based on the actual strain and stress distribution corresponding to the applied loading. From the proposed equivalent force system, 3D strut-and-tie models for drilled shaft footings under biaxial eccentric loading scenarios were developed that consider the internal force flow of the footings. The complicated stress distribution over the

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column section was simplified to conservatively define the bearing face of the CCC node. Lastly, the team proposed a methodology to define the 3D nodal geometry of the CCC node by subdividing the simplified bearing face and multiple struts acting at the CCC node.

This project supplemented the drilled shaft footing design example of Project 0-6953 by designing the same footing with two biaxial eccentric load cases using the refined design recommendations.

What They Found

This research identified that few studies on the application of the 3D STM to drilled shaft footings subjected to biaxial loading have been conducted. However, many biaxial load cases are considered when designing in-practice drilled shaft footings.

While this project has added some refinements, most of the design recommendations proposed by Project 0-6953 were still applicable for designing drilled shaft footings under biaxial loading. Therefore, the overall design procedure employed for this research's design example was consistent with that of the uniaxial load cases covered in that project.

The drilled shaft footing in the refined and updated design example was confirmed to be safe even under the most extreme of the load cases reviewed.

What This Means

As a follow-up project to TxDOT Project 0-6953, this research developed a drilled shaft design example under the most complicated loading scenario: biaxial eccentric loading. Due to the lack of research on the behavior of drilled shaft footings under biaxial loading, the research team conservatively refined the design recommendations. The design example from this research, which was safe even for extreme biaxial load cases, validates the conservativeness of the proposed refinements.

The refined design recommendations of this study allow for the design of drilled shaft footings with complicated internal force flow using the 3D STM. Using the recommendations of this project as well as those developed in Project 0-6953, drilled shaft footings can be designed and detailed consistently, regardless of the applied loading conditions.

For More Information

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