IFCEE 2021

GSP 323

Installation, Testing, and Analysis of Deep Foundations

Selected Papers from the
International Foundation Congress and Equipment Expo 2021
Dallas, Texas ■ May 10–14, 2021

Edited by

Chadi El Mohtar, Ph.D.;
Stacey Kulesza, Ph.D.; Tugce Baser, Ph.D.;
and Michael D. Venezia, P.E.

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SELECTED PAPERS FROM SESSIONS OF THE INTERNATIONAL FOUNDATIONS CONGRESS AND EQUIPMENT EXPO 2021

May 10–14, 2021
Dallas, Texas

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Deep Foundations Institute
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The Geo-Institute of the
American Society of Civil Engineers

EDITED BY
Chadi El Mohtar, Ph.D.
Stacey Kulesza, Ph.D.
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Preface

This is the first volume of four Geotechnical Special Publications (GSPs) containing papers from the 2021 International Foundations Congress and Equipment Expo (IFCEE21) held in Dallas, Texas on May 5–10, 2021. This volume includes a wide variety of topics that can generally be split into two collections: 1) Piles, Shafts & Load-Bearing elements, and 2) Deep Foundations. The first collection incorporates papers pertaining to varying types of deep foundation elements. The second collection of papers features topics related to engineering design, numerical analyses, load transfer mechanisms, LRFD, NDT, and thermal & energy aspects associated with deep foundation elements. The IFCEE conference series combines a technical conference and equipment show dedicated to the design and construction of foundation systems, using the latest geoengineering and geoconstruction technologies and practices. The IFCEE conference series is a one of a kind event that attracts attendees from around the world for the world's largest equipment exposition dedicated solely to the deep foundations industry. This Congress combined the 2021 annual meetings of ASCE's Geo-Institute, the International Association of Foundation Drilling (ADSC), the Pile Driving Contractors Association (PDCA) and the Deep Foundations Institute (DFI). This event was the fourth Congress in the IFCEE conference series, following the successful 2009, 2015, and 2018 meetings, in which these leading geotechnical and geotechnical-related organizations joined together for a single and singular annual congress. IFCEE'21 provided an international forum despite the unusual times to discuss technological advances, case histories, and present challenges and emerging topics related to geotechnical and foundation engineering. The congress was attended by a wide range of geo-professionals including engineers, contractors, academicians, equipment manufacturers, geo-technologists, researchers, and service, material and tooling suppliers.

This publication culminates two years of effort by the technical planning committee whose focus has been to continue the success of the previous meetings in the IFCEE conference series. Many individuals are responsible for the content of this volume, all of whom served in the efforts to maintain the standard set by previous proceedings. An international call for papers and a rigorous peer review process yielded 189 accepted technical papers, that were presented in 36 sessions, in addition to invited keynote presentations. Papers were reviewed in accordance with ASCE GSP standards. Accordingly, each paper was subjected to technical review by two or more independent peer reviewers. Publication requires concurrence by at least two peer reviewers.

The year 2020 has opened a global outpouring for a change, exposing some of the most insidious elements of the health and societal regime to public examination. Despite the difficulties, the Editors worked hard with the members of the organization committee and session chairs closely. The Editors would like to express their appreciation for having been provided the opportunity to be a part of this Congress' organization, their sincere thanks to the numerous session chairs and reviewers, and they hope that these proceedings will be of use to the geotechnical engineering community for many years to come.

The Editors,
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Experimental Studies of Rock Socketed Piles with Different Transverse Reinforcement Ratios

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ABSTRACT

Piles socketed into rock are frequently utilized to carry large loads from long-span bridges and high-rise buildings into solid ground. The pile design is derived from internal shear and moment magnitudes following code recommendation and numerical predictions. Little experimental data exist to validate code prescriptions and design assumptions for piles embedded in rock. To help alleviate the lack of large-scale test data, the lateral response behavior of three 18-in. diameter, 16 ft long, reinforced concrete piles was evaluated. The pile specimens were embedded in a layer of loose sand and fixed in "rock-sockets," simulated through high strength concrete. The construction sequence simulated soil-pile interface stress conditions of drilled shafts. The pile reinforcement varied to satisfy the internal reaction forces per (1) code requirements, (2) analytical SSI predictions, and (3) structural demands only. The pile specimens were tested to complete structural failure and excavated thereafter. Internal instrumentation along with crack patterns suggested a combined shear-flexural failure, but do not support the theoretically predicted amplification and de-amplification of shear and moment forces at the boundary, respectively.

INTRODUCTION

Rock socketed, bored piles are frequently used to transmit large lateral forces to the ground in cases where the soil overlying the rock layer is not capable of providing adequate lateral restraint. Lateral design of rock socketed drilled shafts is commonly based on the beam on an elastic foundation concept (*p-y* curve). Unfortunately, and primarily due to the expensive costs associated with large scale testing, laterally loaded rock-socketed piles have been given limited experimental attention, resulting in a lack of empirical validation of analysis and design methods. Previous experimental research predominantly focused on geotechnical response aspects of rock-socketed piles and the derivation of *p-y* relationships for rock materials (e.g., Frantzen and Stratten, 1987, Carter and Kulhawy, 1992, Dykeman and Valsangkar, 1996, Gabr *et al.*, 2002, Parsons *et al.*, 2010 and Guo and Lehane, 2016).

Impedance contrasts between strong rock layers and softer surface soils have historically challenged design engineers in adequately capturing the internal pile response behavior. Particularly, predictions using Winkler-type foundation analyses yield abrupt changes in the pile's moment profiles which translate into amplified shear forces at the interface boundaries of stiff and soft soil layers. This amplification originates from the differentiation of the fourth order differential beam equation. The foundation engineering community has experienced much

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