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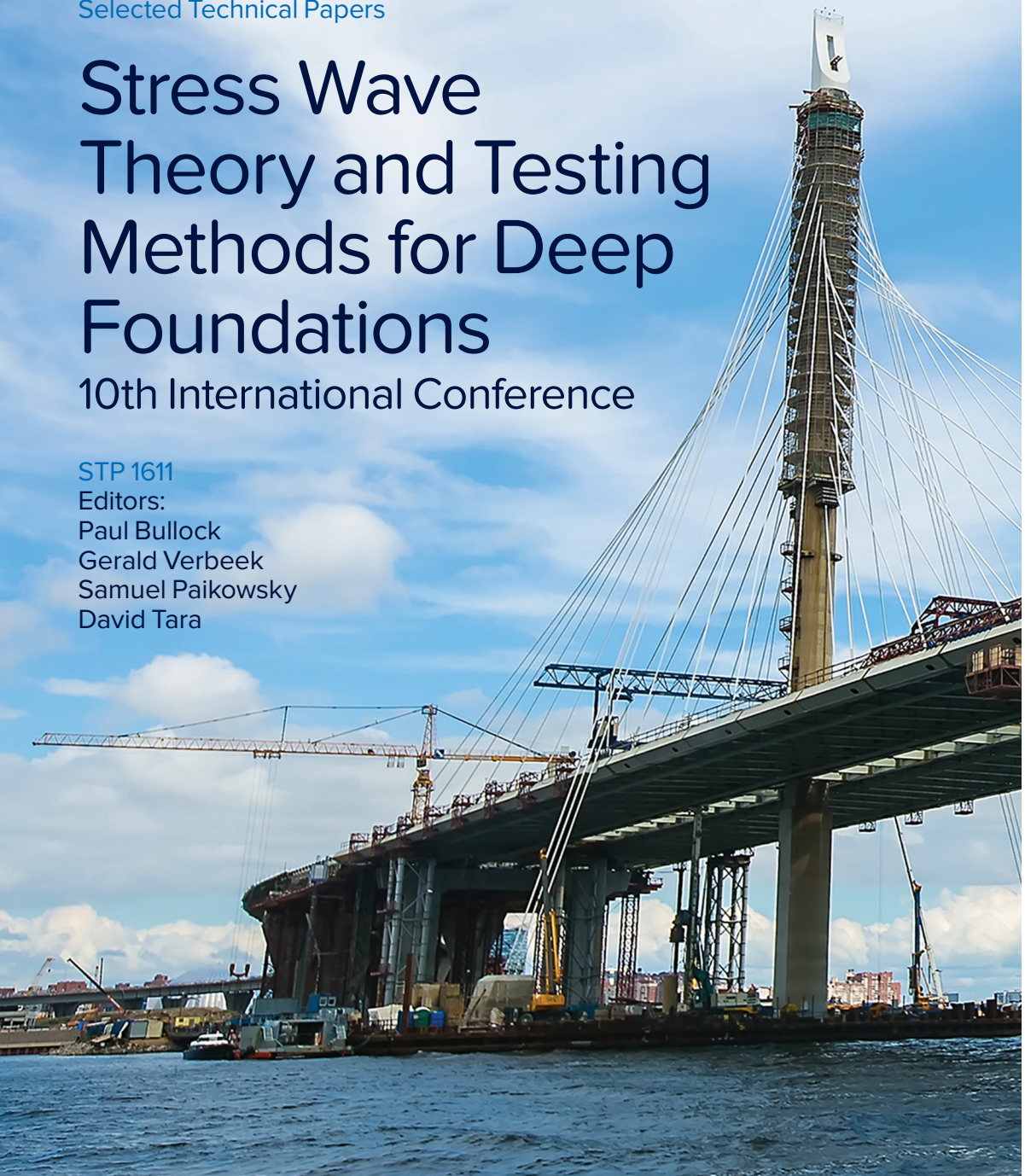
Selected Technical Papers

Stress Wave Theory and Testing Methods for Deep Foundations

10th International Conference

STP 1611
Editors:
Paul Bullock
Gerald Verbeek
Samuel Paikowsky
David Tara



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Stress Wave Theory and Testing Methods for Deep Foundations: 10th International Conference

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Foreword

THIS COMPILATION OF Selected Technical Papers, STP1611, *Stress Wave Theory and Testing Methods for Deep Foundations: 10th International Conference*, contains peer-reviewed papers that were presented at a symposium held June 27–29, 2018, in San Diego, California, USA. The symposium was sponsored by ASTM International Committee D18 on Soil and Rock and Subcommittee D18.11 on Deep Foundations.

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Overview

Deep foundations (piles) support bridges, large buildings, and many other structures through weak ground to bear on competent soil and rock. Although piled foundations are believed to date back 6,000 years, design challenges with complex pile–soil interaction and site variability remain. Early cultures developing along waterways relied on timber piling, likely improving their "design" from past failures. Engineers eventually began static testing to eliminate surprise. The twentieth century advanced capacity analysis and measurements for driven piles using stress wave concepts. Cast-in-place piles were also developed. With static capacity tested in excess of 31,000 tons, these large structural elements require both capacity and integrity testing for reliability.

ASTM International, through Subcommittee D18.11 on Deep Foundations, standardizes test methods for support of deep foundation design and quality control. The Technical Committee D18 on Soil and Rock has sponsored three past Symposia to develop deep foundation standards: STP444 (1969), STP670 (1979), and STP1089 (1991). An independent organizing committee held the 1st International Seminar on the Application of Stress Wave Theory to Piles in Sweden (1980), which continued to the 9th International Conference in Japan (2012).

The 10th International Conference on Stress Wave Theory and Testing Methods for Deep Foundations—sponsored by ASTM International in San Diego, CA, during June 27–29, 2018—encompassed all testing methods for deep foundations. Presenters traveled to San Diego from as far as Singapore and Australia. Five keynote lectures, thirty-eight additional technical presentations, and a panel discussion were included in the conference. The co-chairs accepted a total of forty-one papers for presentation in this Selected Technical Papers (STP1611).

Dr. Frank Rausche (Pile Dynamics) began the conference with a keynote lecture reviewing damping and rate effects for a range of pile penetration rates from static to dynamic tests, focused on high plasticity soils. He presented case studies that overestimated static capacity in these soils, requiring a reduction factor of 0.7 on the static capacity calculated by signal-matching analysis for high-strain dynamic tests (ASTM D4945). He also recommended adjusting test energy to limit set per blow to 2.5 mm. Static tests were recommended to verify rate effects. Dr. Rausche prepared a technical paper with his co-authors Patrick Hannigan and Camilo Alvarez.

The keynote lecture by Dr. Samuel Paikowsky (University of Massachusetts) focused on the use of finite element method (FEM) analyses for special high-strain dynamic testing situations with significant three-dimensional wave propagation.

These include unplugged or partially plugged pipe piles, irregularly shaped piles, and nonuniform piles. He showed examples for pipe piles and a drilled rock socket. Dr. Paikowsky concluded that violating the typical one-dimensional assumptions of uniformity and slenderness generally did not affect overall signal-matching static capacity, but did change the distribution of resistance and stresses. Details can be found in his technical paper.

Dr. Evelyn Heins (Hamburg University of Technology) presented an FEM study of high-strain dynamic testing on large-diameter, tubular steel piles driven open-ended to support offshore wind turbines. An axisymmetric numerical simulation was used to investigate stress and pore pressure propagation through saturated sand within and adjacent to the pile. Complex, nonlinear, pile-soil interaction resulting from the stress wave in the pile was found to affect the mobilized end bearing. High-frequency driving improved the penetration rate. An inverse analysis of dynamic test data for capacity showed promise for further development. Dr. Heins and her coauthor, Dr. Jürgen Grabe (Hamburg University of Technology), prepared a technical paper with additional details.

The editors are grateful that Dr. Soon-Hoe Chew (National University of Singapore) could respond to a last-minute keynote request on rapid load testing in Singapore and Malaysia, where over two hundred tests have been performed in the past five years. He provided an overview of different rapid test methods and unloading point analysis. Dr. Chew discussed rate effects that are important for cohesive soils and test requirements adopted from the Eurocode. Rapid testing is now accepted as a viable part of a foundation test program in Singapore and Malaysia, with static test confirmation, providing advantages in cost, time, and safety. A short deadline did not allow Dr. Chew to prepare a technical paper for the STP, but he has published similar papers on the topic.

Dr. Bengt Fellenius (University of Ottawa, ret.) presented the final keynote, a retrospective on the development of high-strain dynamic testing and analysis. He provided examples of wave equation analysis and considerations for quake, pile wall thickness, pile damage, and pipe plugging. He also showed examples of signal-matching agreement by different engineers and cautioned attendees to compile test results together to properly interpret multiple tests on the same pile. His sixty years of experience provide inspiration and validation to dynamic testing. Though he did not prepare a technical paper, past publications covering these topics are available at www.fellenius.net.

The balance of the conference was organized in five main sessions. The *Cast-in-Place Pile Testing* session included papers on reaction pile effects for static tests, rock socket capacity, dynamic testing, and in-hole slurry testing. The *Pile Integrity* session included papers on quality control and low-strain dynamic testing and analysis, with both conventional and newer forms of excitation. *Rapid Load Testing* included papers describing different rapid tests and analysis methods, and comparing static vs. rapid load test results in Southeast Asia.

The *Stress Wave Concepts* session had thirteen papers accepted on a variety of topics, including measurement locations, increased wave speed in steel pipe, and two papers on vibratory driving. Several papers addressed improved signal matching and recommended capacity verification by static testing. Energy transfer, pore pressures, and improved modeling of stress waves were also considered. Both this session and the final *Case Studies* session referenced offshore testing of large monopiles, which might be considered an overriding theme in this conference. Case studies were presented for steel pipe, H-piles, and concrete piles bearing on soil, till, and rock. Authors also discussed codes, pile setup, and rebound.

A panel discussion on "Justifying the Cost of Testing" took place on Thursday afternoon and engaged the audience with panel members Gerald Verbeek, Samuel Paikowsky, Patrick Hannigan, and Paul Bullock. The members recognized the value of testing services for site-specific problems. However, all agreed that increased testing leads to more economical foundations when integrated into a design approach that begins with site investigation, continues to design validation, and concludes with quality control. Because testing increases reliability, foundations can use fewer, shorter, smaller piles. Engineers must communicate these concepts to the client early in a project to be effective. Typical project savings are five to ten times the cost of testing.

Many people worked together to prepare this conference and STP. On behalf of the co-chairs and myself, we extend our grateful recognition to the authors who prepared the papers in STP1611 and to the peer reviewers who helped edit them. The keynote lecturers deserve special recognition for their valuable contribution to the engineering profession. We also recognize and thank ASTM staff and D18 leadership, who gave up their lunch hours to keep us on schedule and worked tirelessly to help this conference succeed.

Paul J. Bullock

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