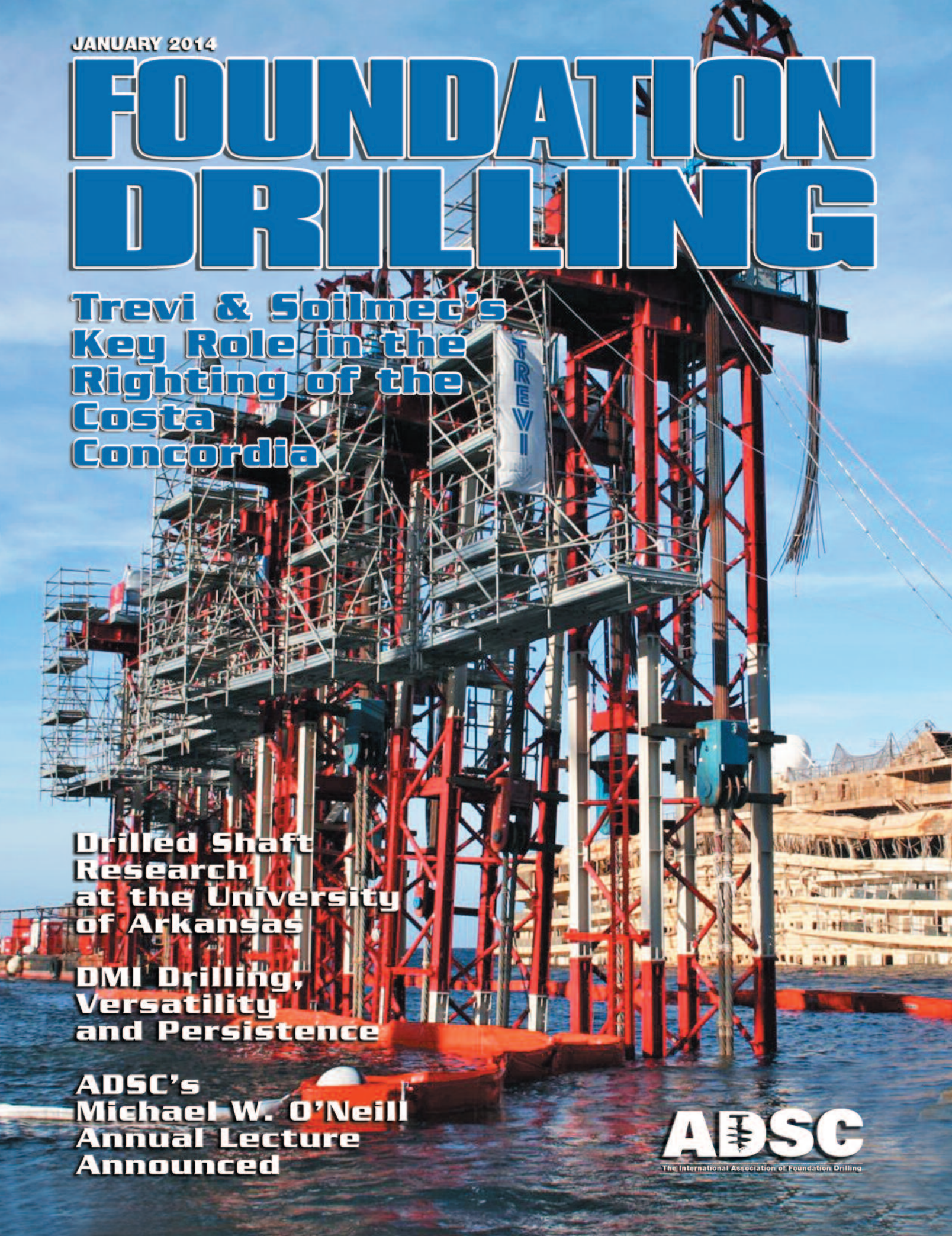
JANUARY 2014

FOUNDATION DRILLING



Trevi & Soilmec's Key Role in the Righting of the Costa Concordia

Drilled Shaft Research at the University of Arkansas

DMI Drilling, Versatility and Persistence

ADSC's Michael W. O'Neill Annual Lecture Announced

ADSC
The International Association of Foundation Drilling

ADSC to Assist in University of Arkansas Drilled Shaft Research Project

By Peggy Hagerty Duffy, P.E., ADSC's Technical Adviser

The ADSC has long been acknowledged as the industry leader for its commitment to, and support of, original research in the technologies represented by the association. These include research activities focusing on drilled shaft foundations, anchored earth retention systems, soil nails, and micropiles. Over the past 40 years and through the Industry Advancement Fund, the International ADSC, and its nine regional and international chapters, the association and its members have provided over $10 million in funds and contributions-in-kind to support vital research that has advanced the industries beyond measure. The program described in the following article is one of the latest examples of the association's commitment to this important area of emphasis. (Editor)

The nature of geotechnical engineering is somewhat inexact. To some, this might be the understatement of the year. In the realm of structural engineering, steel is steel, concrete is concrete, and the behavior of a structure can be determined whether it is in Bangor, Maine, or Mobile, Alabama. But the characteristics of foundation support materials vary widely, and the interactions among steel and concrete and those materials are as different as the millions of different geological conditions in which soil and rock were formed.

The challenge with designing safe, cost-effective foundation systems is to determine accurately soil and/or rock strength and behavior characteristics, and to determine whether the strength and stiffness parameters assumed for design were appropriate for the actual in-situ performance of the foundation system. Many subsurface exploration programs are so limited that sweeping assumptions must be made in design, leading to high costs needed to cover potential inaccuracies. In many design projects a minimal number of borings with standard penetration testing are the extent of the standard exploration program. In addition, most often load testing is not performed on the completed foundation system, therefore no real correlation can be made between the design assumptions, vague though they may be, and the in-situ behavior of the system when it is loaded. The only conclusion that is reached on a regular basis is that the design was adequate because the structure didn't collapse.

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NDT expert ADSC Technical Affiliate Member, Bernie Hertlein (left) and Sean B. Brady, Senior Instrumentation Specialist at GEI Consultants, Inc., who donated their services to the project.

Due to the lack of data about foundations not used frequently in a certain area, these generalized design assumptions often result in narrow scope when selecting foundation type. This presents another layer of unknowns. For many projects potentially suitable foundation types are not even considered. Obviously, the lower the number of options for solving a problem, (in this case a design), the lower the possibility of maximizing cost-effectiveness.

Mandatory implementation of the American Association of State Highway and Transportation Officials

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The forest provides a picturesque background for soil sampling.

(AASHTO) Load Resistance Factor Design (LRFD) standards for bridge projects has made the design process seem even more complicated on transportation projects than when allowable stress analysis (ASD) was the norm. As a result, many state highway departments have been expanding exploration programs and performing full-scale load tests on completed projects to amass a database of foundation performance in various geological environments. This is intended to aid in selecting appropriate resistance factors, including factors applicable in only selected regions.

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In Arkansas, geotechnical explorations for the Arkansas Highway and Transportation Department (AHTD) traditionally have consisted only of standard penetration testing with Shelby tube samples obtained for minimal laboratory testing. Full-scale load tests of drilled shaft foundations have not been conducted frequently, therefore correlations could not be made between the soil and rock data, (scarce that it was), and the actual load-carrying performance of the completed foundation system. To complicate matters, the northeastern portion of the state is located in the New Madrid fault zone, thus adding seismic concerns to the mix. There really is no comprehensive collection of data on the behavior of drilled shafts in this specific environment during seismic events. As such, drilled shaft foundations are rarely used for transportation projects in the state of Arkansas, despite the fact that utility transmission projects all over the state are being completed successfully and economically using drilled shafts.

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In order to improve the AHTD design process **Dr. Rick Coffman**, of the University of Arkansas, recognized the need for more complete data. He proposed a two-phase plan of research for test sites to the AHTD: an in-depth subsurface exploration program using methods more comprehensive and diagnostic than standard penetration testing; and full scale load testing on drilled shafts to be installed at each site. In order to correlate exploratory test results with strength characteristics, strength data obtained in the explorations and laboratory testing phase would be compared to actual resistance behavior exhibited in the load tests. The plan would be implemented at three sites intended to represent most general subsurface conditions throughout the state of Arkansas. Data obtained from these sites would form a basis for a database of conditions across the state. Future projects would add to the database. The underlying expectation was that the load tests would demonstrate that drilled shafts could be a suitable and cost-effective foundation type for many projects within the state.

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In 2010 Dr. Coffman approached the Drilled Shaft Committee of the ADSC and inquired as to whether the association was interested in participating in the project. The potential benefit to association members was obvious. In April, 2011, the committee pledged their support in a Letter of Commitment written by former ADSC Operations Director Tony Marinucci. The AHTD subsequently accepted Dr. Coffman's proposal and allo-

Soil samples evaluated.

cated $387,800 for the project. The ADSC's contribution was included as in-kind drilling, labor for concrete and steel placement, and materials (concrete and steel). Osterberg load cells were to be provided at cost by ADSC Associate Member **Loadtest, Inc.**

The first phase of the project involved site selection. The three sites were intended to represent three geological conditions prominent in Arkansas:

The underlying expectation was that the load tests would demonstrate that drilled shafts could be a suitable and cost-effective foundation type for many projects within the state.

1) Bedrock material consisting of limestone, sandstone, and/or shale common in western and northern Arkansas,
2) Clay deposits common in southwestern and eastern Arkansas, and,
3) Clay underlain by sand deposits common in northeastern Arkansas. Three sites were evaluated and were deemed to appropriately represent the geological profiles. The sites were located in Siloam Springs, Turrell, and Monticello. The Turrell site is located within the New Madrid fault zone.

Once the sites were confirmed, Dr. Coffman and graduate students from the University of Arkansas oversaw subsurface investigations at each site using equipment from the AHTD, the Missouri Department of Transportation, and the University of Arkansas. Fifteen soil test borings were advanced at each of the three sites. Six borings were made using a conventional drill rig to perform standard penetration testing and to obtain Shelby

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The AHTD subsequently accepted Dr. Coffman's proposal and allocated $387,799.74 for the project. The ADSC's contribution was included as in-kind drilling, labor for concrete and steel placement, and materials (concrete and steel). Osterberg load cells were to be provided at cost by ADSC Associate Member Loadtest, Inc.

tube samples for laboratory testing. Six borings were advanced using standard penetration testing in sands, Osterberg hydraulic fixed-piston sampling in clay, Pitcher barrel sampling in stiff clay or soft rock, and a double swivel core barrel in hard rock. Five borings were made at sites containing clay using cone penetration test methods.

Laboratory testing on the samples obtained from each site also followed both the standard limited testing regime and a more expanded round of tests. As is usual for AHTD projects visual classifications, Atterberg limits tests, moisture content tests, unit weight determinations, grain size analyses, calcium

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All terrain soil sampling rig.

carbonate tests, and specific gravity tests were completed. In addition, direct shear, unconsolidated-undrained triaxial compression, constant-rate-of-strain consolidation, direct simple shear, and consolidated-undrained triaxial compression and extension tests were conducted.

During 2013, Dr. Coffman and his team spent a number of months performing the laboratory testing and reviewing and analyzing the test data. Each site now has a profile, which is a characterization that can be used to predict the behavior of drilled shaft foundations in each environment. Pending is the second half of the correlation: "Road-testing" the assumptions, so to speak. Three drilled shafts are being constructed at each site by ADSC contractor members, complete with Osterberg load cells, so that accurate data can be obtained about how the shafts behave when loaded. The load test data will provide information on how the subsurface materials resist the loads from the drilled shaft, therefore providing a basis for comparison between the inferred actual properties and the strength assumptions made from the laboratory and field test data. In addition, cross-hole sonic logging will be performed on each shaft to confirm successful construction of the shafts as designed.

University of Arkansas students observe Bernie Hertlein at work.

At press time, ADSC Contractor Member **Aldridge Drilling, Inc.**, of Libertyville, Illinois, had completed the first site in Siloam Springs. ADSC Contractor Member **McKinney Drilling Company**, of Memphis, Tennessee, was set to begin the second site in Turrell.

Construction and testing on each site and the results and conclusions of the study will be detailed in upcoming issues of *Foundation Drilling* magazine. Future articles also will track the response from the AHTD to the research, as well as changes, if they occur, in the Department's design policies.

Peggy Hagerty Duffy is the ADSC's Technical Advisor. She is the President of Hagerty Engineering, Inc., and a Principal in Construction Solutions, LLC, Jeffersonville, Indiana.

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Soil sampling rig at other location on site.