DID YOU KNOW? *Newsletter No. 108 - December 2023*

The Kola Superdeep Borehole SG-3 retains the world record as the deepest drilled hole measuring 40,230 ft (12,262m) deep.

GRL Engineers, Inc. Pile Dynamics, Inc.

Recent Advances in Drilled Foundation Structural Integrity Methods

by Michael Morgano, P.E., Pile Dynamics, Inc.

In the deep foundation industry, the vertical alignment and base cleanliness of drilled shafts (also known as "bored piles") are critical parameters that can significantly influence the overall performance of the foundation. Achieving and maintaining verticality is a process requiring experience and expertise, and any deviation from the intended vertical alignment can have profound consequences on the stability and load-bearing capacity of the structure. For shafts designed to resist loads using end bearing, the shaft base condition and cleanliness is of particular interest.

This article illustrates the essential aspects of verticality and base cleanliness of drilled shafts, exploring the various factors and methods employed to evaluate compliance, and the importance of maintaining specified standards in construction practices so that deep foundations satisfy the design intent.

A recent Stresswave paper, co-authored by White, Morgano and Phetteplace (Quantitatively Assessing the Geometry and Base Conditions of Drilled Shaft Excavations) explains that drilled shafts are common foundation elements that are used for structural support throughout the world of large axial and lateral loadings. The trend is towards larger shafts with less foundation redundancy due to larger capacities with the number of foundation units being reduced. Therefore, the construction quality of drilled shaft foundations is critical due to the large structural loads and limited redundancy of typical drilled shaft foundations. For typical drilled shaft projects, the project specifications identify the quality control procedures. These specifications generally address shaft geometry, verticality, base cleanliness, concrete quality, shaft integrity, and reinforcement cage alignment.

Figure 1. SQUID

Many quality control methods currently used do not address all design considerations. Recent advances in drilled shaft quality control testing address some of these issues. The Shaft Quantitative Inspection Device (SQUID™, **Figure 1**), quickly and conveniently attached to the Kelly Bar, measures force as a function of penetration of the shaft bottom material. Three independent penetrometer measurements of force versus displacement are simultaneously viewed in real time during testing. The resultant force-displacement curves are evaluated for debris thickness and soil/rock strength.

An example SQUID penetrometer force-displacement result is shown in **Figure 2** for a drilled shaft bearing in shale bedrock. The shaft excavation had been filled with drilling fluid for four days prior to testing. Over 123 mm (4.8 inch) of debris was measured which exceeded the project specification limits. The shaft was subsequently redrilled 0.3 m (1 ft) deeper, followed by cleaning with an airlift. The SQUID re-test results, shown in **Figure 3**, indicated from 11.5 mm to 19.9 mm (0.45 to 0.78 inch) of debris which was acceptably below the project specification limits.

Many project specifications require the excavation verticality to be within a tolerance of typically 1% to 2%. The PDI Shaft Area Profile Evaluator (SHAPE®, **Figure 4**) simultaneously measures the shaft geometry every second in eight directions as SHAPE is lowered into the drilled hole. SHAPE can be deployed using the crane's Kelly Bar or by an independent winch system. The results are automatically processed to provide a rendering of the shaft geometry and verticality. SHAPE systems are available to measure in any type of drilling fluid or in dry conditions.

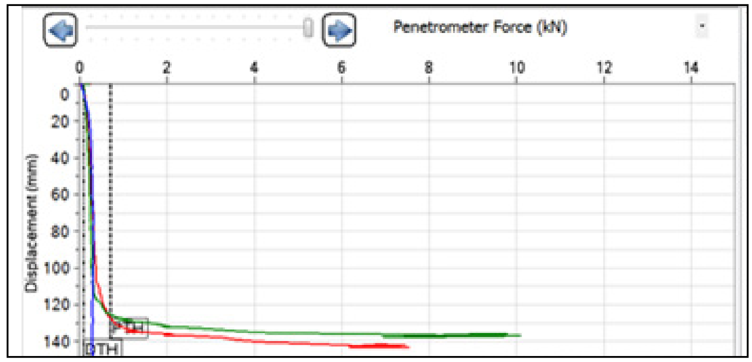

Figure 2. SQUID results from shale bedrock exposed to drilling fluid for days.

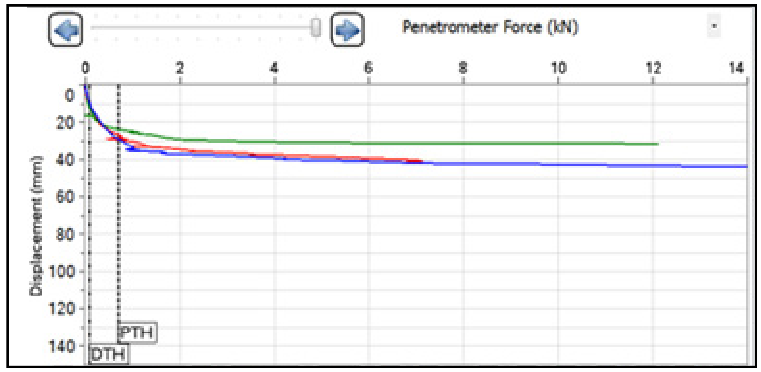

Figure 3. SQUID results from shale bedrock after re-drilled/cleaned by air lifting.

SHAPE testing was performed on an infrastructure project in the Eastern United States. Results shown in **Figure 5** include one of four vertical profiles and a comparison of the centroids at the shaft top and bottom. The centroid offset from top to bottom was 0.12 meters (4.7 inch). In this example, the centroid of the base is clearly southwest of the centroid of the top. The measured verticality offset of 0.93% was within the required offset of 1.5%. The subject paper presents more detailed test results as well as other case histories where interesting data were observed and suggestions for best practice when testing are discussed. <Read paper>

Additionally, a recent article in NBM&CW out of India entitled, Quality Control Measures Prior to Pouring of Concrete for Deep Foundations, by Parthasarathy C R, Nandhagopal AR, Srinivas N, and Soumik Ghosal, from Sarathy Geotech & Engineering Services, Bengaluru, presents a case study of methods to understand the processes involved during installation of bored cast-in-situ piles using the SHAPE and SQUID, including the test procedure and results for both systems.

***Figure 4.** Shaft Area Profile Evaluator being lowered into a drilled shaft excavation.*

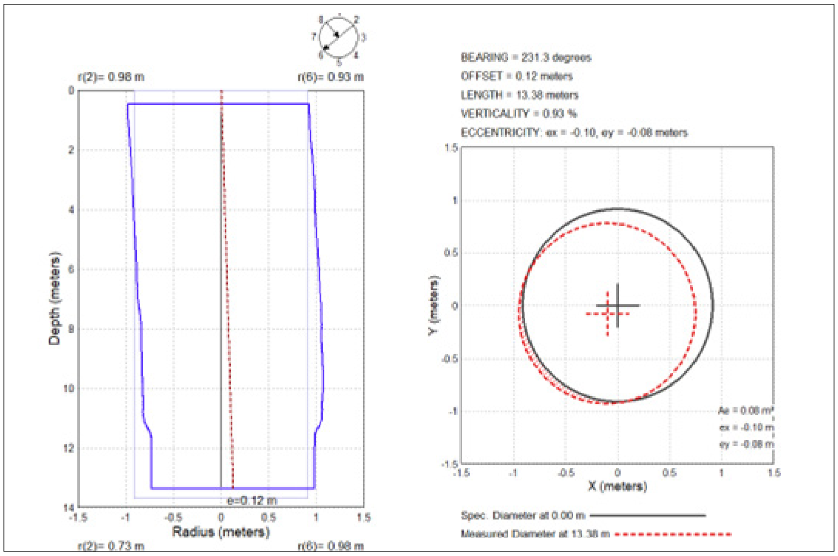

Figure 5. *Maximum calculated eccentricity and resulting excavation verticality.*

Drilled shafts or bored cast-in-situ piles are the most used deep foundations in the Indian subcontinent for major infrastructure and commercial projects. The present technology allows bored cast-in-piles of larger diameters, 1.2 - 1.8 m (4 - 6 ft) to a depth of more than 60 m (200 ft). In small scale projects, the Direct Mud Circulation (DMC) method is adopted and, in major projects, the drilling is performed with rotary rigs. There have been several cases of under performance of bored cast-in-situ piles. One of the major reasons can be identified as the improper stabilization of the borehole sides and bottom during different stages of boring operations. Soil collapse during the boring operation is a common problem, despite bore hole stabilization with bentonite slurry, particularly in a loose non-cohesive saturated soil. IS 14593 - 2008 recommends not to consider any frictional resistance from the overburden soil for rock-socketed piles. As a result, it is preferable to get all the resistance from the socketed portion and hence, it is particularly essential that the bottom of the borehole for rock-socketed piles be clear of any sediments to mobilize the end bearing resistance. <Read Full Article>

Testing of drilled shafts is critical to good foundation performance due to their reduced redundancy and the high loads that they carry. In addition to the verticality and base cleanliness discussed above, testing for structural integrity can be performed by crosshole sonic logging or thermal integrity profiling. Axial load capacity can be evaluated by either high strain dynamic testing or static load tests (either applying load at the top or more commonly using embedded bi-directional load cells). There are several articles and papers which provide an overview of several of these evolving technologies that can be used for drilled shaft evaluations to provide timely and cost-effective quality control and quality assurance. For additional information, visit pile.com or grlengineers.com.

PDI Announces Mario Saavedra, Sales Engineer

As of December 2023, Mario Saavedra joins PDI's Sales team in the role of Sales Engineer after 22 years of service with GRL Engineers, Inc. In his new role, Mario will bring an abundance of technical expertise to PDI's clients around the world. He has a thorough understanding of PDI's QA systems, technical features and benefits, and is readily available to answer client questions and/or concerns promptly and accurately. Mario has extensive experience in conducting high strain dynamic testing and low strain dynamic testing and analysis, cross hole sonic logging, thermal integrity profile testing, and more, in onshore and offshore projects throughout the United States and abroad. Mario will work closely with PDI's vibrant and dynamic sales team to promote PDI's premier deep foundation testing solutions globally.

GRL Engineers Central Office Expands Team

David Jakstis

David Jakstis joined the Central office in October. Jakstis is a certified Professional Engineer with 20+ years of experience in deep foundation testing. He graduated from the University of Florida with a Bachelor of Civil Engineering.

Dan Mackney

Dan Mackney II joined GRL Engineer's Central office with 10 years of experience as a geophysicist working in the construction and the oil & gas industries. He's a graduate of The Ohio State University with a Bachelor of Science in Geophysics.

Welcome, David and Dan.

Upcoming Events

Jan 7-11	TRB Annual Meeting, Washington D.C. Learn More
Jan 21-26	ASTM Committee Week, Louisville, KY Learn More
Jan 28-31	ADSC Annual, San Antonio, TX Learn More
Feb 8-9	FTBA Construction Conference, Orlando, FL: Booth #421 Learn More
Feb 12-13	GeoCarolina, Charlotte, NC: Booth #24 Learn More
Feb 25-28	GeoCongress, Vancouver, BC: Booth #512 Learn More
Mar 4-6	**Deep Foundations Dynamic Testing & Analysis Seminar & Workshop, Orlando, FL** Register Now
Mar 13-14	PDCA Gulf Coast Engineers Conference, Baton Rouge, LA Learn More
Mar 20-21	West Virginia Construction & Design Expo, Charleston, WV Learn More
Apr 22-25	IPF Wind, New Orleans, LA: Booth #1827 Learn More
May 6-10	IFCEE 2024, Dallas, TX: Booth #1226 Learn More
May 21-23	Southwest Geotechnical Conference, Albuquerque, NM Learn More

A complete list of PDI and GRL events can be found on pile.com or grlengineers.com

GRL Engineers, Inc.

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GRL Engineers, Inc.
+1.216.831.6131
info@GRLengineers.com
www.GRLengineers.com
California • Colorado • Florida • Georgia • Hawaii
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Pile Dynamics, Inc.
+1.216.831.6131
info@pile.com
www.pile.com
30725 Aurora Rd, Cleveland, OH 44139