
DID YOU KNOW? Newsletter No. 98 - June, 2021
The SHAPE™ conforms to ASTM Standard D8232 – *Standard Test Procedures for Measuring the Inclination of Deep Foundations.*
GRL Engineers, Inc. Pile Dynamics, Inc.

The Economic Benefits of Testing Driven Piles

By Patrick Hannigan, P.E. and Brent Robinson, PhD, P.E.

We have all heard grumbles that the only thing testing does is increase driven pile foundation cost. In actuality, several modern codes reward the increased reliability and reduced uncertainty obtained through more reliable testing methods with higher resistance factors in LRFD (Load and Resistance Factor Design) codes or lower factors of safety in ASD (Allowable Stress Design) based codes. Two good examples of this philosophy are incorporated into the AASHTO LRFD Bridge Design Specifications (2020) which govern highway design practice in the USA, and the Australian Standard, AS 2159-2009: Piling - Design and Installation (2009). The codified testing philosophy in these documents saves money by lower pile capacity and thus shorter piles, or higher loads per pile resulting in fewer piles for the project.

The AASHTO LRFD Bridge Design Specifications state that the uncertainty in "nominal resistance" (e.g., ultimate capacity) is strictly due to the reliability of the resistance determination method used in the field during installation. AASHTO Table 10.5.5.2.3-1 (Figure 1) lists resistance factors for different driven pile resistance determination methods. Piles could also be driven to a predetermined depth based on the AASHTO resistance factor for the static analysis method. However, the AASHTO resistance factors for static analysis methods range from 0.35 to 0.50 depending on the soil conditions and analysis method which are substantially less reliable than most field methods.

AASHTO Table 10.5.5.2.3-1 Condition / Resistance Determination Method		AASHTO Resistance Factor
Nominal Bearing Resistance of Single Piles – Dynamic Analysis and Static Load Test Methods, $Ø_{dyn}$	Driving criteria establish by successful static load test of at least one per site condition and dynamic testing* of at least two piles per site condition, but not less than 2% of the production piles.	0.80
	Driving criteria establish by successful static load test of at least one per site condition without dynamic testing.	0.75
	Driving criteria establish by dynamic testing* conducted on 100% of production piles.	0.75
	Driving criteria establish by dynamic testing*, quality control by dynamic testing* of at least two piles per site condition, but no less than 2% of the production piles.	0.65
	Wave equation analysis, without pile dynamic measurements or load test but with field confirmation of hammer performance.	0.50
	FHWA-modified Gates dynamic pile formula (End of Drive condition only).	0.40

Figure 1. *- AASHTO Table 10.5.5.2.3-1*
*Dynamic testing requires signal matching, and best estimates of nominal resistance are made from a restrike. Dynamic tests are calibrated to the static load test, when available.

In the Australian Piling Standard, a geotechnical strength reduction factor, $Ø_g$, is determined based on a site's average risk rating, foundation redundancy, the percentage of piles tested, and the selected test type. As shown in the Figure 2, the geotechnical strength reduction factor for a moderate risk site ranges from 0.62 to 0.90 depending on test type, percentage of piles tested and group redundancy. Hence, the higher the percentage of piles tested (up to a limiting value), the greater portion of the geotechnical strength that can be used for the driven pile foundation.

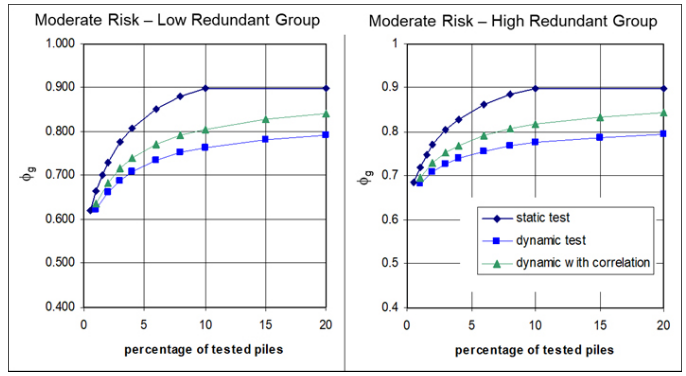

Figure 2. *Geotechnical strength reduction factor for moderate risk*

Using the AASHTO code as an example, consider one site condition that covers five substructure locations each containing 18 piles. The soil conditions for these five substructures are similar. Figure 3 presents the soil conditions along with the nominal and factored resistance versus penetration depth for a 16 inch (406 mm) diameter closed-end pipe pile. The foundation piles have a required factored resistance of 600 kips (2,667 kN) per pile. The estimated pile penetration depth for the required nominal resistance varies from 110 ft (33.5 m) if a static load test and 2% PDA testing (minimum 2 piles) ($Ø_{dyn}$ = 0.80) is performed, to 137 ft (41.8 m), if only the Gates dynamic formula ($Ø_{dyn}$ = 0.40) is used.

The total foundation cost of a given field testing method can be quantified based on the total pile length costs, testing method costs, and the schedule impact cost associated with the testing method. These costs will vary depending upon a project's geotechnical conditions and associated design construction, and contract delivery costs.

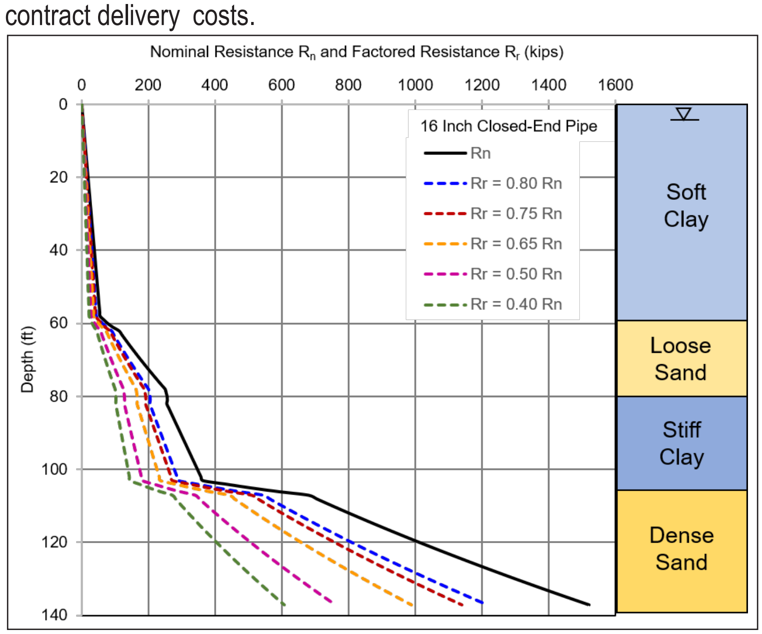

Figure 3. *Nominal and factored resistance vs pile penetration depth*

However, these estimated costs can be compiled to determine the economic impact of a given field testing method on a driven pile project. As observed in Figure 4, testing, when rationally selected, will usually reduce, rather than increase, the total foundation cost.

For additional information about Dynamic Testing Driven Piles, visit www.grlengineers.com.

Test Method	Required Nominal Resistance (kips)	Estimated Pile Length (ft)	Estimated Pile Foundation Cost at $110/ ft	Estimated Testing Cost	Test Method Schedule Impact (days)	Cost of Schedule Impact at $5,000 / day	Total Foundation Testing, and Schedule Cost	Total Cost Rank
Static LT & 2% PDA	750	110	$1,089,000	$55,000	11	$55,000	$1,199,000	3
Static LT	800	112	$1,108,800	$50,000	10	$50,000	$1,208,800	4
100% PDA	800	112	$1,108,800	$54,500	5	$25,000	$1,188,300	2
2% PDA	923	117	$1,158,300	$5,000	1	$5,000	$1,168,300	1
Wave Equation	1200	127	$1,257,300	$1,500	0	0	$1,258,800	5
Gates Dyn. Formula	1500	137	$1,356,300	$0	0	0	$1,356,350	6

Figure 4. *Estimated economic impact of various driven pile testing methods*

Bill Chambers, Sr Engineer, GRL-HI

GRL Opens Hawaii Office

GRL Engineers, Inc. opens its 12th office location in Oahu, Hawaii. GRL Engineers offer a variety of testing and analysis methods for the diverse Hawaiian geotechnical conditions, and challenging driven and drilled deep foundation installations. The new Oahu based office provides testing in Hawaii and Pacific Island projects.

GRL Senior Engineer, Bill Chambers, staffs the GRL-HI office. He has 31 years of experience in the deep foundation industry holding positions as a chief estimator, project manager, piling engineer and managing director for piling contractors and deep foundation testing firms. Bill is a registered professional engineer in Queensland, Australia and holds a Advanced-Level rating on the PDCA/PDI Dynamic Measurement and Analysis Proficiency Test.

Contact Bill at GRL-HI@grlengineers.com for additional information.

Upcoming Events

Jul 23	**Quarterly Webinar: PDA Practices Q&A** *Register Today*
Aug 4 or 5	**Webinar: How to Use NEW Features of GRLWEAP14** *August 4th at 11:00am EST Registration* *August 5th at 9:00pm EST Registration*
Aug 12	**Quarterly Webinar: TIP Practices Q&A** *Register Today*
Sep 15-17	**Conference: PDCA DICEP, New Orleans, LA** *Visit Conference Website*
Sep 15-17	**Conference: ASCE Geotechnical Conference, Hershey, PA** *Visit Conference Website*
Sep 26-29	**Conference: CGS GeoNiagara, Niagara Falls, Canada** *Visit Conference Website*
Sep 21, 22, 28, 29	**Webinar: Wave Equation Analysis of Piles** *GRLWEAP Registration Form*
Oct 4, 5, or 7	**Webinar Series: QA/QC Remote Testing Continue Project Timelines** *October 4th at 11:00am EST Registration* *October 5th at 9:00pm EST Registration* *October 7th at 9:00am EST Registration*
Oct 7	**Conference: Grundlaggningsdagen, Stockholm, Sweden** *Visit Conference Website*
Oct 13-15	**Conference: DFI Annual, Las Vegas, NV** *Visit PDI/GRL Booth #423*
Oct 22	**Quarterly Webinar: PDA Practices Q&A** *Register Today*
Oct 26	**Workshop: State of Practice - QC of Deep Foundations, Houston, TX** *Houston Registration Form*
Oct 28	**Workshop: State of Practice - QC of Deep Foundations, Dallas, TX** *Dallas Registration Form*
Oct 28	**Webinar: Basics of High Strain Dynamic Testing** *Register Today*
Nov 1	**Workshop: State of Practice - QC of Deep Foundations, Boston, MA** *Boston Registration Form*
Nov 3	**Workshop: State of Practice - QC of Deep Foundations, New York, NY** *New York Registration Form*
Nov 5	**Workshop: State of Practice - QC of Deep Foundations, Philadelphia, PA** *Philadelphia Registration Form*
Nov 3	**Seminar: Deep Foundation Integrity Testing and Wave Equation Analysis** *Register Today*
Nov 4-5	**Workshop: High Strain Dynamic Foundation Testing** *Register Today*
Nov 12	**Quarterly Webinar: TIP Practices Q&A** *Register Today*
Nov 15, 16 or 18	**Webinar Series: QA/QC of Drilled/Bored Piles** *November 15th at 11:00am EST Registration* *November 16th at 9:00pm EST Registration* *November 18th at 9:00am EST Registration*
Nov 16	**Workshop: State of Practice - QC of Deep Foundations, Nashville, TN** *Nashville Registration Form*
Nov 18	**Workshop: State of Practice - QC of Deep Foundations, Omaha, NE** *Omaha Registration Form*
Nov 18	**Webinar: Integrity Testing of Concrete Foundations by Low Strain Dynamic Testing & CSL** *Register Today*

Pile Dynamics, Inc.
30725 Aurora Rd,
Cleveland, OH 44139

Pile Dynamics, Inc.
+1.216.831.6131
info@pile.com
www.pile.com

GRL Engineers, Inc.
+1.216.831.6131
info@GRLengineers.com
www.GRLengineers.com

GRL Engineers, Inc.
California • Colorado • Florida • Georgia • Hawaii • Illinois • Louisiana • North Carolina • Ohio • Pennsylvania • Texas • Washington

Follow Us On Social Media