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**PILE DYNAMICS, INC.**  
TURNS 35 YEARS OLD  
IN MAY, 2007.



## Capacity Confusions in 2007

Frank Rausche, Garland Likins, Pat Hannigan

In an article published in the GRL Newsletter Number 24, of November 1994<sup>1</sup>, Dr. George Goble presented a typical experience of a foundation testing engineer who comes to a construction site and is instructed to test a 100 ton driven pile. The engineer asks whether 100 tons is the design load or the required ultimate capacity, but cannot get a clear answer. The article exemplifies the sometimes hilarious, sometimes embarrassing and sometimes even outright antagonistic exchanges that arise from this lack of understanding of the basics of foundation design.

Since 1994, some progress has been made towards a better understanding of these basics, due to the efforts of the Federal Highway Administration. The FHWA, which under the leadership of Jerry DiMaggio, sponsored the updating, dissemination and teaching of material contained in Design and Construction of Driven Pile Foundations (Hannigan et al, 2006). Today most foundation professionals use **Allowable Stress Design** with the required ultimate capacity equal to the design load times a factor of safety (FS). In the United States, FS = 2.0 for buildings (as per International Building Code 2006) regardless of load testing method; for highway bridges the factor of safety varies with the capacity verification method (Hannigan, 2006, p. 9-14).

Starting in October of 2007, American Association of State Highway Transportation Officials Interim Specifications (AASHTO, 2006) will require **Load and Resistance Factor Design (LRFD)** for highway bridge design. When using LRFD, the structural engineer will calculate a Factored Load which, depending on its dead load, live load and other load components, will be multiplied by associated **Load Factors** (e.g., 1.25 for dead load and 1.75 for live load).

The geotechnical engineer will estimate the foundation depth for a **Required Nominal Resistance** (AASHTO's equivalent term for "Ultimate Capacity") that has to exceed **Factored Load** divided



by a **Resistance Factor**. The specified **Resistance Factors** vary with the capacity verification method since each method (static or dynamic test, wave equation or dynamic formula) has a different reliability and may also yield a method-specific capacity value. Also, capacity increase with time (called "set-up") is often the cause for differences between different tests. To obtain the Nominal Resistance of dynamic tests conducted with a Pile Driving Analyzer<sup>®</sup>, the records must be evaluated by signal matching (e.g., by CAPWAP<sup>®</sup>). A wave equation bearing graph together with an observed blow count yields the wave equation specific Nominal Resistance.

Shown below are **Resistance Factors,  $\phi$** , of the current 2006 AASHTO Interim Specifications. The resulting **Global Factors of Safety, GFS**, were calculated for best case scenario for sites with low variability and 5 or more driven piles in a pier (highly redundant foundation), assuming a 70/30 dead load / live load ratio for a combined average **Load Factor** of 1.4. Current practice AASHTO factors of safety, **FS**, (Hannigan, 2006, p. 9-14) are shown for comparison.

Capacity Verification Method	$\phi$ AASHTO 2007	GFS AASHTO 2007 Example	Current Practice FS
1 static test	0.80	1.4/0.80 = 1.75	2.00
4 dynamic tests	0.65	1.4/0.65 = 2.15	2.25
Wave equation	0.40	1.4/0.40 = 3.50	2.75

In this example, static and dynamic testing global factors of safety differ by -12.5 and -4.5% from current practice. However, the resulting GFS for wave equation exceeds current practice by a surprising 27%. Even higher factors of safety for all methods will result when reduced redundancy and higher site variability are considered under AASHTO 2006 Interim. The current AASHTO 2006 Design Interim is only a recommendation to the various State Departments of Transportation and changes to these factors are expected as experience is gained with time.

Let us hope that the understanding of the basics of foundation design will continue to improve in the future. Ideally, when a foundation testing engineer will arrive on site, the designer will have clearly spelled out the Required Nominal Resistance. Let us also hope that job specifications will require re-strike testing for soils with set-up potential and that, when many foundation elements are tested, a slightly low capacity of a single pile can be offset by the higher capacity of others. Then the practice of the tester need not differ much from what we are doing today and the potential advantages of the LRFD method can be realized.

AASHTO Bridge Design Specifications, 2006 Interim Revision, American Association of State Highway Transportation Officials, Washington DC.

Hannigan, P., Goble, G., Likins, G., and Rausche, F., 2006. Design and Construction of Driven Pile Foundations, Volumes I and II. National Highway Institute, Federal Highway Administration, US Department of Transportation, Washington, D.C.. Previously published in 1997.

International Building Code 2006, International Code Council, Inc., Leesburg, Virginia, USA

<sup>1</sup>The article is available at [www.pile.com/newsletter](http://www.pile.com/newsletter).

## 2007 Calendar of Events

please visit [www.pile.com/events](http://www.pile.com/events) for a complete listing

### May 17, Los Angeles area, CA: Foundation Testing Seminar.

Sponsored by GRL Engineers. Visit [www.pile.com/events/pdievents](http://www.pile.com/events/pdievents) or email [info@pile.com](mailto:info@pile.com).

### May 18, Los Angeles area, CA: GRLWEAP Workshop.

Sponsored by GRL Engineers. Visit [www.pile.com/events/pdievents](http://www.pile.com/events/pdievents) or email [info@pile.com](mailto:info@pile.com).

**June 8, Internet Teleconference by Michael Morgano, GRL OH, 1:00 to 2:30 pm: Load Testing and Quality Control Methods for Deep Foundations.** Sponsored by Lorman Education. Seminar ID 375790; Priority 15801. Visit [www.lorman.com](http://www.lorman.com).

### June 18-22, Logan, UT: PDCA Professors Institute.

Sponsored by Pile Driving Contractors Association. Visit [www.piledrivers.org/events](http://www.piledrivers.org/events) or email Stevan Hall at [execdir@piledrivers.org](mailto:execdir@piledrivers.org).

**July 16-20, Margarita Island, Venezuela: 13th Panamerican Conference on Soil Mechanics and Geotechnical Engineering: Integration of research, practice and education in Geoenvironmental Engineering.** Sponsored by the Venezuelan Society of Geotechnical Engineering. Visit [www.xiiicpmsig.org](http://www.xiiicpmsig.org) or [svdg@telcel.net.ve](mailto:svdg@telcel.net.ve).

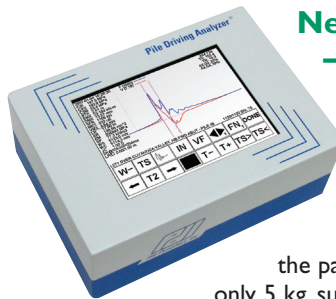
**July 25-28, Lake Tahoe, Nevada: ADSC 2007 Summer Meeting.** Sponsored by the International Association of Foundation Drilling. Camilo Alvarez will present. Visit [www.adsc-iafd.com](http://www.adsc-iafd.com) or email Jan Hall at [jhall@adsc-iafd.com](mailto:jhall@adsc-iafd.com).

### September 24-27, Boston, MA: 7th International Symposium on Field Measurements in Geomechanics.

Sponsored by Geoinstitute of ASCE. Visit [content.asce.org/conferences/fmgm07/](http://content.asce.org/conferences/fmgm07/) or email Jerry DiMaggio at [jerry.dimaggio@fhwa.dot.gov](mailto:jerry.dimaggio@fhwa.dot.gov). PDI will exhibit.

**September 27, Baltimore, MD (tentative) – Design and Installation of Cost Effective Piles.** Sponsored by PDCA. Contact Stevan Hall at [execdir@piledrivers.org](mailto:execdir@piledrivers.org).

**October 11-13, 2007, Colorado Springs, CO: DFI 32<sup>nd</sup> Annual Conference** – Visit [www.dfi.org/conferences.asp](http://www.dfi.org/conferences.asp) or email Theresa Rappaport [trappaport@dfi.org](mailto:trappaport@dfi.org). PDI will exhibit.



## New Pile Driving Analyzer® – PAX – launched by Pile Dynamics

Dynamic testing of driven and drilled foundations with the Pile Driving Analyzer (PDA) is routine QA/QC practice worldwide. Pile Dynamics has released a new PDA model: PAX. The PAX, with up to eight sensors, crowns the succession of improvements that PDAs have experienced during the past 35 years. It is portable, battery operated, and, at only 5 kg, surprisingly light. Its high visibility display doubles up as control panel and keyboard. The PAX allows both traditional on-site operation and remote data transmission via fast broadband internet.

### Continuing Education News

- **Seminar and GRLWEAP Workshop set for California.** GRL Engineers will hold a Foundation Testing Seminar and a GRLWEAP Workshop in California. This should be good news for all of you who have been asking for events on the West Coast. See calendar for details.
- **Pile Dynamics, Inc. and GRL Engineers, Inc. are IACET authorized providers of Continuing Education Units.** In the USA most States require professional engineers to obtain a certain number of Professional Development or Continuing Education credits per year. IACET CEUs are accepted by the following Boards of Registration for Professional Engineers: AL, AR, DE, GA, IL, IO, KS, KY, LA, MD, MA, MN, NE, NJ, NM, NC, OK, OR, RI, SC, SD, TN, TX, VT, WV, WY. Other Boards of Registration may accept seminars, workshops and training sessions provided by PDI or GRL as Professional Development Hours.
- **GRL Engineers is a State of Florida approved Education Provider.**
- **Great attendance at PDA and CAPWAP Workshop.** Foundation QA and PDCA held a seminar and the workshop "PDA Test Interpretation and CAPWAP Analysis Skills Development" in Orlando this past March. Forty people attended the workshop, which was followed by the High Strain Dynamic Pile Testing Certification Examination.

## Geo-Denver 2007 report – Congratulations Dr. George Goble

Geo-Denver 2007 took place February 18 to 21st. Dr. George Goble, founder of both Pile Dynamics, Inc. and of Goble Rausche Likins and Associates (now GRL Engineers, Inc.) delivered the Terzaghi Lecture, one of the highest honors of Geotechnical Engineering. Please join PDI and GRL in congratulating Dr. Goble for having joined the list of distinguished geotechnical engineers previously awarded this lectureship, established by the Soil Mechanics and Foundations Division (now Geo-Institute) of the American Society of Civil Engineers in honor of Karl Terzaghi, Hon.M.ASCE. Mohamad Hussein (GRL Florida) chaired one of the Deep Foundation sessions and Dr. Frank Rausche presented: "Behavior of Cylinder Piles during Pile Installation" by Rausche and Webster and "Defect Analysis for CSL Testing" by Likins, Rausche, Webster and Klesney (papers available at [www.pile.com/reference](http://www.pile.com/reference)).



## New Specification for Driven Piles

The Pile Driving Contractors Association has made its recently published Installation Specification for Driven Piles available for free download from [www.piledrivers.org](http://www.piledrivers.org). Dynamic testing performed with the Pile Driving Analyzer meets these specifications, as does performing Wave Equation Analysis with the GRLWEAP software.

## Call For Papers – STRESSWAVE 2008

– Science, Technology and Practice – 8th International Conference on the Application of Stress-Wave Theory to Piles

If you are reading this newsletter, chances are this is one of the most important conferences for you. Abstracts for Stresswave 2008 are due June 1, 2007. The important conference, will be in Lisbon, Portugal in September of 2008. Visit [www.stresswave2008.org](http://www.stresswave2008.org) or email Prof. Jaime Santos at [sw2008@civil.ist.utl.pt](mailto:sw2008@civil.ist.utl.pt).



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