



## DID YOU **KNOW?**

**Pile design based on dynamic formulas was already discouraged in the 1940s, due to inaccuracies.**



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### **LARGE DIAMETER OPEN END PIPE PILES - CHALLENGES & OPPORTUNITIES**

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Many things in deep foundations get bigger and bigger and that is particularly true for open-ended pipe piles. For decades they have been driven to deep penetrations and GRL has monitored their installation, tested them dynamically, and analyzed them for driveability on offshore, nearshore, and on-land projects. The National Cooperative Highway Research Program Synthesis (NCHRP Synthesis<sup>1</sup>) defines Large Diameter Open-End Driven Pipe Piles (LDOEP) as either concrete or steel pipes with diameters of 36 inches (910 mm) or more. For offshore oil platforms, 48 to 96 inch (1220 to 2440 mm) diameters are common, and have been successfully used following American Petroleum Institute (API) specifications. Lately, windfarm monopiles of more than 200 inch (5000 mm) diameters have been considered. LDOEPs are also used in port construction, and occasionally on bridge foundations, when heavy equipment and material can be economically transported.

In favorable soils installation may be by vibratory hammer, however in most cases an impact hammer is needed to reach design penetration and to evaluate capacity by dynamic testing. Bearing capacity evaluated during pile installation, however, may not fully represent the pile response in the static service condition. The high inertia of the soil prevents plugging during driving. The pile “cookie cuts” its way into the ground, making installation to design penetration relatively easy but reducing end bearing during driving. In fact, even the internal friction will not exhibit its full static potential during driving because of the up-and-down motion of the pile during installation. Not surprisingly, dynamic methods generally predict lower capacities than anticipated from static considerations. During static loading, however, internal friction may be enough to resist the end bearing acting over the whole pile bottom area. So while the contractor is happy about the installation progress, the pile designer is often concerned about the low apparent soil resistance.

To make things worse, designers occasionally install “constrictor plates” (with a center hole to allow water and soft soil to escape) inside piles at a location where they would generate “end bearing” effects without causing too much of an installation problem. The uncertain condition of the soil plug under the constrictor plates and its effect under dynamic conditions, unfortunately complicate the driveability assessment and evaluation by dynamic load testing.

The NCHRP Synthesis makes clear that designers and construction professionals need dynamic analysis and testing methods both for LDOEP job preparation and for construction control. Static load testing, while the indisputable method for static soil capacity determination, is usually not a feasible alternative due to cost and time constraints. Moreover, driving stresses and pile integrity assessments, not possible by static testing, are often very important due to the limited number of LDOEP's used in a foundation. Dynamic tests during installation are the best means of assuring that installation meets specifications. Fortunately, dynamic methods

perform well, particularly when local conditions and experiences are taken into account.

GRL was recently involved in a number of challenging LDOEP projects, most notably the Kentucky Lakes Bridge where the load test program included static, dynamic, and rapid force pulse tests on 48 and 72 inch (1220 and 1830 mm) diameter pipe piles. The challenges of evaluating static bearing capacity of LDOEP by dynamic methods were addressed in part by employing advanced modeling in the CAPWAP<sup>®</sup> software, in particular using radiation damping in lieu of the standard Smith model. Other considerations for successful dynamic testing of LDOEPs include: (i) Dynamic tests during restrike have high benefit/cost ratio and are highly recommended, since low dynamic testing capacity results during driving are more frequently due to disturbed soil than a moving plug. (ii) Excessive energies loosen the soils, resulting in low dynamic resistance. Try to limit energies and, during data analysis, use superposition of early with late restrike resistance distributions. Reduce high energies by cushioning to improve chances of measuring the full end bearing. (iii) The unit resistance at the plugged LDOEP pile toe will be less than that for the small area against the steel only (when performing driveability analysis with GRLWEAP, use only 50% of the anticipated unit end bearing). (iv) When investigating potential toe damage, realize that all dynamic methods assume uniform stresses over the pile cross section. However, a large diameter pile encountering obstructions or sloping rock can have very high local stresses at the toe. Thus, for non-uniform resistance conditions, consider lower allowable average driving stresses at the toe.

Research is ongoing in many parts of the world and we all need to stay informed about progress in this important deep foundation specialty. Fortunately, dynamic testing provides a cost effective option that can be successfully implemented into many LDOEP projects.



Kentucky Lakes Bridge project

<sup>1</sup> Brown, D.A., and Thompson, W.R., *Design and Load Testing of Large Diameter Open-Ended Driven Piles; A Synthesis of Highway Practice*; NCHRP Synthesis 478, Transportation Research Board, Washington, D.C., 2015

**Highlights of the 2015 Calendar of events (Sept-Feb)** More events, info and registration forms at [www.pile.com/events](http://www.pile.com/events)

**Pile Dynamics Seminars on Deep Foundation Integrity Testing and Wave Equation Analysis, followed by High Strain Dynamic Foundation Testing Workshop and Proficiency Test Workshops – 3 opportunities around the world, all featuring senior PDI engineers as instructors:**

September 30-October 2 in **Cleveland, Ohio**, in collaboration with Pile Driving Contractors Association. Info: [holly@piledrivers.org](mailto:holly@piledrivers.org)

October 1-3 in **Bangalore, India**, in collaboration Earth Products India.

October 19-21 in **Chengdu, China**, in collaboration Earth Products China.

**PDI Webinars - Learn without leaving your desk:**

All webinars require Internet and phone connection and start at 9:00 am Eastern Time (New York Time). Info: [registration@pile.com](mailto:registration@pile.com)

November 10, 11, 17 and 18: **Advanced Applications of CAPWAP® 2014 Software** with Brent Robinson (four 2 hour lectures).

December 1: **Pile Driving Hammer Performance Webinar** with Dr. Frank Rausche (one 1.5 hour lecture).

December 2: **Load Testing & Quality Control of Pile Foundations** with Michael Morgano (one 1.5 hour lecture).

December 15-16: **Integrity Testing of Concrete Foundations by Low Strain Dynamic Testing, Cross Hole Sonic & Thermal Integrity Profiling** with Ryan Allin (two 1.5 to 2 hour lectures).

**GRL, PDI and/or PDI representatives will exhibit at the following events** (a good chance to learn about new developments!)

September 27-October 1, in Branson, MO: Visit the **PDI Booth** at the ASCE Structural Engineering Institute **2015 Electrical Transmission and Substation Structures Congress** and view a **Thermal Integrity Profiling poster presentation**. [www.etsconference.org](http://www.etsconference.org)

**New Model of Cross Hole-Analyzer Released**

The much awaited new model of the Cross-Hole Analyzer is now available. With a cleaner, tablet-like look, the model XV has significantly more memory than the previous one and four USB ports, making data transfer much more convenient. The Cross-Hole Analyzer model XV operates on Windows 7. Tried and true characteristics such as sampling and scan rates and trigger levels remain unchanged and comply with ASTM D6760. Collected data continues to be analyzed by the CHA-W software, with a completely reprogrammed Tomography analysis software scheduled for release in the near future.



**GRL Welcomes Christian Gonzalez**

Christian has a B.S in Civil Engineering from The University of Texas Pan American in Edinburg, TX and has joined the Central Office of GRL Engineers.

October 12-15, in Oakland, CA: Visit **GRL at Booth 124** and **PDI at Booth 524** at the **Deep Foundations Institute 40th Annual Conference on Deep Foundations**. [www.dfi.org/dfieventlp.asp?13235](http://www.dfi.org/dfieventlp.asp?13235)

October 19-23 in Greenville, SC: Visit the **PDI booth** at the 46th Annual Southeastern Transportation Geotechnical Engineering Conference (STGEC). [www.stgec.org](http://www.stgec.org)

October 27-28, in Columbus, Ohio: Visit the **GRL booth** at the **Ohio Transportation Engineering Conference**. [www.dot.state.oh.us/engineering/OTEC](http://www.dot.state.oh.us/engineering/OTEC)

**Other Learning Opportunities:**

November 3, in Mannheim, Germany: PDI representative GSP presents a **Workshop on Low Strain Integrity Testing of Piles** (in German) with Dr.-Ing. O. Klingmüller, Dipl.-Ing. Ch. Mayer and Dr.-Ing. M. Schallert. [info@gsp-mannheim.de](mailto:info@gsp-mannheim.de)

November 4, in Mannheim, Germany: PDI representative GSP presents a **Workshop on Dynamic Load Testing of Piles** (in German) with Dr.-Ing. O. Klingmüller, Dipl.-Ing. Ch. Mayer and Dr.-Ing. M. Schallert. [info@gsp-mannheim.de](mailto:info@gsp-mannheim.de)

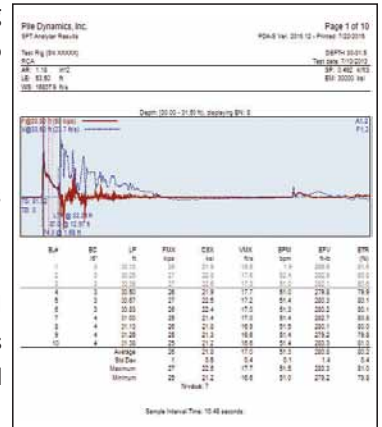
November 15-18 Buenos Aires, Argentina: **Gina Beim** will present a paper on **Thermal Integrity Profiling** (in Spanish) at the Pan-American Conference on Soil Mechanics and Geotechnical Engineering. [www.conferencesba2015.com.ar](http://www.conferencesba2015.com.ar)

February 14-17, 2016, Phoenix, Arizona: **Anna Sellountou** will present a paper at the ASCE Geotechnical & Structural Engineering Congress 2016. [www.geo-structures.org](http://www.geo-structures.org)

February 16-20, 2016, Scottsdale, Arizona: **PDI** will make a product presentation at the ADSC Annual Meeting. [www.adsc-iafd.com](http://www.adsc-iafd.com)

**New SPT Analysis Software for the PDA-8G**

The software add-on that allows using a Pile Driving Analyzer® system to perform energy calibration of SPT hammers (ASTM D4633) has been completely revamped, and is now compatible with the PDA-8G. Users of the program will particularly enjoy the report creation option, which significantly reduces the time and effort required to produce test results in deliverable format. A new model of the SPT Analyzer is also being released.



SPT Analysis Software Output

**Complimentary Webinars**

PDI has made a couple of educational webinars available for complimentary download at [www.pile.com/webinars](http://www.pile.com/webinars). Check them out!

**www.pile.com:** the portal for deep foundation testing services, instruments and software

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