**DID YOU KNOW?** *Newsletter No. 110 - June 2024*

The Louisiana Lake Pontchartrain Causeway, built in 1956, is the longest bridge in the USA, spanning 24 miles.

GRL Engineers, Inc. Pile Dynamics, Inc.

# 100% Dynamic Pile Testing May Save Project Time and Money

**by Ben White, P.E. and Mohamad Hussein, P.E.**

Driven piles are commonly used as deep foundations to support all types of structures in various geotechnical conditions. They are typically made of timber, concrete, steel, or composites and are usually driven with impact air/steam, hydraulic, or diesel hammers. Their engineering design includes structural, geotechnical, and drivability considerations; and their construction involves manufacturing, driving, testing, and inspection.

Dynamic pile testing with the Pile Driving Analyzer® (PDA) and associated computer software GRLWEAP™ and CAPWAP® is routinely used worldwide for the comprehensive evaluation of the hammer system performance, dynamic driving stresses, structural integrity, soil resistance and static load bearing capacity. Testing is typically performed during initial installation, and during restrike sometime after initial driving, in order to assess geotechnical time-dependent effects. PDA and CAPWAP® testing and data analysis is generally considered the "gold standard" of dynamic pile testing worldwide. Field testing may be performed by the testing engineer present on site, or remotely with the testing engineer being off site utilizing the PDA built-in SiteLink® remote testing capabilities.

***Figure 1.*** *Using the Pile Driving Analyzer® to Monitor Concrete Pile Installation*

Conventionally, a designated number of Test Piles are installed for the purposes of confirming the engineering design assumptions, assessing the contractor's means and methods, and establishing production piles' length and driving criteria for the project. The process typically involves:

- Pre-construction GRLWEAP™ wave equation analyses for hammer suitability
- Field testing with the PDA to evaluate specific hammer, pile soil characteristics
- CAPWAP® analysis to obtain pile-soil dynamic/static resistance characteristics
- Refined GRLWEAP™ analyses incorporating the PDA and CAPWAP® findings
- Issuance of a pile driving criteria for the remaining project production piles

The driving criteria typically lists the specifics of the project such as the hammer model and serial number used during the Test Pile driving program, hammer cushion (and in the case of concrete piles, pile top cushion) details, pile size and length. It also includes requirements for minimum penetration depth (if dictated by foundation design), and termination blow count and associated hammer stroke height or energy setting. Foundation acceptance is subsequently based on the production pile(s) meeting the driving criteria as recorded in the field on the pile driving inspector's logs utilizing the automated Saximeter inspection device.

In recent years the practice of performing 100% PDA testing, and related CAPWAP® data analyses, on all piles, as well as the acceptance of the foundation based on dynamic testing results has seen increased use. This is typically employed where a Test Pile driving program may not be cost-effective, is time-consuming, not warranted, or practically ineffective. In some cases, both Test Piles and 100% testing of production piles are employed. Depending on the situation, the use of conventional Test Pile driving program, 100% dynamic testing, or a combination of the two has its application for the most efficient, economical, and reliable driven pile foundations.

### 100% Dynamic Pile Testing

The practice of 100% dynamic pile testing optimizes construction efficiency and economy and increases engineering reliability. On many design/build type projects, the contractor and the design engineer elect to implement 100% dynamic pile testing to expedite the work, save time and money, and allow the use of lower safety factors in conventional allowable stress design procedures (or higher resistance-factors in LRFD designs).

In the United States, the Federal Highway Administration (FHWA) has allowed higher design resistance factors (i.e., lower factors of safety) for piles where certain amounts of testing take place. Table 7-2 in FHWA GEC 012 presents the various resistance factors depending on field determination methods including dynamic testing.

For example, if a pile is needed to support a design load of 100 tons and is installed based on dynamic formulas only (e.g., modified Gates), the pile would be designed using a resistance factor of 0.4 and installed to nominal resistance (i.e., ultimate capacity) of 250 tons. However, the same pile could be designed using a resistance factor of 0.75, should 100% dynamic testing be used, and driven to a nominal capacity of 134 tons. This allows for consideration of a smaller pile section, shorter pile length, fewer piles, and/or smaller installation equipment, easily offsetting the cost of the additional testing.

### Case Studies

Recently, a design/build project for construction of a 3,300 ft (1000 m) long bridge in Florida, founded on 210 square prestressed concrete piles (24-in (610 mm)), with lengths varying between 65 and 140 ft (20 to 43 m) utilized 100% PDA/CAPWAP testing of all production piles. In addition, 12 initial probe Test Piles were also tested using PDA testing techniques. According to the contractor, this approach to the piling work saved 17% of the foundation cost.

Additionally, two bridge projects in Ohio used this idea to their advantage. The first case was a bridge replacement project utilizing H-piles to support the structure primarily through shaft resistance, no apparent bearing strata was evident in the soil boring logs. The piles did not achieve the required Ultimate Bearing Value (UBV –

synonymous with required nominal capacity) of 113 tons during initial or restrike driving after a 6-day waiting period, at their design depth of 55 ft (16.8 m). One pile was spliced and driven to 85 ft (25.9 m) depth and still did not achieve the UBV. A 6-day restrike of a pile installed to the design depth indicated a pile capacity of approximately 105 tons. GRL suggested that 100% dynamic testing be performed. Table 7-2 from GEC 012 allows a resistance factor of 0.75 for 100% dynamic testing. Applying a resistance factor of 0.75, the required UBV reduced to 98 tons.

***Figure 2.*** *Pile Driving Analyzer® Monitoring H-Pile Installation*

The proposal was accepted, and additional testing was completed in a single day. The pile capacities ranged from 99 to 109 tons during short-term restrikes. The EOR accepted the piles installed to the original design depth. Performing one additional day of dynamic testing removed the need for 5 pile splices and up to 150 ft (75 m) of additional piling at this abutment.

The second Ohio case was a bridge widening project utilizing 14-in (356 mm) diameter, closed end steel pipe piles, where again, the piling did not achieve the required UBV of 141 tons at the end of driving. Twelve day restrikes of 4 tested piles indicated that 2 of the piles still had not achieved the UBV, with restrike capacities ranging from 119 to 151 tons. The project was on a very tight schedule and the contractor did not have additional pile material to splice the piles. Instead of ordering additional material and splicing the piles, the engineer accepted a proposal to perform PDA testing on 100% of the piles in both abutments. This dropped the UBV from 141 to 122 tons. All piles were accepted as installed. With 2 days of additional dynamic testing to complete the 100% requirement, 7 splices and an unknown amount of pile length, were not necessary.

Increasing the resistance factor for design has many advantages, including the use of smaller or shorter piles, smaller installation equipment, faster pile installation, and a reduction in the overall foundation carbon footprint. In many cases, as presented here, the quickest and most basic method to increase the resistance factor, according to the **FHWA GEC 012 publication**, is to increase the amount of dynamic testing to 100%. Either through preplanning of the testing scope or during foundation construction, the implementation of 100% dynamic pile testing is a convenient and cost-effective tool that can be useful in the success of deep foundations projects.

## Upcoming Events

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| Jun 12-14 | SuperPile, San Francisco, CA: Booth 202 *Learn More* |
| **July 2** | **State of Practice Seminar: Advanced Solutions for Deep Foundations, Nepal** Register Now |
| Jul 11-12 | ASCE Florida Conference, Naples, FL *Learn More* |
| Aug 26-30 | XVIII European Conference on Soil Mechanics and Geotechnical Engineering, Lisbon, Portugal *Learn more* |
| **Sep 16** | **Advanced High Strain Dynamic Testing Workshop & Exam, Vadodara, Register Now** |
| Sep 19-21 | DFI India 2024 *Learn More* |
| Sep 27 | GEO-CT, Rocky Hill, CT *Learn More* |
| Oct 7-10 | DFI49 Annual Conference, Aurora, CO: Booth 213 *Learn More* |
| **Oct 8** | **Estado Actual de las Practicas: Soluciones Avanzadas para Cimentaciones Profundas, Ciudad de Mexico, Mexico *Register Now*** |
| Oct 8-9 | Ohio Transportation Engineering Conference, Columbus, OH *Learn More* |
| Oct 7-10 | Central Pennsylvania Geotechnical Conference, Hershey, PA *Learn More* |
| Nov 1 | Rocky Mountain GeoConference, Westminster, CO *Learn More* |
| **Nov 6** | **Seminar: Deep Foundation Integrity Testing & Wave Equation Analysis, Cleveland, OH *Register Now*** |
| **Nov 7-8** | **Workshop: High Strain Dynamic Testing & Proficiency Test Option, Cleveland, OH *Register Now*** |

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

## GRL Engineer's California, Illinois, and Pennsylvania Office Expand Teams

Fernanda Moraes

Tanvir Ahmed

Syed Hussan

In mid-April, GRL-California office welcomed Fernanda Moraes. Fernanda has experience as a project engineer and obtained her Civil Engineering degree from Universidade da Amazonia Brazil. Early June brought Tanvir Ahmed to the GRL-Pennsylvania office and Syed Hussan to the Illinois Office. Tanvir has worked as a structural engineer and a research assistant. Tanvir received their Masters of Science in Civil Engineering and Construction from Georgia Southern University and their Bachelors of Science in Civil Engineering from Shahjalal University of Science and Technology. Syed Hussan has experience as a project engineer and received his Masters of Science and Civil Engineering from Georgia Southern University and his Bachelors of Engineering from the Chittagong University of Engineering & Technology. Welcome Fernanda, Tanvir and Syed!