GRL + PDI

Newsletter No. 32

Information gathered by the engineers of
Goble Rausche Likins and Associates, Inc. and *Pile Dynamics, Inc.*

April 1998

Driving Stresses in Piles

by Garland Likins

Pile foundations must have adequate soil support **and** be structurally sound. Soil strength uncertainty causes many engineers to specify static or dynamic pile testing and relatively high safety factors. In general, the pile's structural strength is much greater than the soil strength. However, when a pile fails structurally, it is likely to have very low load capacity compared with design loads, and/or a reduced effective length, and therefore displacements under design loads are likely to be excessive, particularly under tension loads. Unfortunately, pile damage cannot always be detected by merely checking driving records. Thus, dynamic testing should be used to assess the extent and location of suspected potential damage.

Hammer impact stresses are probably the most severe conditions the pile will ever experience in its life. Therefore, driving stresses have interested engineers involved in pile driving for decades and is one of the prime reasons the wave equation analysis was developed.

Allowable stresses are determined from the static strength of the pile material. However, most experts agree that the material strength is higher under short duration loading. Furthermore, actual pile strength often exceeds the nominal material strength. Because of this extra margin of safety and because driving stresses are only temporary, experience has shown they can be allowed to be near the nominal structural material strength.

In the United States, the Federal Highway Administration recommends the allowable **axial** driving stresses given in the table below (bending stresses occurring in practice cause extreme fiber stresses to be higher).

Typical Allowable Dynamic Pile Stresses in the US

Pile Type	Compression	Tension
Prestr. Concrete-US	$0.85(f'c)-f_{pe}$	$f_{pe} + 3.0\,(f'c)^{0.5}$
Prestr. Concrete-SI	$0.85(f'c)-f_{pe}$	$f_{pe} + 0.25\,(f'c)^{0.5}$
Precast Concrete	0.85 (f'c)	0.70 (f'y)
Steel	0.90 (f'y)	0.90 (f'y)
Timber	$3\,\sigma_a$	$3\,\sigma_a$

In this table, f'y is steel yield strength, f'c is the 28 day strength of concrete, f_{pe} is the effective prestress and σ_a is the allowable static timber stress. The concrete tension strength limits are dimensional and are given in both USA (psi) and SI (MPa) units.

Other agencies and codes in other countries specify different limits. For readers interested in more detail, GRL will be happy to provide more information upon request.

In a **wave equation analysis, *e.g.,* GRLWEAP**, the hammer, cushions and pile are modeled and stresses are calculated at every point along the pile. If the predicted stresses are too high for the pile strength, the hammer stroke could be reduced, a smaller hammer used, the cushion made softer, the pile material strength increased, or a heavier pile section chosen. Since GRLWEAP calculates **axial** stresses, the engineer should assure that the calculated values remain below the material strength.

Did you notice this Newsletter is now called "GRL + PDI"?
We made this change because our international readers are more familiar with Pile Dynamics, Inc. than GRL.
Yet, no matter what the name,
The news is still the same.

Many engineers prescribe **dynamic measurements during driving** using a **Pile Driving Analyzer® (PDA)** to verify that driving stresses are within acceptable limits. The typical dynamic test measures the axial stresses at the sensor location (usually near the pile top). This measured axial stress is often the maximum compression stress experienced by the pile. It is logical with current practice to allow higher stresses if they are measured, rather than simply estimated from assumptions and a computer model. In fact, the Australian code, AS2159, specifically states "Where stresses are actually measured during driving, the above values (limits) may be increased by up to 10%."

The PDA also calculates the maximum tension stresses occurring anywhere below the sensors, which is important for concrete piles. The maximum compression stress at the bottom of the pile can also be estimated from wave propagation theory. Both the tension stress along the shaft and the bottom compression stress are the average axial values. Bending or local contact stresses, for example at the bottom when the pile toe encounters sloping rock, must be considered separately. The extreme fiber compression stresses for each sensor can be determined, at least in one plane. However, these extreme stresses should not be held to the same limits as established for the average axial strength.

A dynamic testing program at the beginning of production can investigate the most effective and safe method to install the piles. Axial driving stresses are then known. Adjustments can be made, if necessary, to hammer energy or cushions if stresses are excessive. If the incidence of pile damage is too high, dynamic testing can reveal the extent of the problem, and the probable cause, leading to a rational suggestion for corrective action.

Occasionally pile structural damage occurs at low driving stresses. Possible causes include poor pile quality (material, reinforcement details) or improper pile handling, non-uniformity or lack of squareness of the pile top, loose or tight helmet fit, uneven helmet surface, high local contact stresses, improper pile guiding, applying excessive bending forces, obstructions in the ground, *etc.*

Collapse of a steel pipe may be caused by too thin a section for the lateral pressures from earth pressure or from driving adjacent piles. Bottom damage may occur from obstructions or non-uniform contact with hard bearing layers such as rock. Concrete pile damage may also occur in "flexible" or "bouncy soils" causing high tension stresses.

GRLWEAP NEWS

An interesting case was analyzed by *Bert Miner*, GRL WA. His **driveability** analysis indicated a higher blow count for a lower capacity due to a lower gain-loss factor. As it turned out, the lower capacity had a substantially higher end bearing associated with a large quake, explaining the higher blow count.

Please note for driveability analyses: variable setup time and energy limit analysis is only possible for **1 (one)** gain-loss factor.

To make it simple: For driveability analyses, several users successfully work with unit end bearing and apply the toe cross sectional area as the toe gain/loss factor.

Hyundai Engineering and Construction Co. has prepared input data for 8 hydraulic **DKH** hammer models PH5 - PH40. Please contact us for either hammer or cushion information. This data will be included with the next program release.

Several GRLWEAP users asked us about **discrepancies between ram weights in hammer sales literature and in the GRLWEAP data file**. We use factory supplied values which may be conservative. Ram weights apparently vary and sales literature may reflect more optimistic values. Some users may want to repeat their analyses with the data from brochures, particularly, for more conservative calculations. In any event, the user must check and verify all input data.

Golden Pile Award

We read on Europile's home page (www. europile.bachy.se) that Carl-John Grävare, Managing Director of PDI rep. Pile Dynamics Europe, AB, has received the coveted award for 1998 from the Swedish Piling Commission for his distinguished services.

Congratulations, Carl-John!

READERS, CLIENTS WRITE

California

GRL California's *Steve Abe* worked with Dr. G. Neelakantan of Geotechnical Consultants, Inc. at the San Francisco International Airport expansion project during 1997. Our client expressed his appreciation of Steve's work as follows: *"Your expertise in carrying out the PDA and CAPWAP analyses as well as the many technical discussions we had with you contributed significantly towards the success of this project."* And Keith D. Gilliam of Smith Emery Geoservices wrote: *"I have worked with Steve Abe recently and enjoyed the project."*

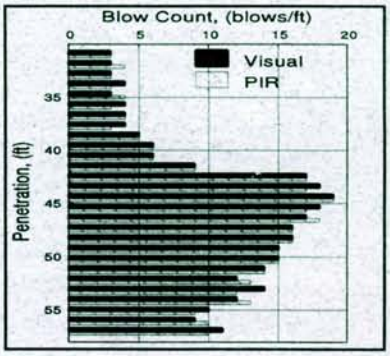
GRL Newsletter

Mr. Peter Friedli of Friedli Geotechnik in Zürich Switzerland wrote: *"Thank you for those good informations all the years over."* And Mr. Ray Lundgren of Lundgren Engineering Consultants, Lafayette, CA suggested a larger print for our Newsletter.

Old Times

Mr. Raymond Grover, formerly of the Ohio DOT and Burgess, Nipple in Columbus, OH had been research project monitor when the Case Method of pile testing was being developed. He sent us a fine Christmas Card and writing, among other mementoes: *"In my wildest dreams, in those days, I would have never dreamed that the testing would lead to the wonderful organization that you have developed."*

NEWS FROM PILE DYNAMICS



For improved quality assurance, productivity and efficiency, Pile Dynamics has developed the **P**ile **I**nstallation **R**ecorder (PIR) which consists of a rugged network processor with display and automatic data storage and several associated sensors. The equipment has been in field use. **For a complete report, please contact PDI's Garland Likins.**

The ***Driven PIR*** (for impact driven piles) has already been tested on several sites. (See chart for a comparison of visually and PIR-automatically measured-blow counts.) The PIR is capable of accepting additional channels of information such as pile inclination, pile rebound, *etc.*, thereby providing for a complete pile installation record.

The ***CFA PIR*** (for auger cast piles) helps reduce excess grout pumping for greater profits while giving the owner the assurance that the shaft has been installed according to specifications. Measurements include grout volume and pressure *vs.* depth at the pump and, if desired, pressure at the auger bottom. Other measurements, like torque, inclination, *etc.*, can be easily added.

SEMINARS AND WORKSHOPS

We have been frequently asked to conduct wave equation seminars and workshops. In response, GRL now offers two seminars, one in Baltimore, MD and one in Los Angeles, CA. Key goals for both events will be a hands-on workshop, teaching the participants pile design using the GRLWEAP wave equation program and its incorporation into practice. The new Windows based program will be introduced. An invitation describing the Baltimore workshop has been sent to our readers in the eastern half of the US; an invitation is enclosed for the California event.

Prof. Joe Caliendo of the University of Utah, together with *Dr. G. Goble* and GRL Chicago manager *Pat Hannigan*, will present a pile design short course in Logan Utah in June. An invitation is enclosed.

1998 CALENDAR OF EVENTS

April 16, 17; Pile Design and Construction Using Wave Equation Analysis and Dynamic Monitoring, Baltimore, MD; organized by *Wondem Teferra*, GRL PA. Call 216 831 6131.

May 15, 16; Applications of Wave Equation Analysis and Dynamic Testing Methods; Irvine, CA; organized by *Steve Abe*, GRL CA. Call 216 831 6131.

June 15-17; 7th DFI Int. Conference & Exhibition on Piling and Deep Foundations; Vienna, Austria. Call Caroline Prescot, 44 923 778311

June 24-26; Pile Foundation Short Course; Logan UT; organized by Prof. Joe Caliendo. Call 800 538 2663.

GRL

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