



GRL NEWSLETTER

No. 25

INFORMATION GATHERED BY THE ENGINEERS OF
GOBLE RAUSCHE LIKINS AND ASSOCIATES, INC.

APRIL 1995

Hydraulic Hammers and GRLWEAP™

by Garland Likins

Times are changing and so are pile driving hammers. Engineers performing wave equation analyses should understand the operation of these new hammers and inspect them properly during pile driving. Contractors must learn how to utilize the new technology for maximum productivity and minimum danger of pile damage.

New hydraulically powered hammers are available from several manufacturers. Most models allow for a **continuously variable energy or stroke** between some small minimum and the maximum rated energy to improve control of driving stresses and optimize productivity. For most single-acting hydraulic hammers, the ram is raised by hydraulics and then, either by mechanical or hydraulic design, the drop often is more or less a free fall; guides cause some friction losses which are higher for inclined piles. Double-acting hammers use either hydraulic or nitrogen assistance in addition to gravity (g) to speed the fall.

Many hydraulic hammers have **built-in sensors** to measure the ram impact velocity and hence the "kinetic impact energy" or "equivalent stroke" (kinetic energy divided by ram weight). Usually this measurement occurs when the ram is about 30 to 100 mm above impact; thus, the velocity may change between the time of measurement and impact.

When running a wave equation analysis the user inputs an **equivalent stroke**, h , and a hammer **efficiency** value, e . This input is converted to a velocity of the ram immediately prior to impact from square root of $2g(h)(e)$. When the efficiency is unity, all potential energy is converted to kinetic energy. A lesser efficiency would result in a reduced ram impact velocity to account for various loss factors (friction, poor alignment induced lateral motions, etc.; losses in cushions are accounted for separately).

Often wave equation users ask GRL how to perform a wave equation analysis for hydraulic hammers. First, the equivalent stroke must be input. This might be the maximum stroke, or a reduced value from either visual inspection or the built-

in sensor results. We strongly recommend that the field inspector should continuously observe the monitor for kinetic energy or equivalent stroke, and record the result in the driving log.

Next, a hammer efficiency must be given. GRL assigned efficiency values in the GRLWEAP hammer data file from hammer specifications or experience. For hammer models which are **always** fitted with built-in sensors and a kinetic energy readout, the hammer file efficiency is 0.95. Efficiency reductions for inclined pile driving are not required.

For hydraulic hammers without a built-in monitor as standard equipment, the efficiency may be listed as only 0.67 unless there is a positive indication that the ram falls freely (and not pushing against the hydraulics). For inclined pile driving a smaller value should be used.

Before pile driving starts, the GRLWEAP analyst may run the wave equation with several strokes and capacities to obtain stroke versus blow count that yields tolerable driving stresses. The field inspector and hammer operator are given a graph of maximum

allowable stroke versus observed blow count. A "**drivability analysis**" with user inputs of unit friction and end bearing as a function of depth is another possibility. An assumed stroke (and even different cushion stiffness and hammer efficiency) can be specified for each analyzed depth of penetration; output includes capacity, stresses, stroke and blow count as a function of pile penetration.

When analyzing an already installed pile with energy reading, we recommend that the wave equation analysis be performed with this readout energy converted to equivalent stroke (by dividing observed energy by the ram weight) and a hammer efficiency of .95, thus allowing for some losses during impact.

Any wave equation analysis contains assumptions regarding dynamic soil properties and hammer performance. **To assess soil and cushion behavior and investigate actual driving stresses and actual hammer energy transferred to the pile, we always recommend dynamic testing with a PDA (Pile Driving Analyzer®).** We have occasionally observed the built-in hammer monitor to give incorrect readings ■

STRESS WAVE '96 THE FIFTH INTERNATIONAL CONFERENCE ON THE APPLICATION OF STRESS-WAVE THEORY TO PILES

This very important conference is held every four years and will be held for the first time in 1996 in the USA (see Calendar of Events on reverse). It covers all aspects of dynamic pile testing and we hope that you will be able to attend. Please mark your calendar.

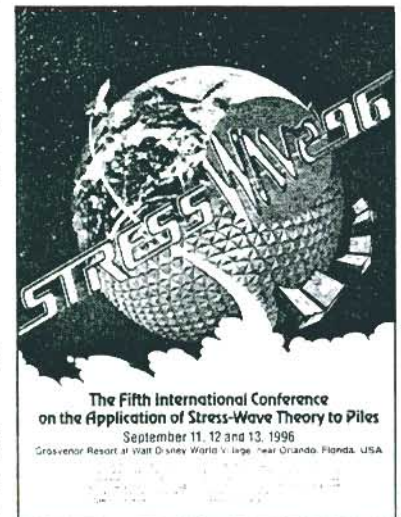
CALL FOR PAPERS

Conference Secretary, *Mohamad Hussein* reminds all stress wave engineers that abstracts of papers to be submitted for the September 1996 Orlando Conference are due on May 15, 1995. Please send abstracts to the Conference Chairman:

Professor Frank C. Townsend
Department of Civil Engineering
Box 116580, University of Florida
Gainesville, FL 32611-6580

Ph: 904-392-0926 Fax: 904-392-3394
Accepted Papers due: November 1, 1995

A poster announcing the conference has been commissioned by Pile Dynamics, Inc. and is now available for display. Please contact GRL if you can display one or more of these collectors' items.



GRL TESTS OFFSHORE

GRL engineers *Wondem Teferra*, *Gabriel Thendean* and *Scott Webster* spent their 1994/95 holiday season on an offshore pile driving rig in the Persian Gulf. Three jackets were installed within a three week period. As part of the monitoring, the PDA results were used for hammer performance and cushion property evaluation.

NEWS FROM PILE DYNAMICS, INC.

PDI delivered a set of underwater gages and cables to an offshore site in the South China Sea. GRL's *Steve Abe*, *Bert Miner* and *Neil Hamar* and *P. Somehsa*, *Somehsa Geosciences*, Singapore successfully employed this equipment to test 8 piles of 84-inch diameter. Two platform installations were flawlessly monitored with sensors in water depths to 110 m. The underwater testing equipment is available to all PDA users.

LITERATURE

In December 1994, a paper was presented at the Federal Highway Administration's International Conference on Deep Foundations by *Likins* et al. entitled "Hardware Solutions for Quality Control of Deep Foundations". PDI would be pleased to send a copy of this paper to those interested.

JAPAN

PDI's *Garland Likins* demonstrated to *Dr. and Mrs. Kenji Mori* and other engineers of *Kiso-Jiban Consultants* the P.I.T. equipment for use at the earthquake site in Kobe, Japan.

1995 PDA USERS DAYS, SEMINARS

- Bangkok, Thailand
- Jinan, China
- Cleveland, Ohio, USA
- Heidelberg, Germany

Successful application of modern measurement and analysis techniques, whether static, dynamic or somewhere in between, requires continuous updating of the user's know-how. For decades, GRL has been offering seminars and workshops at regular intervals. In 1995, Users Days will be held in May in the Far East, and in September in Europe and USA. In Bangkok, Cleveland and Heidelberg, a general seminar for anyone interested will precede the Users Days (see Calendar of Events and enclosure).

1995-96 CALENDAR OF EVENTS WITH GRL PARTICIPATION

USA

- Apr 7-8 Honolulu, HI. **Modern Piling Practice Using Dynamic Methods Seminar and Workshop**, organized by InSituTech (Ph: 510-254-0460, Fax: 510-254-0461).
- May 6 **SPT Symposium**, ASCE Seattle; For information contact Tom Armour, DBM Contractors. (Ph: 206-838-1402, Fax: 206-874-6574).
- Sept 14 Cleveland, OH. **Seminar on Dynamic Pile Testing Methods**. (Ph: 216-831-6131, Fax: 216-831-0916).
- Sep 15-16 Cleveland, OH, **PDA Users Days**. (Ph: 216-831-6131, Fax: 216-831-0916).

INTERNATIONAL

- May 4 Bangkok, Thailand. **Seminar on Wave Equation Analysis of Pile Driving and Dynamic Pile Testing**, organized by Pyramid Development Int'l Corporation Ltd. and ABV Singapore Pte. Ltd. (Ph: 66-2-235-8976-7, Fax: 66-2-236-9956).
- May 5-6 Bangkok, Thailand. **PDA Users Days**, organized by Pyramid Development Int'l Corp. Ltd. and ABV Singapore Pte. Ltd. (Ph: 66-2-235-8976-7, Fax: 66-2-236-9956).
- May 12-13 Jinan, China. **PDA Users Days**, organized by Earth Products (China) Ltd. (Ph: 86-852-23928698, Fax: 86-852-23955655).
- Sep 27 Heidelberg, Germany. **Seminar on Dynamic Pile Testing Methods**, organized by GSP (Ph: 49-621-331361, Fax 49-621-334252).
- Sep 28-29 Heidelberg, Germany. **PDA Users Days**; organized by GSP and PDE (Ph: 46-31-450-015, Fax: 46-31-459-980).

1996

- Sep 11-13 Orlando, FL. **Fifth Int'l Conference on the Application of Stress-Wave Theory to Piles**, organized by the Univ. of Florida; see **STRESSWAVE '96** on first page.

GRLWEAP NEWS

The latest GRLWEAP version (1.994-1) was shipped in February. Several new features of this program have been described in earlier GRL Newsletters. One important change was made in the diesel hammer efficiency values. (For a discussion of efficiencies assigned to hydraulic hammers, see our main article.)

In the past, efficiencies were set to 0.72 for diesels with liquid fuel injection and a 1.25 expansion exponent and 0.8 for other diesel hammers. In the new hammer data file, all default efficiencies for diesels are now 0.8. GRLWEAP was then programmed such that computed results matched those for older program versions with the 0.72 efficiency.

GRL would like to emphasize that efficiency values contained in the GRLWEAP hammer data file are a part of the mathematical hammer model. They do not express a statement of quality and **cannot be used to judge relative hammer performance**. Furthermore, depending on its state of maintenance, a hammer may require a higher or lower efficiency for agreement with actual performance.

GSP COOPERATES WITH PDE

Dr. O. Klingmüller of GSP, Mannheim, Germany will assist Pile Dynamics Europe, Sweden with user support and other activities in Central Europe. See September 27 in Calendar of Events for phone and fax numbers.

SPT TESTING IN SEATTLE

The Seattle section of ASCE will present a symposium on subsurface investigation on May 6, 1995. In preparation for the program, extensive field testing was performed on Feb. 11 and Mar. 11 at a liquefaction sensitive site in Seattle. Eleven drill rigs were used and subjected to energy calibration testing by GRL engineers. The huge amount of data collected is now being evaluated by Seattle geotechnical engineers and GRL. Both symposium and test results should be of great interest to all readers. GRL Seattle Manager *Bert Miner* who was involved in the planning of the event, will present the data at the symposium in May. A summary of GRL test results will be available after June 1 to those interested.

Please note the change in area code for **GRL's Seattle office (Ph: 360-871-5480, Fax: 360-871-5483)**.

GRL

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