GRL NEWSLETTER

No. 30

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GOBLE RAUSCHE LIKINS AND ASSOCIATES, INC.

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HIGH-STRAIN DYNAMIC TESTING OF DRILLED SHAFTS

by Mohamad Hussein, GRL Florida

Drilled shafts are produced by forming holes in the ground and filling them with concrete. Holes may be drilled with or without a steel casing, dry or with mud slurry. Diameter sizes may reach 3 m or more, and lengths of 60 m are not uncommon. Deep foundations are used to support structures where subsurface conditions are difficult and it is the very nature of these conditions that sometimes evoke questions regarding their structural and geotechnical load carrying capability. For quality assessment, a few days after installation, structural integrity of drilled shafts may be evaluated by the low-strain dynamic pile test method P.I.T. (see also GRL Newsletter No. 29) or by the so-called Cross Hole method (see reverse). Both methods have limitations and do not address bearing capacity considerations.

Capacity has traditionally been verified by static testing. Because of the high costs associated with static testing, high-strain dynamic pile testing has become routine for evaluating drilled or cast-in-place shafts in many parts of the world today. Testing is usually performed for evaluation of pile bearing capacity, assessment of shaft structural integrity, and appraisal of pile-soil load transfer and pile load-movement relationships. In the field, pile strain and acceleration records are measured under typically 2 or 3 impacts of a drop weight. The Pile Driving Analyzer® (PDA) and CAPWAP® provide the data acquisition and analysis tools, respectively.

To design a successful dynamic test system, the GRLWEAP™ wave equation analysis may be used with drilled shaft specific inputs (*e.g.*, Smith-viscous soil damping, "constant capacity and variable stroke" analysis, realistic ram and non-linear cushion modeling). In this way, drop weight, drop height and cushion can be selected for sufficient pile movement under the dynamic load to mobilize the required soil resistance and for safe dynamic stresses. The loading system must be constructed for a uniform, high energy impact to the pile head, mobility on the job site and safety. Naturally, the smallest satisfactory hammer weight is the most desirable. Free release mechanisms of several types have been used in many different countries. A short set of leads, or either an external or internal centering rod are often employed to guide the impact device. A steel striker plate of 50 to 100 mm thickness is placed on the cushion.

When performing detailed GRLWEAP analysis to design a test system, the following parameters may be used as starting values[1]:

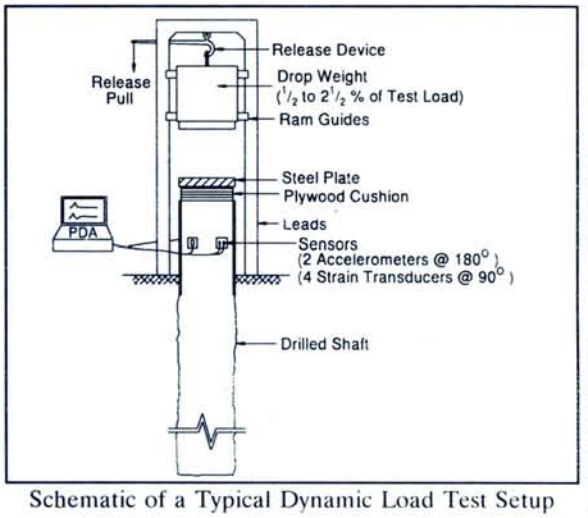
- drop weight equal to 1.5% of the required static test load
- drop height of 8.5% of shaft length, L, or at least 2 m
- plywood cushion diameter equal to 90% of the shaft diameter, D
- cushion thickness, $t = L^2/2D$ (mm), with a minimum of 100 mm (250 mm for $L > 30$ m)

Of course, refined GRLWEAP analysis must be performed, with careful consideration to shaft and soil specifics, and local availability of a ram. For example, it may be convenient to construct a special heavily reinforced concrete or concrete-filled pipe hammer, together with and near the test shaft(s). Large hammers can be made in segments and assembled at the job site. The modular design of segmental hammers allows for flexibility in application under different conditions.

Testing should be performed after the concrete has acquired sufficient strength. For accuracy, four strain transducers and at least two accelerometers should be attached to the shaft at least one pile diameter below its top. The test is usually started with a relatively low hammer drop height. The uniformity of impact is checked and adjustments to hammer-pile alignment are made, if necessary, before application of suitable subsequent higher drop heights. Shaft dynamic stresses, structural integrity and aspects of soil resistance may be immediately evaluated from the PDA records. It may be constructive to perform a P.I.T. low-strain dynamic integrity test on the shaft both before and after application of high-strain test impacts. The two test procedures may be combined for optimum results.

Dynamic shaft test records are rigorously evaluated by CAPWAP analysis, often using a soil radiation damping model to account for soil motions. The analysis results include:

- static pile capacity
- soil resistance distribution
- dynamic soil parameters
- shaft-soil load transfer
- simulated static load-set curve



Schematic of a Typical Dynamic Load Test Setup

Dynamic pile testing and analysis are well established methods in foundation engineering practice around the world on thousands of projects annually both for design and construction control. Field testing equipment and analytical procedures have been proven to be reliable and accurate through their long track record of scientific study and practical application spanning over a quarter of a century.

The technique is well suited for the evaluation of cast-in-place deep foundations. Advantages over other types of static or quasi-static methods include: low cost, convenience and speed of testing, minimal pile preparation, assessment of structural integrity, and the ability to randomly test shafts after installation. We have been told that drop weights up to 35 tons are routinely used to apply test loads up to 40 MN.

WE ARE ON THE WORLDWIDE WEB

Please visit us at our http://www.pile.com site. We will attempt to keep that page updated with all the newsworthy events of our GRL Newsletter.

[1] Hussein, M., Likins, G., Rausche, F., (1996), "Selection of a Hammer for High-Strain Dynamic Testing of Cast-in-Place Shafts," 5th Int. Conf. on the Appl. of Stress-Wave Theory to Piles, Orlando, FL.

GRLWEAP NEWS

The 1997-1 Version has been released to, and beta-tested by, GRL engineers. The new version includes updated driving system and hammer data files and an easy-to-use data retrieval system for driving system parameters. A new hammer type has been coded and a few subtle changes were made in the vibratory analysis. The Background Report was re-edited and reprinted in its entirety. Insert pages for the Users Manual describe new features. The update is currently being shipped to **GRLWEAP** users with current support.

GRL Washington Manager *Robert Miner* alerted us that GRLWEAP 1.996-2 and earlier versions show an incorrect final result stroke in the Inspectors' Chart (Analysis Type -2 or 2), if the hammer has a relatively large compressive stroke. This error can be avoided by specifying a starting stroke in the input. The 1997-1 version fixes this problem.

P.I.T. SOFTWARE NEWS

Pile Dynamics, Inc. (PDI) and GRL have both worked on improved data collection and analysis systems for low strain pile testing. **P.I.T.-Collector** improvements include a 2-velocity measurement option which is particularly useful for the testing of existing pile foundations. The associated PITPLOT software was also updated.

Another development is **PITSTOP** (Pile Integrity Tester: Sonic/Transient Output Program) which has now been beta-tested and which offers automatic calculations of both Pile Profile and Transient Response and multiple record plotting. For a description of PITSTOP, please contact GRL Cleveland.

PDA USERS DAYS SLATED

PDA and P.I.T. owners, users or those using the results of dynamic test reports are cordially invited to attend this year's PDA Users Days. GRL and PDI have held PDA Users Days events on a regular basis at several locations worldwide since 1979 as a commitment to providing strong support and continuing education opportunities for PDA, P.I.T. and CAPWAP users.

On August 22 and 23, 1997, a PDA Users Days will be held in Cleveland, OH. The program will demonstrate how both the Finite Element program TIPWHIP and the new PITSTOP software can help in the interpretation of dynamic test records. A GRLWEAP session will discuss driveability options and a CAPWAP demonstration will discuss the proper use of new and existing automated procedures. Similar topics will be presented on Sept. 12, 1997, immediately following the conclusion of the Int. Soil Mechanics Conf. in Hamburg, Germany. A seminar on pile design and construction control will also be held. Those interested in international trends of pile design and testing should benefit from the seminar. Further details on all events will be given in the next issue of the GRL Newsletter.

1997 CALENDAR OF EVENTS

INTERNATIONAL

Apr. 24-26	China, PDA Users Days; contact Frank Ko, Earth Products China, Ph: 852-2392-8698, Fax: 852-2395-5655
May 1, 2	Hong Kong, PDA Users Days; contact Earth Products China (see above)
May 6, 7	Korea, PDA Users Days; contact J. S. Cha, Young Shin Trading, Ph: 822-529-8803, Fax: 822-3461-3021
Sep. 12	Hamburg, Germany, PDA Users Day; contact GRL Cleveland or Dr. O. Klingmüller, Pile Dynamics Europe (PDE), Ph: 49-621-331361, Fax: 49-621-334252
Sep. 12	Hamburg, Germany, Dynamic Testing Seminar; contact PDE (see above)

USA

May 30-31	Orlando, FL, Current Practice and Worldwide Trends; contact GRL and Associates, Inc., Ph: 407-826-9539, Fax: 407-826-4747
June 25-27	Logan UT, Pile Foundation Short Course; contact Prof. J. Caliendo, Utah State Univ., Ph: 801 797-2896; Fax: 801 797-1185
Aug. 22-23	Cleveland, OH, PDA Users Days; contact GRL Cleveland

FLORIDA SEMINAR ON WORLDWIDE TRENDS

GRL Florida Manager *Mohamad Hussein* has put together an informative program with an impressive list of speakers for a 2-day seminar in Orlando. To be held on May 30 and 31, this seminar will provide background and State-of-the-Art information as well as case studies on modern pile design and construction methods. Please register using the enclosed brochure.

PILE INTEGRITY BY CROSS HOLE TESTING

GRL has acquired the necessary hardware to perform pile integrity testing by sonic logging. This method requires that a minimum of 2 tubes (50 mm dia or larger) are installed in a shaft prior to concrete placement. Sonic transmitters and receivers are then lowered into the tubes and the concrete between them is tested. Results can be displayed and printed in the field or a report can be generated in the office. Please contact your local GRL engineer for further information.

NEW BOOKS BY UNISOFT

Books on Foundation Design and Piling Specifications may be ordered through Dr. B. Fellenius in Ottawa, Canada at telephone: (613) 741-5594 or fax: (613) 741-5594.

NEWS FROM PILE DYNAMICS, INC.

PDI has developed **VWA**, a battery powered, inexpensive warning device for the investigation of site vibrations. An LED on the unit is activated when a user specified vibration level has been exceeded. Please call PDI for further information on the **Vibration WArner**.

PILING WORKSHOP

Professor Joe Caliendo of Utah State University announces a short course on pile design and pile installation for June 25-27, 1997 as described in the enclosed brochure.

PDCA RELEASES FHWA DESIGN MANUAL

The Federal Highway Administration Manual, "Design and Construction of Driven Pile Foundations", recently edited by GRL, is now available from the Pile Driving Contractors Association. To obtain cost and other information, contact Kay Haines, Executive Director, PDCA, telephone: (314) 275-7453 or fax: (314) 576-7989.

RESULTS OF 4th INTERNATIONAL STRESS WAVE CONFERENCE TESTS

Balkema has published results of tests performed in 1992 in The Hague at the above conference. Winners of the pile bearing capacity prediction event were GRL, Pile Dynamics Europe and Fugro, who each used **CAPWAP** to evaluate their measurements.

GRL

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