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HIGH-STRAIN DYNAMIC TESTING OF DRILLED SHAFTS

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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]:

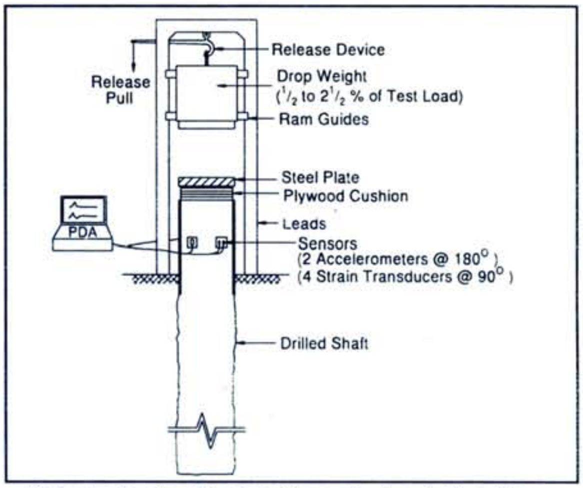
- drop weight equal to 1.5% of the required static test load
- drop height of 8.5% of shaft length, L, or at least 2 m
- plywood cushion diameter equal to 90% of the shaft diameter, D
- cushion thickness, $t = L^2/2D$ (mm), with a minimum of 100 mm (250 mm for $L > 30$ m)

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.

[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.

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