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Pile Dynamics, Inc.

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Just Run a Wave
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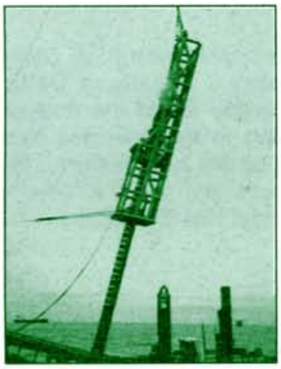

GRLWEAP™

Wave Equation Analysis: Engineers do it. Contractors do it. Hammer manufacturers do it. Most professionals involved in pile driving projects do it and specifications require it.

Why are they doing it? To be sure that a pile can be driven safely and efficiently.

What do they need to know as inputs? The pile properties, the hammer model and associated driving system, and soil information.

When do they run the wave equation analysis? Usually prior to the pile installation, during design, to check whether the selected pile can be driven to the desired depth or capacity, or if a change of pile size or wall thickness is indicated. The analysis also helps in cost estimating, by aiding in hammer selection and in the assessment of driving time.

Why not just use a formula? Doesn't a formula give you a required blow count for a hammer energy value and a required capacity? Sure, but most formulas give the same (inaccurate) result regardless of pile stiffness, hammer or soil type or other parameter variations. None of the formulas yields accurate capacity or stress prediction. Formulas have therefore fallen out of favor with most professionals, and have been generally replaced by user-friendly wave equation analysis.

A factor of safety must be applied to the calculated ultimate pile capacity. Some codes prescribe a factor of safety based on all sources of uncertainty, including project type, care used in pile installation, and accuracy of the method of capacity assessment. A good example is the design code of the Pile Driving Contractors Association (PDCA), which recommends a lower factor of safety for wave equation analysis than for formulas.

It is easy to run a basic wave equation analysis, particularly for anyone familiar with hammers, driving systems, piles and soils. Yes, you have to use the right input values for the various system components, but the GRLWEAP software contains extensive recommendations. The "bearing graph" analysis makes it easy to compare two hammers by showing ultimate capacity and driving stresses versus blow count. You can also estimate how many minutes it should take to drive the pile to a certain depth. Such a "driveability" analysis requires an assessment of the ultimate pile capacity versus depth (here, assistance from a geotechnical engineer is helpful).

As a GRLWEAP example, consider a 300 mm diameter (12 inch) closed ended pipe pile driven into an increasingly dense sand (after driving it will be filled with concrete). The required working load of 50 tonnes with a required factor of safety of 2.5 leads to a minimum ultimate capacity of 125 tonnes. A static soil analysis indicates that the pile has to be driven to roughly 15 m depth to get the required capacity. You are to choose the wall thickness and hammer. An air hammer, acceptable according to the ENR formula, and a higher energy diesel are considered. The table below summarizes the results from GRLWEAP.

Obviously driving the thinner walled pipe with the small air hammer is uneconomical, requiring too many blows and a driving time of more than 1½ hours. Furthermore, damage might occur for mild steel piles because of the larger number of blows at high stresses. With the thicker wall, the pure driving time would be greatly reduced. The diesel hammer could drive either pile very quickly, however, high strength steel would be needed, at least for the 6 mm pile.

Stresses are normally predicted within 10% by GRLWEAP, and calculated blow counts and driving times also have a margin of error, primarily due to hammer performance variations. Thus, the wave equation results should be checked by field measurements during pile driving using a Pile Driving Analyzer®. The safety factor often used for wave equation analysis can be further lowered (by PDCA or AASHTO code) if the pile is either dynamically or statically tested.

PDI regularly offers workshops on wave equation analysis, and GRL Engineers provide individual training at a client's office or at its offices. GRL Engineers also perform the analysis on a consulting basis. The wave equation analysis is an invaluable tool for the selection of hammer and pile sizes, and reduces unnecessary costs due to high blow counts, or due to pile damage from excessive driving stresses.

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Happy Holidays

The end of another successful year for GRL and PDI is a wonderful opportunity to thank you, our readers, and wish you the best for 2003.

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GRLWEAP Calculated Results

Wall Thickness		Hammer	Ram Weight		Rated Energy		No. of blows		Compressive Stress	
mm	(inch)		kN	(kips)	kJ	(kip-ft)	(time in minutes)		MPa	(ksi)
6	(1/4)	air	22	(5.0)	20	(15)	5836	(106)	213	(31)
6	(1/4)	diesel	19	(4.3)	59	(43)	662	(16)	260	(38)
9	(3/8)	air	22	(5.0)	20	(15)	1640	(30)	140	(20)
9	(3/8)	diesel	19	(4.3)	59	(43)	635	(15)	220	(32)