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DYNAMIC LOAD TESTING CONFORMS TO NEW ASTM D-7383 RAPID LOAD TESTING STANDARD

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Stress waves in a pile or any other slender elastic element are a fascinating phenomenon. Mathematically described in the 19th century by Boussinesque, St. Venant and others, they can be studied graphically as shown by Fischer in the 1950's and 60's, or numerically as was most successfully done by Smith in his initial development of the "wave equation". Wave propagation theory helps us to interpret dynamic measurements on any type of slender pile. Such measurements record both an impact force that compresses the pile top and the echo that is generated by changes in soil resistance or changes in pile properties, most importantly the reflection at the pile toe.

In order to provide a visual representation of the stress wave propagation, Pile Dynamics prepared two computer programs which are freely accessible on www.pile.com and are easily used by anyone with an interest in mechanics. The first one, called PIT-S, shows the response of a pile to a very short and sharp impulse as typically generated by a pulse-echo or low strain integrity test (ASTM D5882). It also shows the stress wave paths generated by the light hammer pulse and allows for modeling soil and pile in a realistic manner.

The second program, called PDI-Wave, is based on Smith's wave equation concept and shows what happens when a heavy ram impacts a pile. The left part of Figure 1 shows by its size and blue color that the pile is in compression at some time during the impact event (PDI-Wave represents tension in red). To the right, pile top force, velocity and displacement show data that would be acquired in a high strain dynamic load test (ASTM D4945) or force-pulse (rapid) test (ASTM D7383) on a deep foundation element. Data acquisition and analysis are usually achieved with a Pile Driving Analyzer® (PDA) and CAPWAP®.

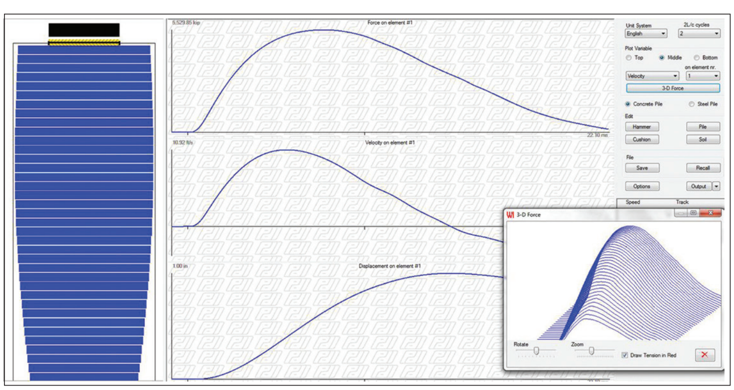

Figure 1: Simulation by PDI-Wave of a lightly cushioned, heavy ram impact

Interpretation of records by wave propagation theory is only successful if the applied pulse has a "wave front", in other words, if the force rises quickly. An over-cushioned impact causes a very slow increase of forces and the resulting reflections give no clear information as to their point of origin (depth along the pile). For this reason, over-cushioned impacts do not lend themselves to the assessment of the soil resistance distribution and/or pile integrity solely from force and velocity measurements at the pile top. On the other hand, a relatively heavy ram has the advantage of making the impulse long enough to suppress tension stresses that may be detrimental to an under-reinforced shaft. According to Rausche et al. (2008) the suppression of tension stresses is primarily a function of the relative ratio of ram weight to pile weight ("alpha"), a conclusion that was already reached in closed form solutions by the 19th century mathematicians studying wave propagation. Figure 2 of Rausche et al. (2008) illustrates this concept.

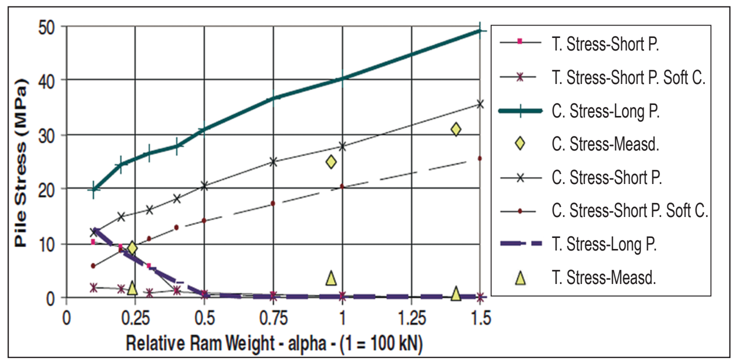

Figure 2: Relationship between ram-pile weight ratio and pile stresses for long and short piles.

GRL California recently tested several drilled shafts in Pico Rivera, CA, using the PDA and a weight of mass 15 ton for the impact. The shafts had a diameter of 900 mm and ranged in length between 9.7 and 10.4 m. The force records were measured by a load cell (unlike in a conventional PDA test which uses strain transducers for force measurements) when the weight was dropped from a height between 0.9 and 1.2 m onto a 0.6 m plywood cushion.

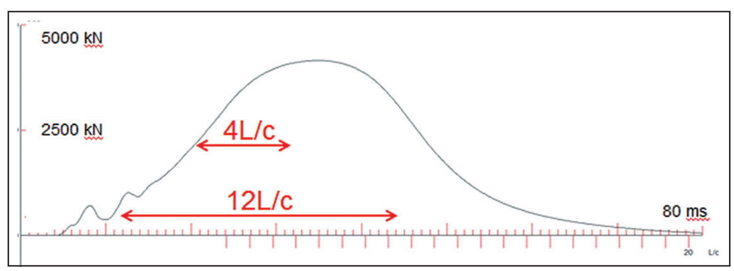

Figure 3: Force at shaft top from dynamic/rapid load test

CAPWAP-calculated static capacities were close to 5000 kN with about 50% end bearing for most test shafts. Tension stress levels were insignificant, which could be expected since the ram to pile weight ratio was 0.83.

Figure 3 shows a force record with a total duration well in excess of the ASTM D7383 requirements (12 times the wave travel time, L/c, overall and 4 times at half load). This shows that PDA tests (normally run according to ASTM D4945) can qualify as rapid load tests under D7383 when a ram of sufficient mass is used, with the considerable advantage that the data with a clear "wave front" can be analyzed by the rigorous CAPWAP analysis (Miyasaka et al, 2008).

References mentioned on this article may be downloaded from www.pile.com/references.