Impact and Vibro Driveability´s analysis

GRL's Wave Equation Analysis of Pile (GRLWEAP) driving program simulates motions and forces in a foundation pile when driven by an impact or vibratory hammer.

The program, via a numerical approach called Smith´s algorithm, solves with good approximation the canonical form of a hyperbolic partial differential equation, the wave equation.

The schematic model for an impact external combustion hammer is shown in Figure 1.

The hammer model consists of masses and springs simulating the ram and the assembly. More than one ram segment is necessary to simulate the new hydraulic offshore hammers.

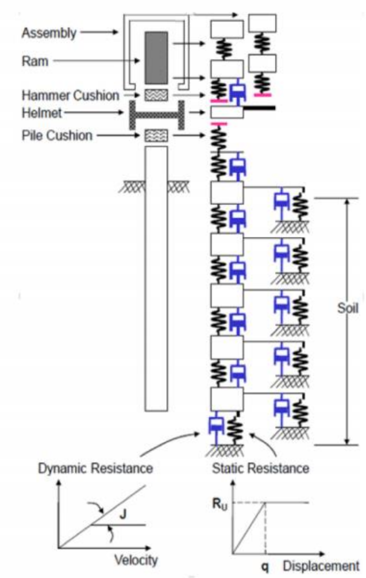

Figure 1 – Schematic model of a typical external combustion hammer (ECH)

The GRLWEAP vibratory hammer model consists of 2 masses connected by a linear spring and linear dashpot, see Figure 2. The Bias (upper) mass serves as a vibration isolator and adds weight to the downward force acting on the pile. It is also subjected to an upward-directed force called the crane line force, F_L, which may represent the crane line pull.

When the pile fully supports the hammer's weight, $F_L = 0$. A downward directed force (negative value) indicates crowd force, which helps the pile penetrate quickly. An upward directed force (positive value) could cause extraction if it exceeds the hammer's weight plus the pile's weight and soil shaft friction.

GRLWEAP applies the sinusoidally varying vibratory force, F_V, to hammer's oscillator (lower) mass, which contains the eccentric masses.

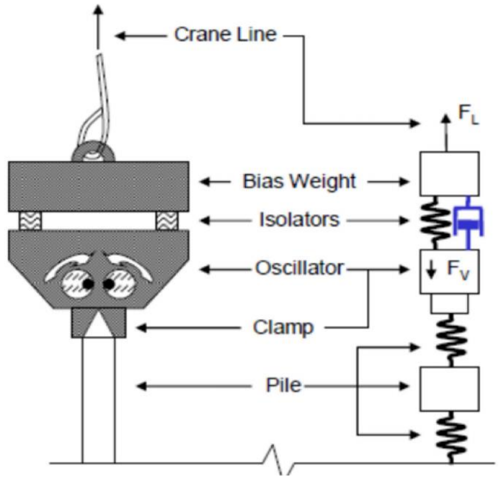

Figure 2 - Schematic model of a vibratory hammer

The pile model, a lumped mass model, consists of springs, masses, and dashpots and is divided into N segments, see Figure 3.

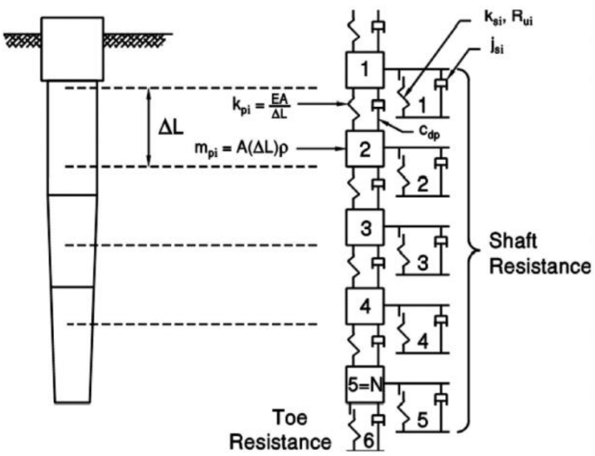

Figure 3 – Numerical wave equation model

GRLWEAP's soil model is a Smith approach, consisting of a spring and dashpot, see Figure 3. The elastic spring yields at a pile segment displacement equal to the quake, q_i (elastic displacement). Beyond this point, there is no further increase in static resistance, R_{si}, with increased displacement, u_i. Thus, if the pile segment's velocity is positive (downward), i.e., during the initial loading phase:

- $R_{si} = (u_i/q_i)\ R_{ui}$, when $u_i < q_i$
- $R_{si} = (u_i/q_i)\ R_{ui}$, when $u_i > q_i$

Where R_{ui} is the ultimate static resistance at segment i.

An accurate static analytical analysis based on quality soil strength information is crucial for the success of the Driveability analysis, depending on the engineer's expertise.

It is the static analysis objective to determine unit shaft resistance and unit end bearing vs. depth.

Another important detail for driveability analyses is the determination of the Static Resistance to Driving (SRD) from the Long-Term Static Resistance (LTSR), calculated by a static geotechnical analysis. SRD develops during driving due to dynamic effects on the soil and results from soil fatigue. After pile driving, the soil regains the long-term resistance from the soil setup (soil cicatrisation). Thus, LTSR is expected to be achieved during a restrike test after a sufficiently long waiting time.

Included in the soil routine of the GRLWEAP software is the Friction Fatigue Method, according to Alm and Hamre (2001). This method calculates the SRD directly without referring to the LTSR.

Below, in Figures 4 and 5, we present two examples of impact and vibratory hammer driveability, respectively.

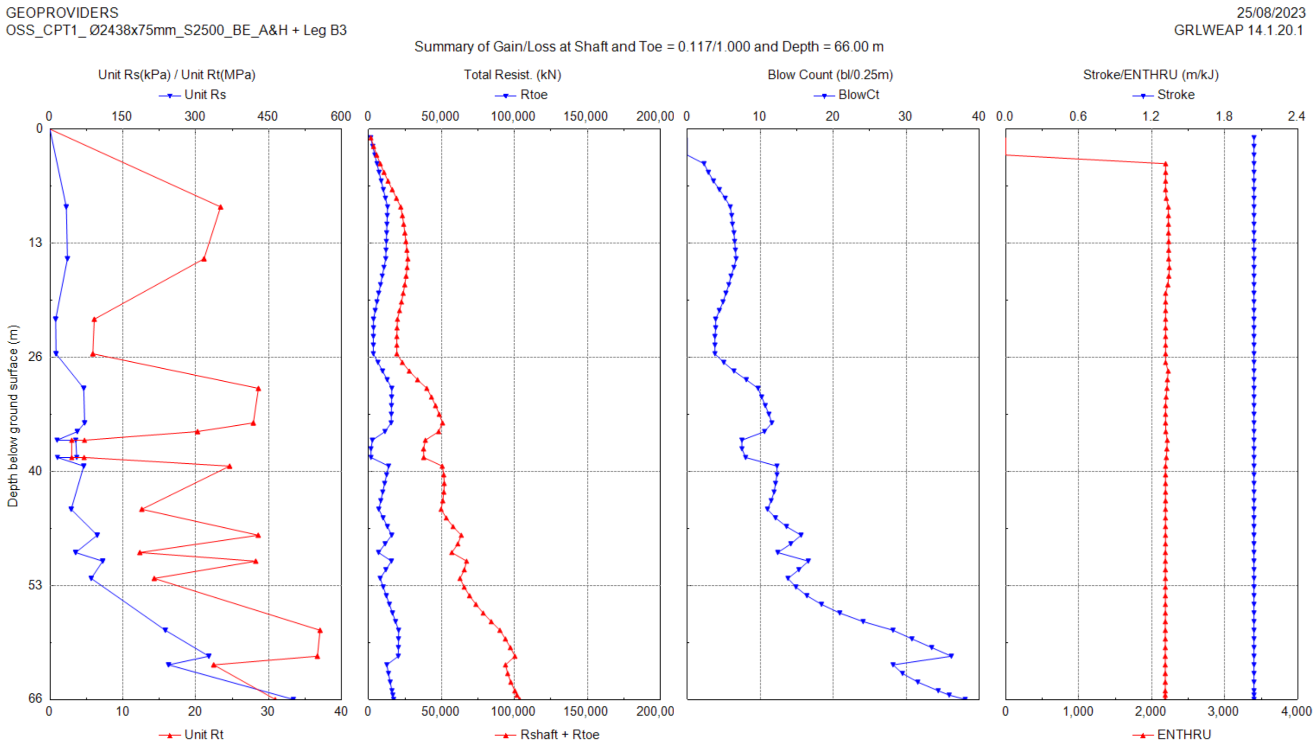

Figure 4- Driveability summary of a North Sea project with the IHC S2500 hammer considering the A&H soil fatigue model.

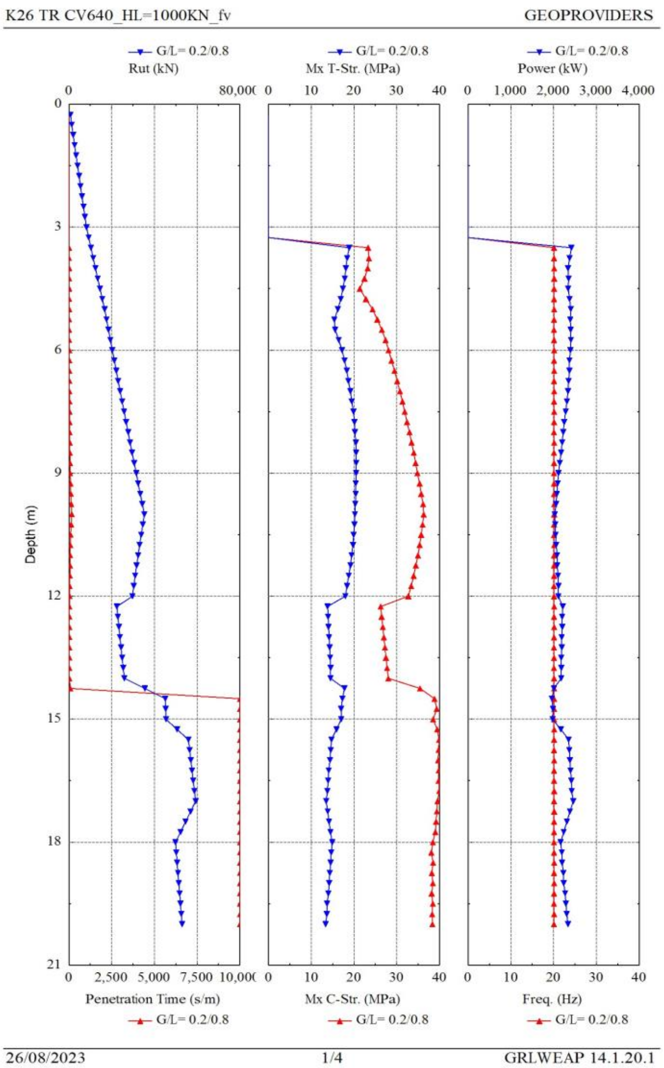

Figure 5 – Vibro-Driveability summary for a North Sea project with TR CV640.

Another software output feature is the particle displacement, velocity, and force analysis in time at depth.

We present in Figure 6 the exercise for a time analysis result of a pile Ø2438x75mm driven by an IHC S2500 at the depth of 66m, considering very little soil shaft friction and almost zero end bearing resistance.

The analysis was done for top, middle, and toe pile particle positions. The graphs show the impulse wave propagation expected from a strike where the shaft and soil end bearing are nearly zero.

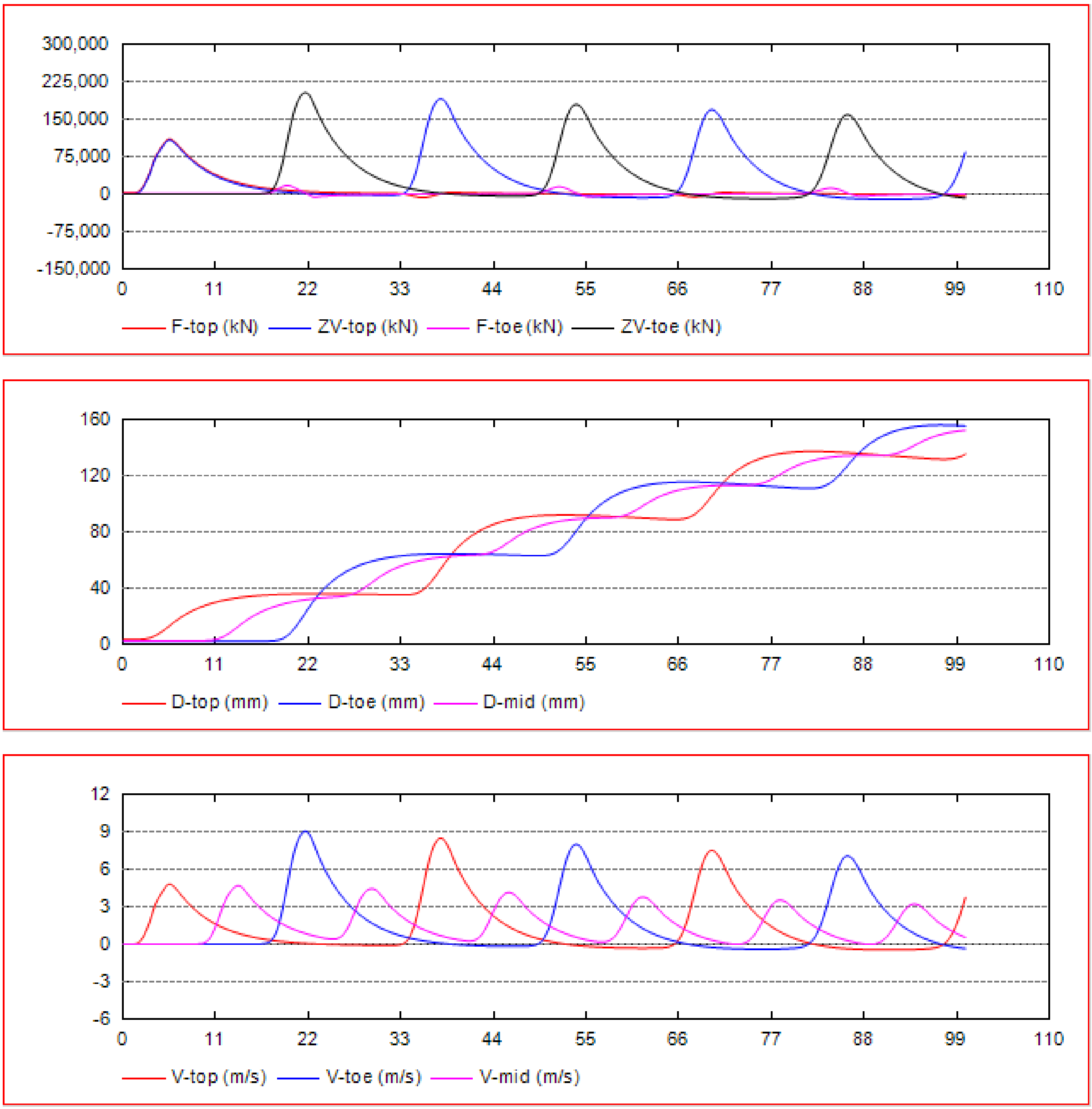

Figure 6 –Time IHC S2500 Impact Driveability analysis at 66m soil penetration. Graphs on the top, centre and below state the particle Force, Displacement, and Velocity at the pile top, middle and toe.