Pile Dynamics, Inc.

Quality Assurance for Deep Foundations

High Strain Dynamic Testing

When a hammer or drop weight strikes the top of a foundation, a compressive stress wave travels down its shaft at a speed c, which is a function of the elastic modulus E and mass density. The impact induces a force F and a particle velocity v at the top of the foundation. The force is computed by multiplying the measured signals from a pair of strain transducers attached near the top of the pile by the pile area and modules. The velocity measurement is obtained by integrating signals from a pair of accelerometers also attached near the top of the pile. Strain transducers and accelerometers transmit data to a high strain dynamic testing system such as the Pile Driving Analyzer® (PDA), for signal processing and results.

As long as the wave travels in one direction, force and velocity are proportional:

F = Zv, where:
Z = EA/c is the pile impedance
E is the pile material modulus of elasticity
A is the cross sectional area of the pile
c is the material wave speed at which the wave front travels

Soil resistance forces along the shaft and at the toe cause wave reflections that travel and are felt at the top of the foundation. The times at which these reflections arrive at the pile top are related to their location along the shaft. The measured force and velocity near the pile top thus provide necessary and sufficient information to estimate soil resistance and its distribution.

The resulting estimated total soil resistance includes both static and viscous components. The static resistance is obtained by subtracting the dynamic component from the total soil resistance. The dynamic component is computed as the product of the pile velocity times a soil parameter called the Damping Factor. The damping factor is related to soil grain size.

The energy delivered to the pile is directly computed as the work done on the pile from the integral of force times incremental displacement ($\int Fdu$) which is easily evaluated as force times velocity integrated over time ($\int Fvdt$). Maximum compression stresses at the pile top come directly from the measurements. The measurements also allow direct computation of the compression stress at the pile toe and the tension stresses along the shaft. Pile integrity can be evaluated by inspecting the measurements for early tension returns (caused by pile damage) prior to the reflection from the pile toe; lack of such reflections indicates a pile with no defects.

High Strain Dynamic Testing encompasses Dynamic Pile Monitoring and Dynamic Load Testing. Both are covered by ASTM D4945. Pile Driving Monitoring consists of performing real time evaluation of Case Method capacity, energy transfer, driving stresses and pile integrity for every blow. Dynamic Load Testing involves combining field measurements obtained with a high strain dynamic testing system such as the PDA with wave-equation based analytical procedures performed with a signal matching program such as CAPWAP® . Dynamic Load Testing predicts soil behavior including static-load capacity, soil resistance distribution, pile soil load transfer characteristics, soil damping and quake values, and pile load versus movement plots (e.g. a simulated static load test).

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