Vibratory Hammers for Pile Driving and Soil Improvement

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Introduction

The capability and versatility of hydraulic vibratory pile driving hammers are often underestimated. For many installations vibratory hammers are better alternatives to impact hammers and in others an important and cost effective complementary tool to impact hammers.

Hydraulic vibratory hammers are in particular well suited for sheet piles, cast-in-situ tubes, H-beams (anchor piles) and steel pipe piles. Besides, they are superior to other equipment for extraction of sheet piles by being fast and by making minimal damage to the piles so they can be used again and again.

The principle of a vibratory hammer

The major components of a vibratory hammer are:

- an even number of shafts with eccentric weights.
- a vibratory case (gear box) containing the eccentric weights and hydraulic motors.
- an elastomer-isolated hammer head (suppresser).
- one or a set of hydraulic pile clamps mounted under the gear box.

The shaft with their weights are synchronised by a gear system and are driven by one or more hydraulic motors. The counter-rotating eccentric masses rotate at 1200 - 3000 rpm (20-50 Hz). By their rotation the horizontal components of the centrifugal forces eliminate each other and the vertical components add. The generated vertical forces result in oscillating pile and hammer movements up and down with amplitudes being a function of the eccentric moment and the total weight of the moved parts.The weight of the moved parts are the sum of the weight of gear box, clamp and pile under installation. This sum is named the dynamic weight.

The hammer head is effectively isolated against vibrations from the vibration case by a number of high-effective elastomer vibration absorbers. The isolation protects the rig or crane against damage from vibrations and contributes to higher hammer efficiency by eliminating energy loss.

The hydraulic motors are driven either by a hydraulic powerpack or by the hydraulic system of a piling rig or crane. The operating frequency of the hammer can be regulated by the speed of the diesel engine. With a handheld block or by remote controls the operation of the hammer and powerpack/diesel engine can be controlled.

On freely suspended hammers the powerpack is connected to the vibratory hammer with a hose set consisting of a:

- pressure and return line for the hydraulic motors
- drain hose for the hydraulic motors
- pressure and return line for the pile clamps
- on resonance-free hammers there is further a set of hoses for regulating the eccentric moment.

The clamp mounted under the vibration case ensures secure attachment to the object which is to be driven or extracted. The standard hydraulic clamp contains two gripping jaws - one fixed and one movable. The clamp cylinder contains a check valve that protects the clamp cylinder from loosing the required pressure for clamping in case the hydraulic hoses are damaged.

How the vibratory hammer functions in the soil

The continuous impulses of energy transferred from hammer and pile to the soil travel outwards away form the pile wall and pile tip in three different types of stress waves:

- The compression waves (P-waves) associated with changes in volume
- The shear waves (S-waves) that induce distortion of the soil without change in volume
- The Raleigh waves (R-waves) that are radiating cylindrical away from the point of excitation

The three waves propagate with different velocities through the soil and change temporarily the stress-strain behaviour and other characteristics of the soil.

Granular soil (sand, gravel)

The travelling stress waves induced by vibration cause continuous movement of the individual particles of the soil and reduce or eliminate their contact pressures. The internal friction of the soil and the pile/soil friction are reduced to a fraction of its maximum static value.

If the frequency of the hammer is reduced slowly, the particles of the soil are able to settle in denser patterns resulting in a higher density and higher internal friction than in the original state.

Only very dense, over consolidated sand has a lower internal friction after vibratory loading.

Cohesive soil (clay)

During vibrating the soil displacement at the penetrating pile tip causes remoulding and excess pore water pressure. The fast, repetitive energy pulse will maintain this condition or even increase the pore pressure and reduce friction.

The vibrations seem to have direct influence on the bonded water. The non-bonded water (the excess pore water) finds its way more easily towards the pile and thereby forms a thin film of water between pipe and soil. After the vibrations are stopped the excess pore water (pressure) dissipates and the clay around the pile shaft will reconsolidate at slightly higher shear stresses.

The drivability of piles in cohesive soils depends largely on the remaining (remoulded or residual) soil strength during vibrations. In general the drivability decreases with increased shear strength.

The reduced frictional and tip resistance during driving enables the pile to penetrate under a low vertical thrust, being the combined effect of the centrifugal force/weight of the pile and hammer, alternative the combined effect of the hammer/pile weight and crowd force of piling machine or excavator.

Soil damping

Only in rare cases a complete fluidization of the soil occurs. So, usually the soil has a dampening effect on the amplitude of the vibratory motion. The degree of damping depends on the total embedded length of the pile and on the soil type. It appears from what it said about cohesive soils and granular soils, that the dynamic damping in cohesive soil is considerable higher then that in sandy soil.

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