How to Select the Right Vibratory Hammer

by Kaj Balsborg

Introduction

To select the right vibratory hammer for a given job some general rules apply.

Sand, gravel and soft soil are especially suited for vibrating. Sand with large variation in grain size is easier to vibrate than uniform sand. Round grains are easier to vibrate than sharp sand. Dense sand gives higher penetration resistance than loose sand requiring larger vibratory hammers with higher centrifugal force to overcome the resistance.

Clay with firm consistence is less suited for vibrating. The size of the amplitude is the major criteria for the ability of the hammer to vibrate the pile.

Stones and Rock. It is impossible to vibrate in bigger stones and rock.

Humidity. The higher the water content in the soil the easier it is to vibrate the pile. Dry soil have higher penetration resistance than saturated soil (requires larger vibratory hammers).

Thumb rules Selecting the Vibratory Hammer

***For clay*:**

The amplitude is important and must be higher than for sand. The necessary eccentric moment in kgm must be 4 to 5 times the pile weight in tons

***For sand*:**

The amplitude is less important than for clay, but should be between 3 and 6 mm.

Pile weight less than 10 tons:

The centrifugal force in tons should be 10 to 15 times the pile weight in tons

Pile weight between 10 and 20 tons

The centrifugal force in tons should be 8 to 10 times the pile weight in tons.

Pile weight over 20 tons

The centrifugal force in tons should be 5 to 8 times the pile weight in tons.

Frequency

Max. frequency should normally exceed the natural frequency of the soil. The natural frequency of most soil is 20 – 30 Hz corresponding to a rotational speed of the vibratory hammer of 1200 to 1800.

Amplitude

Should be calculated for selected hammer and pile weight. The amplitude should be between 3 and 12 mm - highest for clay.

The Capacity of a Vibratory Hammer

The power of the hydraulic driving motors in a vibratory hammer is

Hydraulic Power [kW] **=** { **flow** [litre/min] **x pressure** [bar] }**/600**

The value expresses the capacity of the hammer and is shown in the specifications of the hammers. To perform up to this value, the vibratory hammer needs this power supplied from the engine of the powerpack, crane or excavator.

Technical formulas

The eccentric moment, centrifugal force and amplitude are – as mentioned - important figures when selecting the right vibratory hammer for a job.

Information about eccentric moment and centrifugal force is found in the specifications of the different hammers – please refer to the tables in the relevant chapter in the Nor-Trade web site: www.nortrade.dk.

The tables do not contain information about amplitude, as this depends of the eccentric moment and the sum of the dynamic weight of the hammer, the weight of the clamp and the weight of the pile to be installed (the sum of the moved mass).The amplitude must therefore be calculated separately for the project at hand.

To make basis for understanding the fundamentals and to make it possible to calculate specific jobs, the formulas for calculating these values are given below:

The eccentric moment: $\mathbf{M_{ecc} = \sum mr}$ [kgm]

Here **m** is the mass and **r** the distance from the rotating axis to the centre of gravity of the mass. $\sum$ tells that the product **mr** must be summed up for each of the eccentrics of the hammer. The symbols in bracket [ ] are the dimensions - here kgm - that are used in the equation.

The centrifugal force: $F_C = m\, r\, \omega^2 = m\, r\, (2\Pi f)^2$ [N]

Here ω is the angular speed of the hammer and f the number of revolutions per second. If n symbolises revolutions per minute we have:

The Centrifugal Force: $\mathbf{F_C = M_{ecc} (2\Pi\, n/60)^2}$ [N]

Calculation of Amplitude

The dynamic mass (the oscillating mass or vibrated mass) under pile installation [$\mathbf{m_{dyn}}$] is the total weight of all the moving parts i.e the vibrating mass of the vibratory hammer (called the dynamic weight of the hammer) and the total weight of the clamp and the pile.

Hence: **The Amplitude** $\mathbf{A = 2000\, M_{ecc} / m_{dyn}}$ [mm]

Note that the eccentric moment is put into the formula with the dimension kgm and the dynamic weight in kg. The amplitude is then calculated in mm (The factor 2000 takes the different dimensions into consideration). Also note that the amplitude (A) in practical foundation is twice the amplitude (a) (as used in mathematics).

> **Example:** Calculation of amplitude for APE 170V installing a 14 m BZ 26 pile.
>
> In the table in the APE part of the Nor-Trade web site is seen that M_{ecc} = 0 – 26 kgm and m_{dyn} = 3.130 kg (for hammer and clamp). The weight of a 14 m BZ 26 pile is 1190 kg.
>
> So, the total dynamic weight is M_{dyn} = 4.320 kg and the amplitude
>
> A = 2000x26/4320 = 12,04 mm

Driving aids

When the soil is difficult some aids can contribute to a good result.

Predrilling

In order to loosen up the soil predrilling can be made.

Water jetting

When driving in sand the objective is to concentrate water at the tip of the pile. This will loosen up the soil and reduce the point resistance.

When driving in clay the objective is to create a film of water along the sides of the pile to reduce the skin friction.

The efficiency of water jetting depends on the density of the soil, the applied water pressure and the flow of water. High pressure jetting (350-500 bar) with low water flow (20 l/min) is normally preferred from low pressure jetting (10-20 Bar) with high water flow (200-500 l/min). High volume of water will change the soil characteristics and give way to settlements. Besides the job site will often be negatively influenced.

Extra Weight

By using an extra weight the static weight of the vibratory hammer can be increased. Especially in *firm clay* this will result in a deeper and/or faster penetration.

The same result can of course be achieved by using a crowd force on a rig.

In sand the extra weight is less effective. The reason is that the resistance under the pile must be overcome by the centrifugal force, while - in clay - the friction must be reduced by the amplitude. The extra weight supports the amplitude.

In general unfavourable results can be expected in sand, when the total static weight (weight of hammer head and extra weight) is more than the dynamic weight.

-oOo-