



A 3.1 Terms

Rated Energy

The diesel hammers and air / steam hammers rated energy is potential energy, calculated by the ram weight times the drop height. The diesel hammer drop height of the ram weight depends on pile type soil and hammer condition. The maximum energy in the hammer specifications can be reached under optimum driving conditions but it is not necessarily always achievable.

Hammer efficiency

Is the factor or term applied to a hammer's actual produced energy compared to its potential energy. Divide the kinetic energy by the potential energy to determine the hammer efficiency. The diesel hammer efficiency typically averages 0.8

In diesel hammers, energy losses are typically caused by:

- pre-compression, which transfers already some energy into the pile
- friction between ram and cylinder
- impact and inertia losses of the impact block
- pre-ignition, if the hammer is poorly maintained or overheated
- misalignment hammer - helmet – pile

Driving efficiency or transfer efficiency

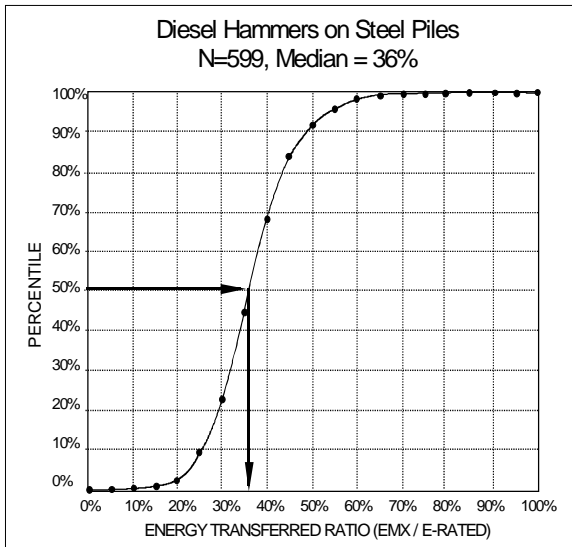
Is the factor or term applied to the amount of the energy put into the pile (Enthru-energy) compared to the rated energy of the hammer. The samples below show Enthru at the end of driving. Smaller steel normally show a higher transferred energy than larger ones because they are more elastic.

Enthru-energy depends on the type of hammer used, size & type of pile and soil conditions. Smaller steel pipes show a higher Enthru energy compared to large and much stiffer steel piles. Concrete and timber piles show a lower transferred energy compared to steel piles.

A 3.2 Correlations

The correlation between the number of blows (per minute) and the drop height of the piston is shown in the diagram.

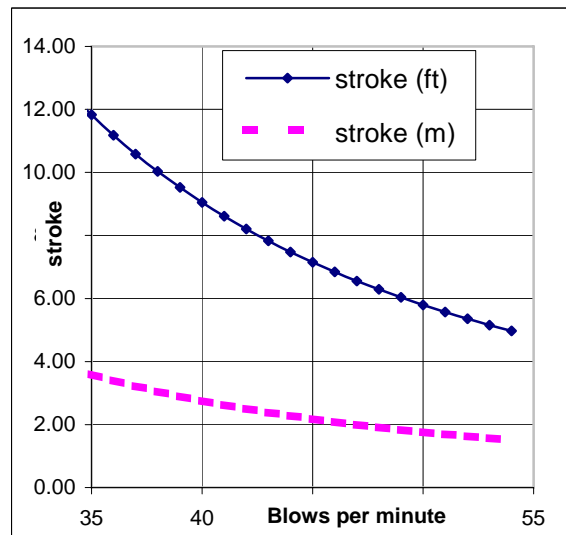
The formulas below do not apply for batter piles, only for vertical piles:



GRL case studies show the Enthru (transferred energy into the pile) by percentage of tested units. 50 percentile of diesel hammers tested show 35% Enthru-energy referring to rated energy. 92 percentile show less than 50% Enthru-energy.

$$\text{Drop height (m)} = \frac{4415}{(\text{Number of blows})^2}$$

$$\text{Drop height (ft)} = \frac{14485}{(\text{Number of blows})^2}$$





A 3.3 Pile capacity and hammer determination

Before the use of computers became common the pile driving industry worked out many different formulas for pile capacity or hammer determination. All these formulas are based on assumptions and they are not valid in general.

The common procedure today is to perform a **WEAP analysis** calculation using a computer program. Pileco, Inc. provides WEAP-analysis as a service to our customers at no charge to estimate hammer size and drive ability.

Based on following customers information a calculation can be done:

- pile size (diameter, length)
- pile type (pipe pile, concrete, timber..).
- required penetration or pile capacity
- soil information (soil layers: depths, type, strength, SPT-N values)

Allowable pile stress during pile driving can be calculated by following formulas:

Pile material	Allowable Tension stress	Allowable Compress. stress
Steel	$0.9 \times f_y$	$0.9 \times f_y$
Pre stressed concrete psi	$F_{PE} + 3 \times f_c'^{1/2}$	$0.85 \times f_c' - f_{PE}$
Pre stressed concrete MPa	$F_{PE} + 0.25 \times f_c'^{1/2}$	$0.85 \times f_c' - f_{PE}$
Regular reinforced concrete	$0.7 \times f_y / A_c$	$0.85 \times f_c'$
timber	$3 \times f_A$	$3 \times f_A$

With following values:

- F_y – yield strength of reinforcement as a force (kips or kN)
- f_y – yield strength of steel (ksi or MPa)
- A_c – concrete area of the pile
- F_{PE} – effective pre stress
- f_c' – concrete strength as stress (MPa or psi)
- f_A – allowable static timber stress

The **ENR-formula** always used in past is a more simple way for an estimation of pile capacity or determination of diesel pile hammer size. Pileco Inc. provides a slide ruler where the formula practically is “programmed”.

$$R = \frac{2 * E_n}{S + 0.1}$$

- E_n – potential energy of the diesel pile hammer in ft.lbs
- S – number of blows needed to drive the pile 1 ft into the ground
- R – pile capacity in tons

Because the formula only works with the potential hammer energy and the blows per foot (pile penetration) the result is not very accurate and the safety factor is relatively high.

A 3.4 Hammer and pile cushion properties

Cushion material	Elastic modulus WEAP (ksi)	CoR WEAP
Aluminum	10 000	0.8
Aluminum / Micarta	350	0.8
Bongossi wood	290	0.75
Conbest	280	0.8
Micarta	225	0.8
Blue Nylon	175	0.92
Oak parallel	750	0.5
Oak (transverse)	60	0.5
Plywood	30	0.5
Wire rope	150	0.8

The elastic modulus for combined cushion material can be calculated by:

$$E_{EQUIV.} = \frac{E1 \times E2 \times (s1 + s2)}{s1 \times E2 + s2 \times E1}$$

with:

- $E1, E2$ – elastic modulus
- $s1, s2$ – thickness of the cushion