Dynamics of pile driving

1. Dynamic pile formula (↔ Static Formula : $Q_0 = Q_p + Q_s$)

Basic idea : It seems obvious that the greater the resistance of a pile to driving, the greater should be the pile capacity to support load.

→ All the common dynamic pile formular equate

[the energy delivered by the hammer] = [the work done by the pile as its tip penetrates a distance S against the resistance R.]

(with various allowance for the losses of energy)

→ The time-dependent aspects of stress transmission phenomena ignored.
(especially in saturated clayey layer)

ex) Engineering News Formula

$$W_H \cdot H = R(S+0.1) \quad \Rightarrow \quad R = \frac{2 W_H H}{S+0.1}$$

where, W_H : wt. of the hammer in R unit

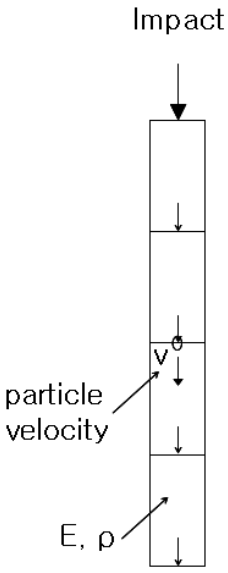
H : distance of free fall of hammer in inches

R : resistance

S : useful penetration (set, inches)

0.1 : lost penetration due to energy loss (inches)

2. Transmission of stresses during driving (in the wave form)



- $c = \sqrt{\frac{E}{\rho}}$

where, E : modulus of elasticity

ρ : mass density of the material in the pile

c : velocity of longitudinal wave propagation or seismic velocity (constant for a given material)

- $p = \frac{E}{c}v = \rho c v \rightarrow P = pA = \rho c A \cdot v$

where, p, P : longitudinal axial stress,(force) transmitted along the pile

ρcA : impedance (constant for given material and geometry)

v : particle velocity = f(z,t)

- since the impedance ρcA determines the maximum force that can be transmitted along the pile.

→ it is a measure of the drivability of the pile.

ex) for 10 inch diameter(or width) pile

material	impedance
wood	1.0
steel pipe (0.279″wall) (0.365″wall)	 1.9 2.3
concrete	3.1
H-pile (HP10×57)	3.3
concrete filled steel pipe (0.279″wall)	4.6

- Cushions : The original purpose was to prolong the life of the hammer by reducing impact stress (or to protect the top of pile from local overstresses)
  → But known to have a significant influence on the stress waves developed in the pile during driving.
  - soft : wood, asbestos
    (stress wave has lower peak, but stays longer)
  - hard : alternating disks of aluminum and micarta

- Cushion and impedance effect

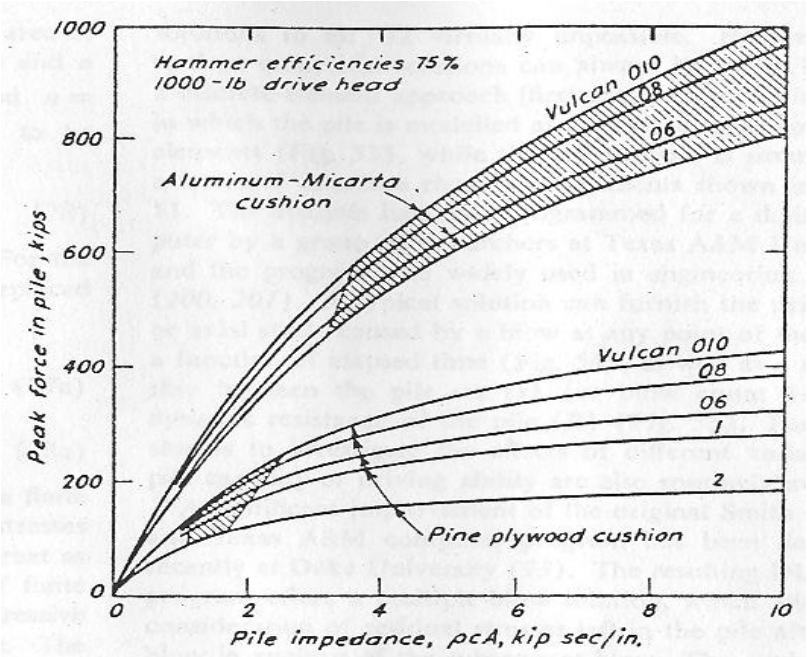


Figure 52. Relationship between peak driving force and pile impedance for Vulcan SA hammers. Shaded area indicates conditions of maximum transmission of driving energy (173).

- Other factors

wt. and stiffness of hammer, helmet;

and the velocity of the hammer at impact;

and damping factors; and resistance of soil …… etc.

Installation of piles.

1. Driving : the most commonly used → impact hammer or vibratory

2. Jacking : press down

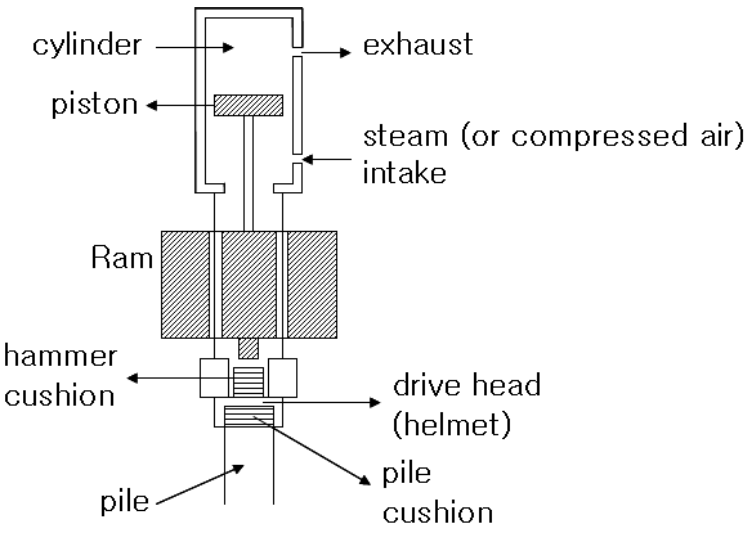
3. Drilling : bored pile, cast in-situ

4. Jetting : water injected near the tip
   → loosens the sand and creates the quick condition

- Driving equipment
  - Impact hammer : drop hammer, steam hammer, diesel hammer
  - Vibratory drivers

① Drop hammer : the hammers that fall from the top of leads(guides) to the top of the pile

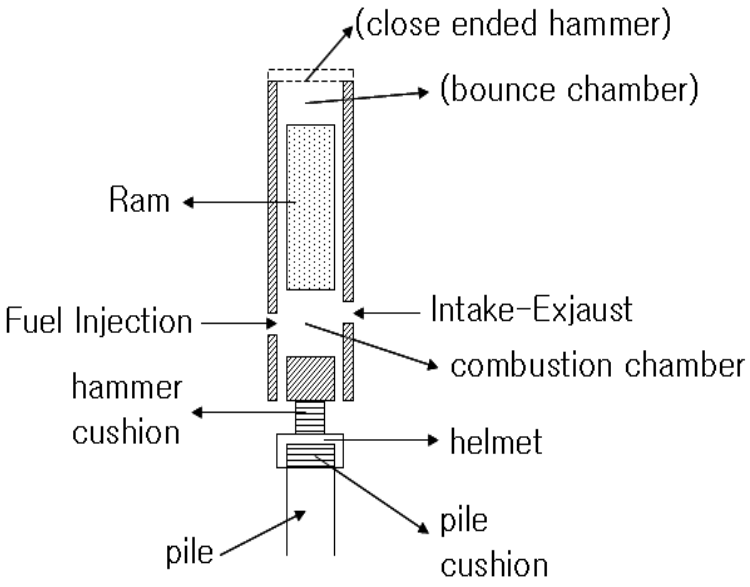
② Steam hammer :



· single acting - If the fall is due to gravity alone after lifted by steam(or compressed air) preseure.

· double acting (or differential) - If steam(or air) pressure add to the downward energy.

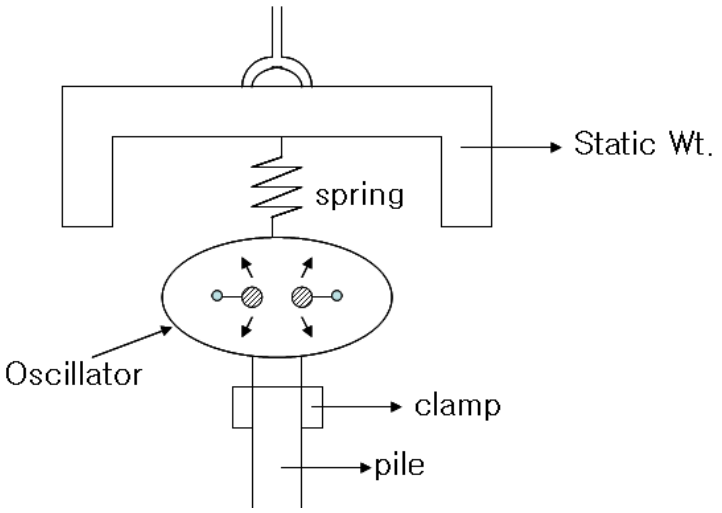
③ Diesel hammer



The ram lifted by explosion of fuel and compressed gas → As it falls fuel is injected into the combustion chamber → At the instant of impact the fuel ignites and lifts the ram → For a significant time, the pressure of burning gases also acts on the anvil and increases the magnitude and duration of the driving force → In this respect, the driving characteristics of diesel hammers differ from others

- Open-ended : Ram falls by gravity
- Close-ended : The compressed air in the bounce (acts like a spring) chamber limits rise of the ram but return its stored energy to the ram on the downstroke.

④ Vibratory driver



- low frequency drivers
  : (operates at) 10 to 30 Hz
- If the frequency can be made equal to the natural frequency of the system (pile, the driver, soil) → A resonant driver (often 50 to 150 Hz)

Load Testing of Piles

- Static test : Davisson / De Beer / 10% …

- O-cell test

- Statnamic test