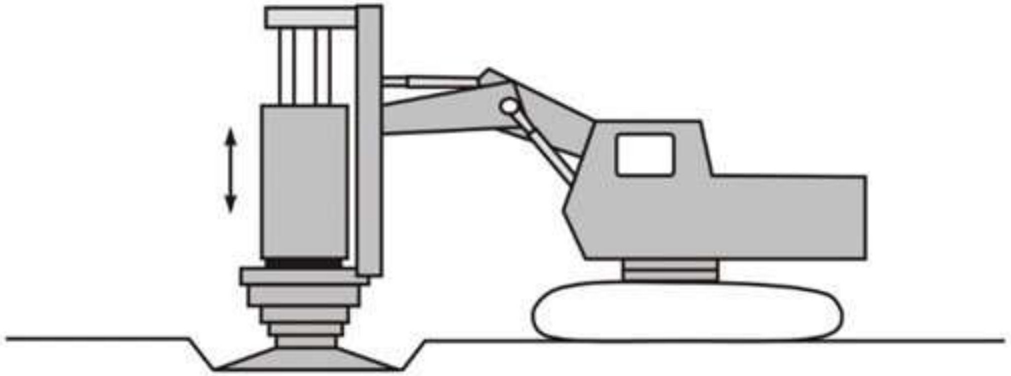
GROUND IMPROVEMENT

Rapid Impact and Compaction

Applications,merits and demerits

Rapid impact compaction: Basic concept

- Is an intermediate compaction method between conventional shallow compaction and deep dynamic compaction
- Repeatedly dropping a hydraulic hammer mounted on an excavator at a fast rate
- Weight of hammer is typically 5-12 tons
- Drop height 1.2 m
- Drop on a circular steel foot of diameter 1.0 to 1.5 m
- Machine can generate 40-60 blows per minute
- Record impact energy and foot penetration
- The production rate is up to 500 m2 improvement area per day



Suitable for:

- **Granular geomaterials including gravel, sands, silts, uncontrolled fill and industrial and mine wastes, used to minimize collapsible potential of loess**
- **Can improve geo-material up to 6 m deep (commonly 3-4 m)**

Applied to:

- **Increase bearing capacity and stiffness of geo-material below building foundations, floor slab, tanks, highways, railways, parking lots, airport runways, mitigating liquefaction and reducing waste volume and collapsible potential**

- **Also used to compact granular fills in large lifts (up to 3 m)**

Advantages:

- Fast and much controlled compared to deep dynamic compaction
- Induces much smaller vibration
- Can be operated closer distances to existing structure
- Eliminates the risk of generating flying debris
- Can detect weak zone during operation
- Better mobility and works in areas with difficult access

Limitations: Depth of improvement is smaller than that of deep dynamic compaction

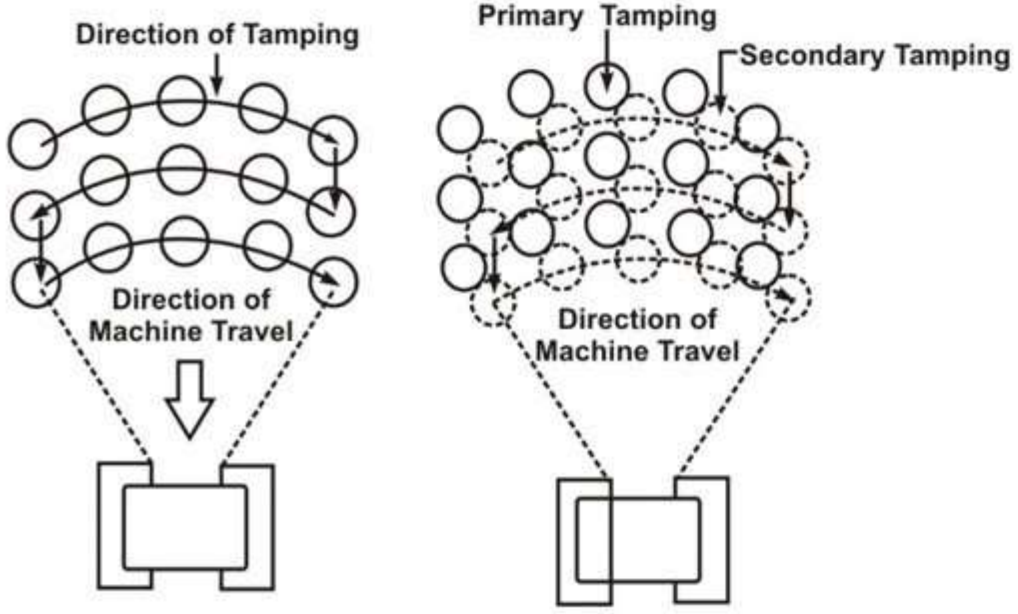
Design Considerations

Depth of Improvement:

Because of the differences of densification processes between deep dynamic compaction and rapid impact compaction method the same formula used to estimate the depth of improvement for deep dynamic compaction, is not applicable for rapid impact compaction. The guidelines (BRE 2003, SAICE 2006) to estimate the depth of improvement for rapid impact compaction is as shown in the Tables

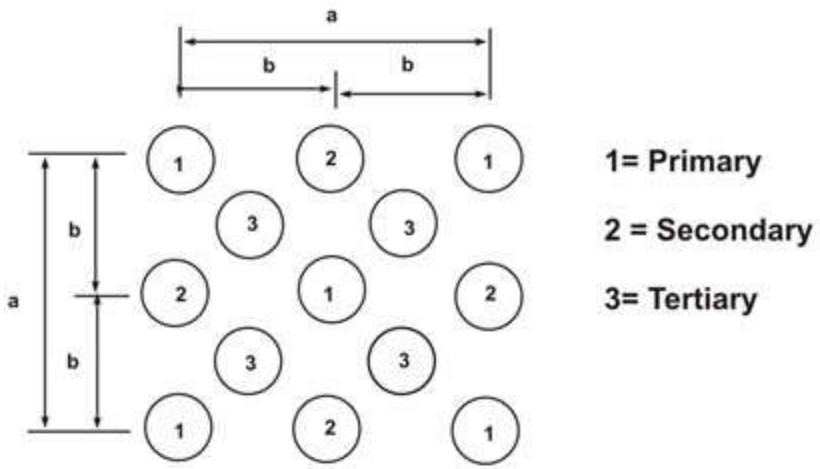
Patterns of Impact Points

1. Arc pattern, that is, primary impact points are arranged in the arc around the center as shown in Figure. Secondary impact points are arranged between primary impact points



(a) Primary Tramping (b) Secondary Tramping

Triangular pattern:



a = 2b = 6 m 0r 9 m

No ironing pass is needed in rapid impact compaction since rapid impact compaction is similar to ironing compaction with low energy and close spacing. However for leveling purpose and densify geomaterial near surface compaction by roller is often needed

Design parameters for rapid impact compaction include:

- Geomaterial type
- Depth of groundwater table
- Weight of hammer
- Height of drop
- Diameter of steel foot
- Depth of improvement
- Pattern and spacing of impact points
- Number of blows
- Distance to existing structures or utility lines

The procedure for design of rapid impact compaction:

$$AE = \frac{N_d W_t H_d}{A_e}$$

1. Determine whether rapid impact compaction is suitable
2. Select the depth of improvement
3. Determine the required applied energy for primary pass presented in lecture 13
4. Select a pattern and spacing of impact points
5. Determine the number of blows using Equation presented in lecture 13, based on the required applied energy and the pattern and spacing of impact points

Soil type	Unit applied Energy(KJ/m3)	% of standard proctor energy
Pervious coarse grained soil	200-250	33-41
Semi impervious fine grained soil	250-350	41-60
Landfill	600-1100	100-180

6. Use the table presented in lecture 13 or other related results to evaluate possible improvement

7. Based on the single-drop energy and the closest distance to existing structures, calculate the peak particle velocity using Equations for two cases and then compare it against the threshold particle velocity or from limiting PPV desired distance from the table

Soil type	SPT N value	CPT MPa	PMT
Pervious coarse grained soil: Sands and Gravel	40-50	19-29	1.9-2.4
Semi-impervious soils			
Sands and Gravel	40-50	19-29	1.9-2.4
Silts and clayey silts	25-35	10-13	1.0-1.4
Partially saturated impervious deposits			
Clay fills and mine spoil	30-40	NA	1.4-1.9
Landfills	20-40	NA	0.5-1.0

$$PPV = 188\left(\frac{\sqrt{W_t H_d}}{x_{dp}}\right)^{1.53} \qquad \frac{\sqrt{W_t H_d}}{x_{dp}} \geq 0.1$$

$$PPV = 36\left(\frac{\sqrt{W_t H_d}}{x_{dp}}\right)^{0.79} \qquad \frac{\sqrt{W_t H_d}}{x_{dp}} < 0.1$$

Type of Structure	Threshold particle velocity (mm/s)	Minimum Allowable Distance (m)
Dry Wall	19	14.5
Plaster	13	19
Al other	51	7.5

Construction: For rapid impact compaction the following procedure is required to be followed

1. Prior to equipment mobilization, Preparation of the site by removing large objects (e.g., trees), leveling ground, dewatering, and filling existing ponds & depressed area if any. Dewatering to lower the ground water level if the groundwater is within 1 m from the ground surface or additional fill is placed. Levelling of site to avoid ponding of water. Removal of large debris or rubble uncovered if any during leveling to avoid interference in compaction work

2. Providing isolation trench to minimize vibration and lateral movement if there are nearby existing structures or utility lines. Trench should 1 m wide at the bottom and at least 2–3 m deep

3. Placing stakes based on the pattern of impact points to layout the area to be compacted

4. Positioning the steel foot and the hammer on the point to be compacted

5. Performing compaction until preset criteria, such as the number of blows and a minimum final set are met. Compaction starts from the outside with large spacing as the primary pass

6. Releveling the work area and reestablish survey points for the next pass after each pass

7. If areas are found to be excessively hard or soft during compaction, they should be over excavated and replaced with granular fill

8. After the final pass, level all craters and apply surface compaction by vibratory rollers

9. Take final surveys to estimate the settlement after compaction

GROUND IMPROVEMENT

Vibro-Compaction

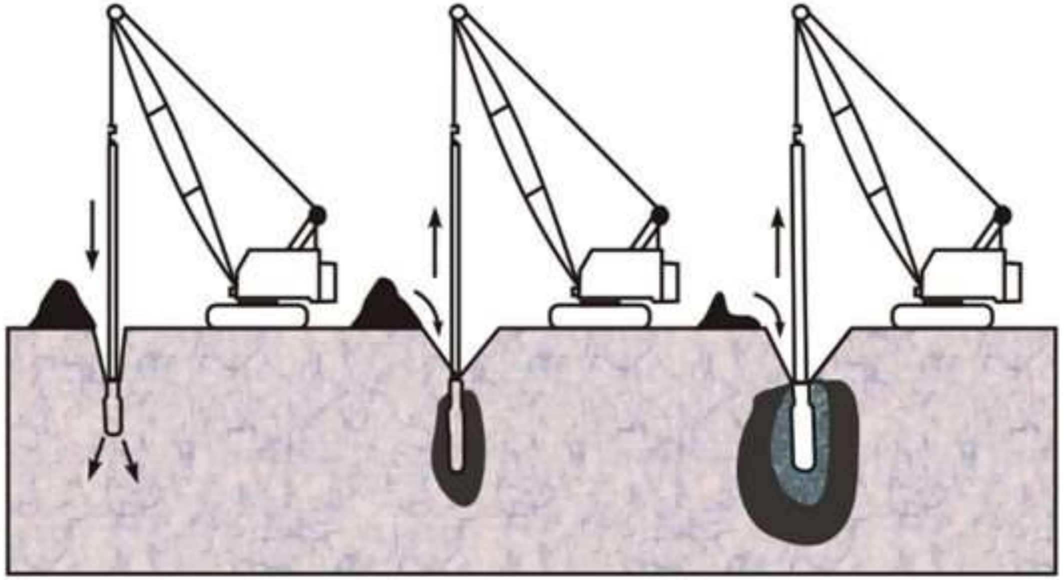
Introduction,merits,demerits

Basic Concept

- Vibro-compaction drives a vibrating probe into the ground
- It generates lateral vibratory forces to rearrange particles into a dense state
- The rearrangement of particles becomes possible only when the induced forces are higher than the interparticle friction force
- In saturated cohesionless geomaterial, vibration cause development of excess pore water pressure, which reduces interparticle contact forces (effective stresses) result in reduction in interparticle friction (i.e., shear strength). As a result, the rearrangement of particles becomes easier
- In dry cohesionless geomaterial, water is injected to make the compaction easier. Water or air is often used to assist the penetration and densification

- Backfill is often used to improve the degree of .This technique, called the vibro-flotation method, was first developed in Germany in 1930s and has been successfully used worldwide.
- The probe for vibro-flotation is commonly referred to as a vibro-flot.

There are other types of equipment used for vibro-compaction. Vibro-flotation has a vibrator at the bottom of the probe (also called bottom vibrator), which generates vibration by the rotation of an eccentric weight at the bottom of the probe. Other types of equipment have a vibrator or hammer on the top of the probe (also called top vibrator). Most of the theory and design methods are developed based on the vibro-flotation; therefore, it is focused herein

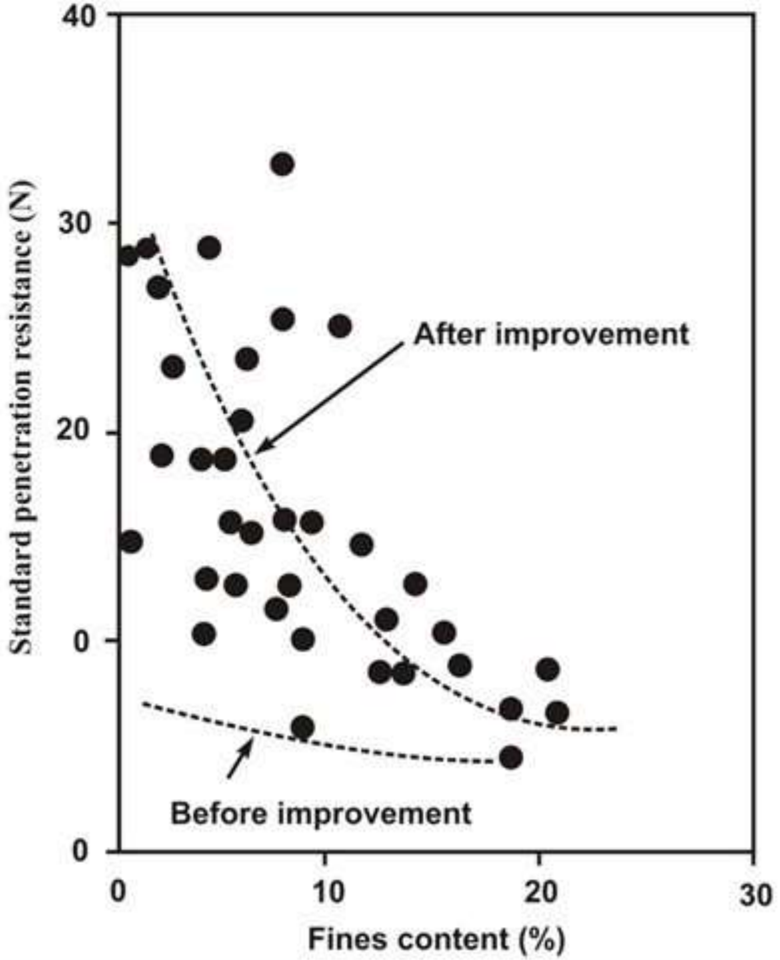


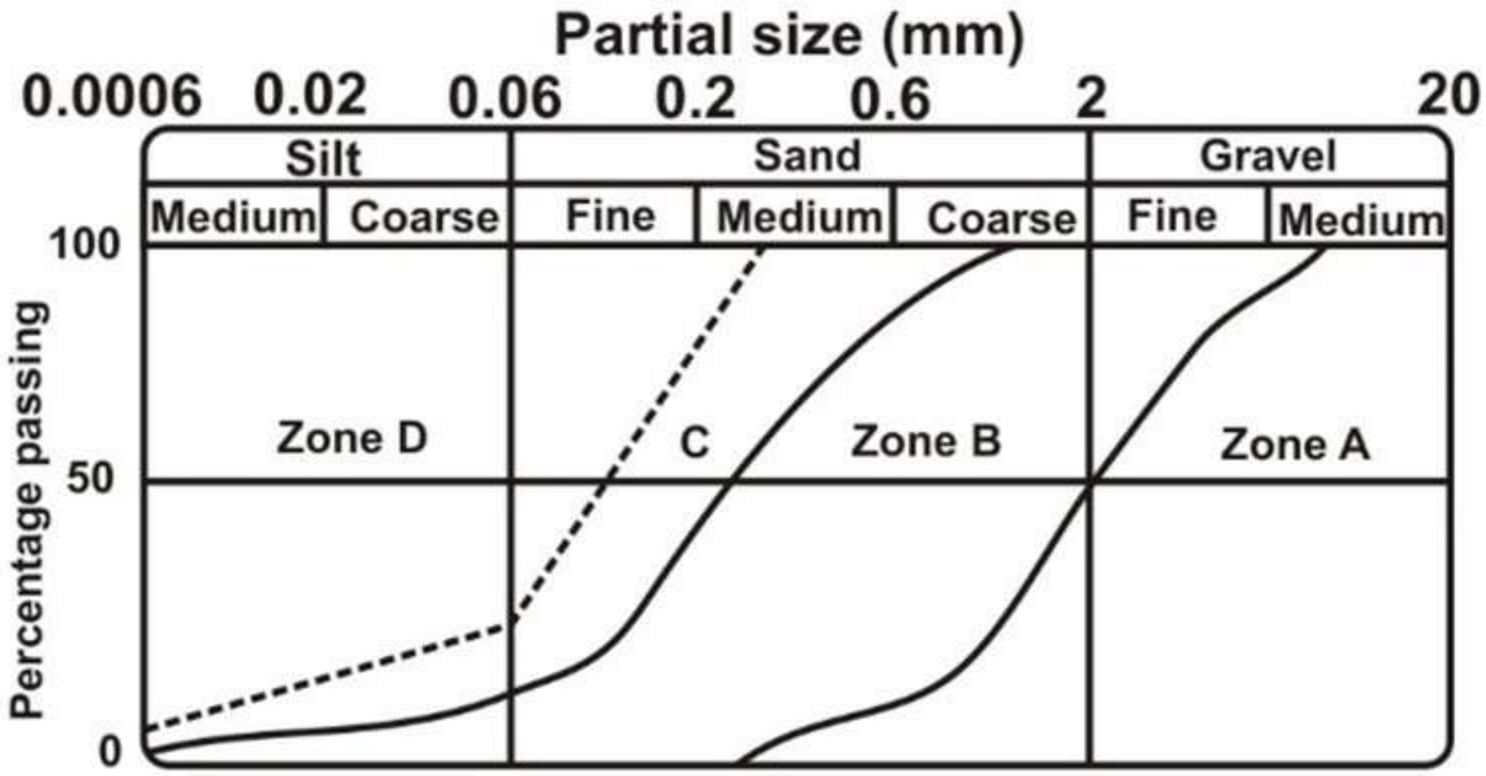
Vibro-compaction

Suitability: Vibro-compaction is suitable for densifying deep deposits of cohesionless geomaterial with up to 20% fines (preferably less than 10%) but less than 2–3% clay particles

Saito (1977) shoed based on the field evaluation before and after vibro-compaction that with the increase of fine content more than 20% densification become less effective/ineffective. It is clearly shown that at a low fine content, the increase of the SPT *N* value is more significant

Effect of fine content on SPT *N* value as shown by Saito, 1977





Zone A: Vibro-compaction appropriate, but penetration difficult
Zone B: Most suitable for vibro-compaction appropriate
Zone C: Vibro-compaction feasible, but longer time required
Zone D: Vibro-compaction not feasible-use stone columns

- The most suitable zone is zone B, which ranges from fine sand to fine gravel

- Zone A is suitable for vibro-compaction but may be difficult due to large particles of gravels.
- Zone C may be feasible but requires longer time for densification due to apparent cohesion for unsaturated soil or relatively low permeability for saturated soil

- Fine-grained soil in zone D makes densification impossible. The increase of fineness and plasticity of soil reduces the effectiveness of vibro-compaction

- This technique works well for saturated loose cohesionless geomaterial. If dry geomaterial is encountered, flushing water may be used or the whole site is even flooded prior to vibro-compaction

- Vibro-compaction method has been used to densify loose cohesionless soil up to a depth of 40 m (mostly within 20 m)

Applications:

Vibro-compaction is widely used to increase bearing capacity, reduce settlement, and mitigate liquefaction for a wide variety of projects where deals with loose cohesionless geomaterial

The examples of typical projects where vibrofoation are used: Storage tanks, buildings, roadways, dams, and dikes or levees

Advantages and Limitations:

Advantages:

- Quick,
- Easy
- Economical construction process.
- Can be used to improve geomaterials above and below the groundwater table

Disadvantages: This method is limited to cohesionless geomaterial with clay content less than 3%. Installation induces vibration and possible ground subsidence

Principles of Vibro compaction: Mechanism

- Densification of cohesionless soil results from the particle rearrangement and volume change by the induced vibratory force
- Vibro-compaction induces lateral vibrations and vibratory forces. The induced forces should be larger than the interparticle friction for rearrangement of particles
- The forces attenuate with an increase of the distance from the compaction point
- Rodger (1979) reported that there is a critical acceleration of pproximately 0.5 *g*, above which the dynamic stresses induced by dynamic compaction destroy the structure of granular soils
- When the acceleration is increased to more than 1.5*g*, the shear strength of the soil is significantly reduced and the soil is fluidized. A further increase of acceleration exceeding 3.0*g* causes soil dilation

Installation Process:

- To minimize probe shaft resistance, Penetration and extraction of probe to be done at a high frequency
- Massarsch and Fellenius (2005) suggested a frequency higher than 30 Hz for penetration and extraction. At higher frequency it causes low ground vibration, and less energy transfer to the surrounding soil causing the penetration and extraction easier

- During compaction stage, the preferable frequency is close to the resonance of the geomaterial mass so that more energy is transferred to the surrounding geomaterial to make the compaction efficient. Also during this process, penetration of probe is also slow
- Typical frequency of resonance of the soil is around 15–20 Hz (Massarsch and Fellenius, 2005)