UNIT-2

Deep Compaction Techniques

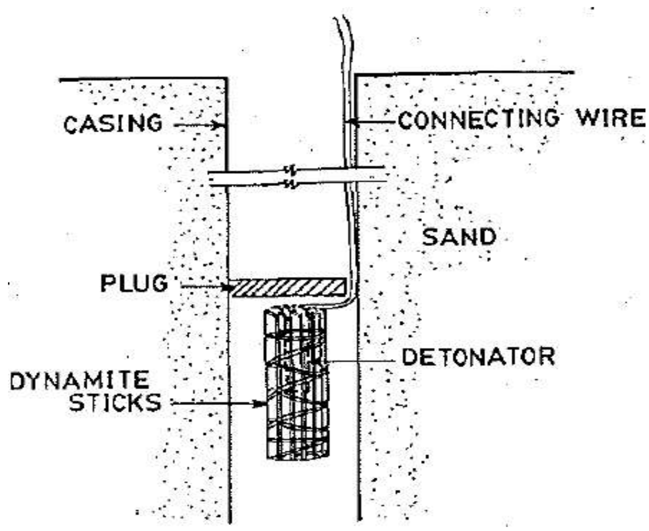
Densification of deep soil deposits is achieved by the following techniques:

- Blasting
- Vibratory probe
- Vibratory compactors

b. Blasting

In this technique a certain amount of explosive charge is buried at a certain depth of a cohesion less soil required to be compacted and is then detonated.

A pipe of 7.5 to 10 cm is driven to the required depth in the soil strata. The sticks of dynamite and an electric detonator are wrapped in the water proof bundles and, lowered through the casing as shown in Fig.



- The casing is withdrawn and a wad of paper or wood is placed against the charge of explosives to protect it from misfire.
- The hole is backfilled with sand in order to obtain the full force of the blast.
- The electrical circuit is closed to fire the charge.
- A series of holes are thus made ready.
- Each hole is detonated in succession and the resulting large diameter holes formed by lateral displacement are backfilled.
- The surface settlements, are measured by taking levels or from screw plates embedded at certain depth below the ground surface.

- Usually the explosives are arranged in the form of a horizontal grid.
- The spacing of the charges is decided by the depth of strata to be densified, the size of charge and the overlapping of the charges.
- A spacing of 3 to 8 m is typical and a spacing less than 3 m should be avoided
- Compaction is carried out in a single tier only if the depth of stratum to be densified is 10m or less.
- In such a case the depth of explosive charge should be below half the depth of the mass or stratum to be densifled (approximately at 2/3 point).
- More than one tier should be planned, if the depth of stratum to be densified is more than 10m. Generally the depth of charge should be greater than the radius of sphere of influence (R).
- Successive blasts of small charges at appropriate spacings are likely to be more effective than a single large blast.
- Theoretically, one charge densifies the surrounding adjacent soil and the soil beneath the blast.
- Charges should be timed to explode such that the bottom of the layer being densified upwads in a uniform manner.
- The uppermost portion of the stratum may be less densified which may be compacted by vibratory rollers.
- The amount of charge to be used should be optimal such that it is just enough to shatter the soil mass uniformly but not to create permanent surface craters.
- A carefully placed charge with required amount and depth shall not create a surface heave more than 0.15 m.

Disadvantages of Blasting Technique

- Although blasting is one of the most economical ground improvement techniques, it suffers the disadvantages of non-uniformity, potential adverse effects on adjacent structures and the danger associated with the use of explosives in populated areas.
- Very fine grained soils which have high cohesive forces cannot be compacted by this method.
- Maximum compaction is obtained only when the soil is dry or completely saturated.

- In case of any loose sand, good results are obtained due to free fall ofsmall size particles into the voids between the soil grains thus making a dense soil.
- But in partially saturated soils due to capillary tension between the soil grains, less densification is achieved.
- Theoretically there is no limit for the depth of densification by this technique.
- However, if the dept is more than l0 m, compaction should be done in more than one tier for which a careful planning is needed to achieve the result.
- Thus it is emphasized that adequate data with regard to type of soil, degree of saturation, depth of deposit to be densified and degree of densification required should be collected.
- A preliminary test may be necessary to ascertain the spacing, depth, amount of charge and sequence of operation.

DEEP VIBRO TECHNIQUES

- Usually the soil conditions are described in a soil investigation report.
- If the properties of the existing soil cannot fulfil the requirements set by the proposed loading conditions, deep vibro techniques offer an economical solution for the ground improvement.
- They can be carried out to almost any depth.
- Deep Vibro techniques present flexible solutions for soil improvement.
- They are mainly used under foundations of structures that are to be constructed on soils of low bearing capacity.

DYNAMIC COMPACTION

Technique involves repeatedly dropping a large weight from a crane

- Weight may range from 6 to 172 tons
- Drop height typically varies from 10 m to 40 m

Degree of densification achieved is a function of the energy input (weight and drop height) as well as the saturation level, fines content and permeability of the material

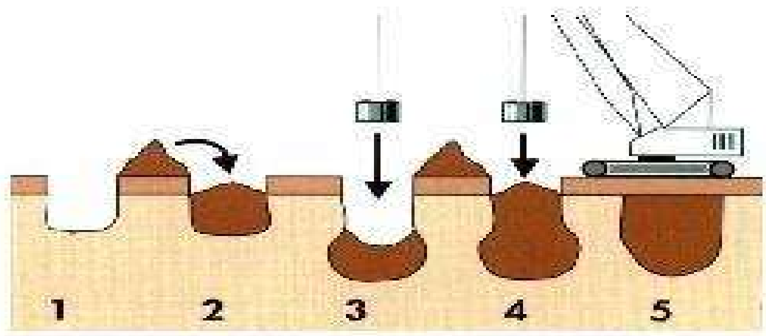
- 6 – 30 ton weight can densify the loose sands to a depth of 3 m to 12 m

Done systematically in a rectangular or triangular pattern in phases

- Each phase can have no of passes; primary, secondary, tertiary, etc.
- Spacing between impact points depend upon:
    - Depth of compressible layer
    - Permeability of soil
    - Location of ground water level
- Deeper layers are compacted at wider grid spacing, upper layers are compacted with closer grid spacing
- Deep craters are formed by tamping
- Craters may be filled with sand after each pass
- Heave around craters is generally small

DYNAMIC REPLACEMENT

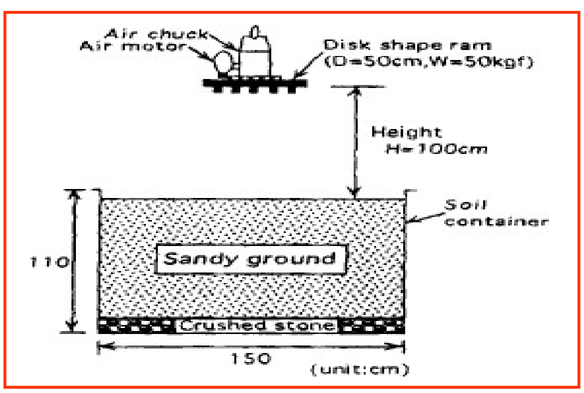
- The formation by heavy tamping of large pillars of imported granular soil within the body of soft saturated soil to be improved
- The original soil is highly compressed and consolidated between the pillars and the excess pore pressure generated requires several hours to dissipate
- The pillars are used both for soil reinforcement and drainage



Process of Dynamic Replacement

ROTATIONAL DYNAMIC COMPACTION

- A new dynamic compaction technique which makes use of the free fall energy as well as rotational energy of the tamper called Rotational Dynamic Compaction (RDC)
- The technique increases depth of improvement in granular soils
- Comparative study showed that the cone penetration resistance was generally larger than conventional dynamic compaction and the tamper penetration in rotational dynamic compaction was twice as large as that of conventional dynamic compaction



APPLICATIONS OF DYNAMIC COMPACTION

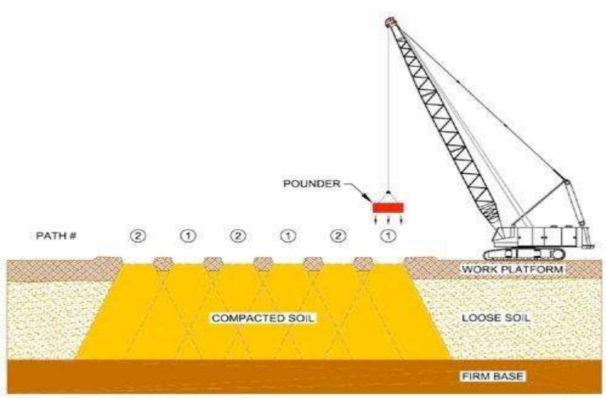
- Reduce foundation settlements
- Densify waste deposits
- Prevent soil liquefaction during earthquakes
- Increase in-situ density of land reclamation fills

SUITABILITY OF DYNAMIC COMPACTION

Soil Type	Effectiveness	When to get expert advice
Sands with < 5% fines	excellent	Grain size curve very steep, High carbonate or Mica content
Sands with < 12 % fines	Marginal to good	Success depends on many factors, such as clay content, grain shape, grain size curve, water table.
Silt	Poor to marginal	Always ask for advice if DC shall work in silt Method may occasionally work in combination with other systems -> Wick drains
Clay	Not applicable	
Land reclamation	Excellent, if spec for fill material is appropriate	Get advice at early stage to influence already the spec for the fill material.

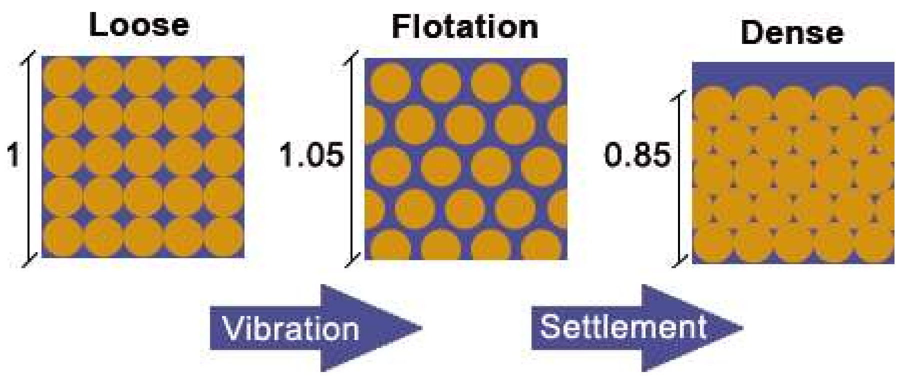
INSTALLATION PROCESS

The weight is dropped in a primary, secondary and often also tertiary grid. The primary grid (widest spacing) is used to achieve compaction at depth. It uses the largest weight and highest drop. The compaction effect at depth is larger as long as the soil surface is not yet densified. The uncompacted soil produces less dispersion of the impact wave. The secondary and tertiary grid are used to achieve compaction at medium and shallow depth. Sometimes a so called “ironing path” with a smaller weight and lower drop height concludes the process. This ironing path can be replaced by roller compaction.



VIBROCOMPACTION

Compaction of granular soils by depth vibrators is known as Vibro Compaction. The method is also known as “Vibroflotation”. Natural deposits as well as artificially reclaimed sands can be compacted to a depth of up to 70 m. The intensity of compaction can be varied to meet bearing capacity criteria. Other improvement effects such as reduction of both total and differential settlements are achieved . The risk of liquefaction in a earthquake prone area is also drastically reduced.



The principle of sand compaction (Vibroflotation):

The compaction process consists of a flotation of the soil particles as a result of vibration, wich then allows for a rearrangement of the particles into a denser state.

Effects of Compaction

- The sand and gravel particles rearrange into a denser state.
- The ratio of horizontal to vertical effective stress is increased significantly.
- The permeability of the soil is reduced 2 to 10 fold, depending on many factors.
- The friction angle typically increases by up to 8 degrees.
- Enforced settlements of the compacted soil mass are in the range of 2 % to 15 %, typically 5 %
- The stiffness modulus can be increased 2 to 4 fold.

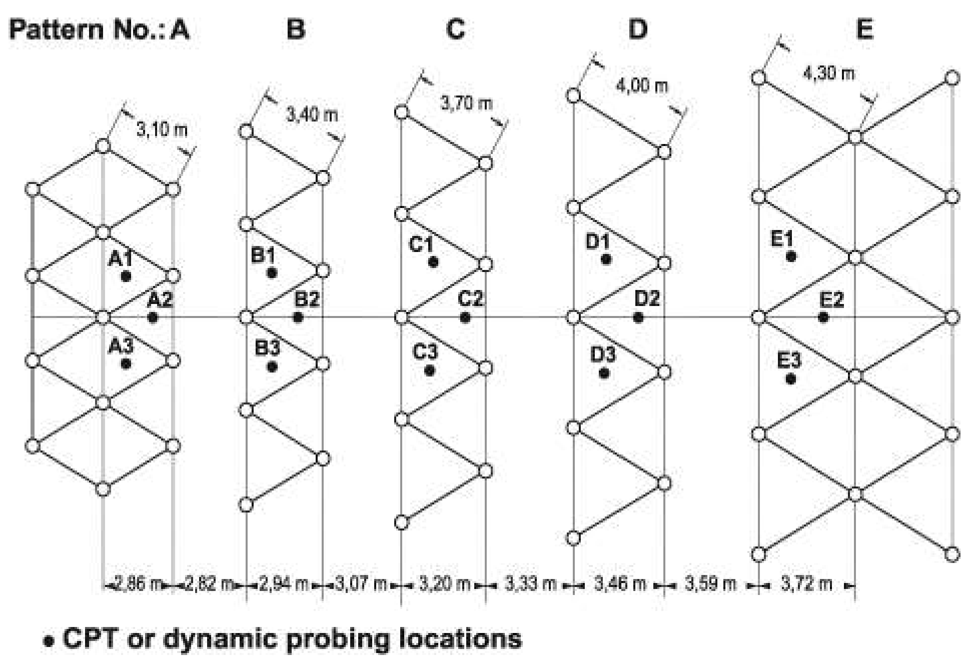
Test Pattern

On large projects the optimal compaction grid spacing has to be determined by test grids.

The compaction effect in the test grids should be as close as possible to the treatment in the later production areas.

In order to achieve this it is advisable to arrange the test grids close to each other.

The distance between grid A (3.10 m) and grid B (3.40 m) should be



DYNAMIC TAMPING

A tamping machine or ballast tamper is a machine used to pack (or tamp) the track ballast under railway tracks to make the tracks more durable. Prior to the introduction of mechanical tampers, this task was done by manual labour with the help of beaters. As well as being faster, more accurate, more efficient and less labour-intensive, tamping machines are essential for the use of concrete sleepers since they are too heavy (usually over 250 kg (551 lb)) to be packed into the ballast by hand.

Early machines only lifted the track and packed the ballast. More modern machines, sometimes known as a tamper-liner or tamping and lining machine, also correct the alignment of the rails to make them parallel and level, in order to achieve a more comfortable ride for passengers and freight and to reduce the mechanical strain applied to the rails by passing trains. This is done by finding places where the sleepers have sunk from the weight of the passing trains or frost action, causing the track to sag. The tamper lifts each sleeper and the rails up, and packs ballast underneath. When the sleeper is laid down again, the sagged rails now sit at the proper level. In cases where frost action has caused adjacent rails to rise higher, ballast tampers can raise rails above their original level to make the line level again. "Lining" rails doesn't involve ballast tamping, it merely ensures the rails are perfectly parallel and straight as possible. Combining tamping and lining into a single machine saves time and money, as only one machine needs to be run over the track to perform both functions.

COMPACTION PILES

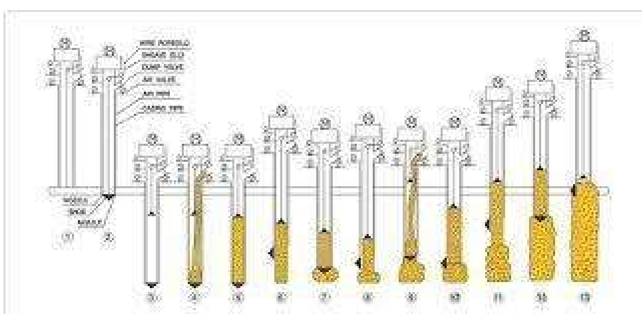
Sand compaction piling (SCP) is a cost-effective method of ground improvement which is commonly used to improve soft seabed soils prior to land reclamation works. This method involves driving closely-spaced sand columns into the soft seabed to form a grid of sand columns, which imparts higher strength and stiffness to the improved ground. The installation of these sand compaction piles often involves a large amount of cavity expansion displacement of the soft clay around the sand piles, which in turn, leads to significant changes in the strength and stiffness of the soft clay around the sand piles. In practice and research, the properties of the soft clay are taken to be those of the in-situ soil.

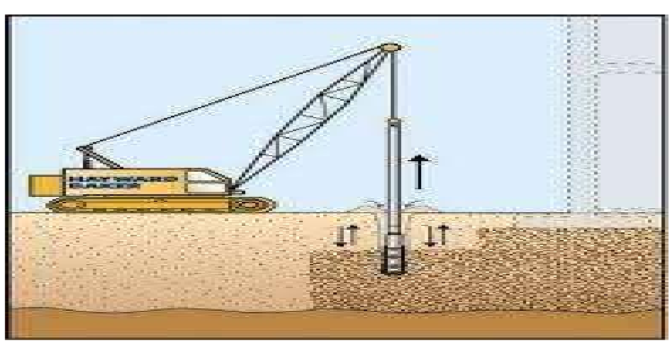
The improvement in the strength of the softy clay is around 25% to 50%.

The results of these experiments allow the changes in total stress and pore pressure due to the installation of sand compaction piles to be quantified. Comparison of the measured changes in lateral stress and pore pressure with conventional plane strain cavity expansion theory shows that the latter gives a reasonably good estimate at large depth for the entire installation process. However, deviation from plane strain cavity expansion theory was noted at shallow depths. To account for the effect of the ground surface, a semi-empirical plane stress cavity expansion theory was proposed for the shallow zones. The establishment of the two limits formed by the plane strain and plane stress theories allows semi-empirical relations to be fitted to the data. These findings also indicated that, in order to mobilize significant set-up of stress in the improved ground, there must be substantial further cavity expansion during the sand injection stage of SCP. The cumulative total stress and pore pressure increment at a given location due to the installation of multiple piles in a grid is also reasonably estimated by superimposing the increments due to the installation of each pile. The measured and computed undrained shear strength after the dissipation of the excess pore pressure is also higher in the clays enclosed within the SCPs. The quantum of improvement in the strength of the soft clay due to the cavity expansion displacement is typically of the order of 25% to 50%.

Tests were also conducted to quantify the relative performance of different methods of installing sand piles. The results of this comparative study show that the effects of cavity expansion displacement in the soft clay do lead to a significant improvement in the strength and stiffness of the soft clay. The sequence of installation also affects the resulting properties of the soft clay, although this is second-order compared to the effect of installation method.

Some of the results of this study have been published in international journals and conferences. The significance of the published results was recently highlighted by a detailed citation of the team‟s research by Professor Osamu Kusakabe in a keynote address in the International Conference on Physical Modelling in Geotechnics, in Newfoundland, Canada.





VIBRO REPLACEMENT

Where fines content of the soils in the target treatment interval exceeds the acceptable range for vibro compaction, another ground improvement process of Vibro-Replacement/Displacement by installation of stone columns can be applied.

Type of soil

- Vibro Replacement is an accepted method for subsoil improvement, at which large-sized columns of coarse backfill material are installed in the soil by means of special depth vibrators.
- Vibro replacement is part of the deep vibratory compaction techniques whereby loose or soft soil is improved for building purposes by means of special depth vibrators.
- Contrary to vibro compaction which densifies non-cohesive soil by the aid of vibrations and improves it thereby directly, vibro replacement improves non compactable cohesive soil by the installation of load bearing columns of well compacted, coarse grained backfill material.

Equipment and execution

- For the construction of Vibro Replacement columns the bottom feed process is frequently employed, which feeds coarse granular material to the tip of the vibrator with the aid of pressurized air.
- To optimize the performance of this process and to accommodate the specialized equipment, vibrocat is developed at base unit which guides the vibrator on its leader and allows the exertion of an additional pull-down pressure during penetration and compaction.
- The Vibro Replacement process consists of alternating steps.
- During the retraction (pull away) step, gravel runs from the vibrator tip into the annular space created and is then compacted and pressed into the surrounding soil during the following re-penetration step.

- In this manner stone columns are created from the bottom up, which act as a composite with the surrounding soil under load.

Vibro-Replacement Procedures

Stage1: The vibrocat positions the vibrator over the required location of the compaction point and stabilises itself using hydraulic supports. A wheel loader fills the skip with aggregate.

The jet at the bottom of the Vibroflot is turned on and lowered into the ground

Stage2: The water jet creates a quick condition in the soil. It allows the vibrating unit to sink into the ground