UNIT-1

GROUND IMPROVEMENT TECHNIQUES

Introduction:-

The process in which insitu soils are improved for the support of the foundations is known as "GROUND IMPROVEMENT TECHNIQUE"

Ground improvement is the primary application of many geotechnical construction techniques. permitting construction on soils by changing their characteristics. Just like soil mixing increases shear strength, reduces compressibility and permeability of soft soils ----

Densification:-

Densification or Reduction in void volume may occur in no of ways such that.

1) Re-orientation of particle.
2) Fracture of the grains
3) Bonds b/w grains
4) distortion of particles.

* **In-situ densification of granular soils**

In cohesionless soils the densification is primarily accomplished by re-orientation of grains which is resisted by the friction b/w the particles.

By the vibration technique we will densify the soils.

1) The vibro compaction → Blasting
   → vibratory probe
   → vibratory compactors.

2) Vibro-displacement compact → displacement piles
   → vibroflotation
   → sound compaction piles
   → stone columns

*(1) **Vibro-Compaction:-**

Vibro-compaction method is a rapid densification technique which could be used effectively in saturated cohesionless soils.

In such loose deposits vibration or shockwaves cause liquefaction followed by densification followed by settlement. The load due to shock is temperorily transferred to liquid

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and soil particles take a much denser pattern aided by the soil particles. Even dry soils due to shock and vibration.

The three methods which are 1) Blasting
2) Vibratory probe
3) Vibratory compactors

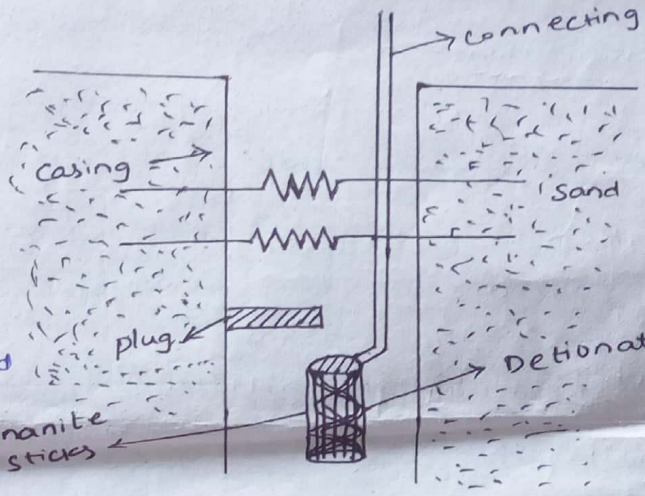
(a)

* BLASTING :-

In this technique a certain amount of explosure charge is buried at a certain depth of a cohesionless soil required to be compacted and is then detonated

A pipe of 7.5 to 10cm 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 casing



→ The casing is withdrawn and a wad of paper or wood placed against the charge of explosives to protect it from misfire.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 electric circuit is closed to fire the charge. A series of holes are thus made ready.

→ Each hole is detonated in succession and resulting large diameter holes formed by lateral displacement are backfilled.

→ The surface settlements are measured by taking levels or form 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 8m is typical and a spacing less than 3m should be avoided.

held for 30 to 60

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Compaction carried out in a single tier
→ depth of stratum to be densified is 10m or less

Compaction carried out in a more than one tier.
→ depth of stratum to be densified is more than 10m.

* Generally length of charge should be greater than the radius of sphere of influence (R).

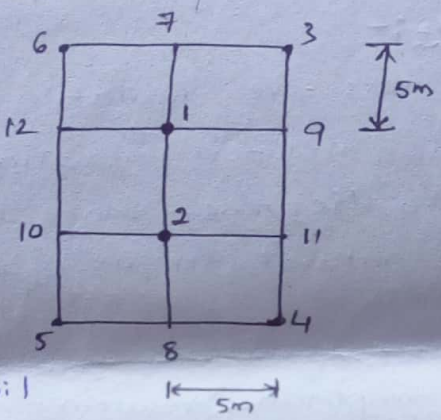
Successive blasts of small charges at different spacings to be more effective than a single blast.

W = weight of explosive (N)

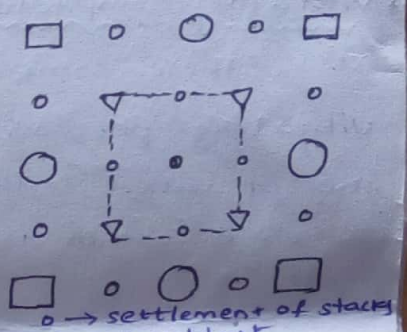
c = co-efficient (0.0025 for 60% detonator)

R = Radius of influence (m)

A typical firing pattern:-



a) Grid pattern



b) Firing pattern

Advantages:-

* Involves less time, labour, and expense.
* This technique needs no special equipment
* used for densifying soil at a great depth.
* Used to compact a large volume to a substantial depth upto 20m.

Disadvantages:-

* Non uniformity, potential adverse effects on adjacent structures.
* High cohesive forces cannot be compacted by this technique.

(b)

* Vibratory probe:-

It is also called as "Terra probe". It is consists a vibro-driver coupled to an open-ended steel tabular probe of 760mm diameter and 15m length.

Vibrodriver activises the probe to vibrate in the vertical direction with vertical impulse of 15Hz with 10 to 25mm. amplitude. The probe is sunk to the desired depth and held for 30 to 60 seconds before extraction. generally adopt 1 to 3m. A square

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A square pattern is followed with a 5th probe at the cen of each square to achieve an increase of densification.

In each insertion the probe densities a cylinder of soil of 1m diameter and 1m deeper than the probe location. The proce is done upto 20m depth.

The operation is very efficient when the ground water is 2 of the surface. Sometimes a water jet may be used to help e penetration of the probe for sites where the water table is deep but the operation of jet has to be stopped during with- -drawal.

This technique is preferred for densificing offshare loc -tions. The Terra probe technique is considerebly faster than the vibro flotation procedure.

(c)

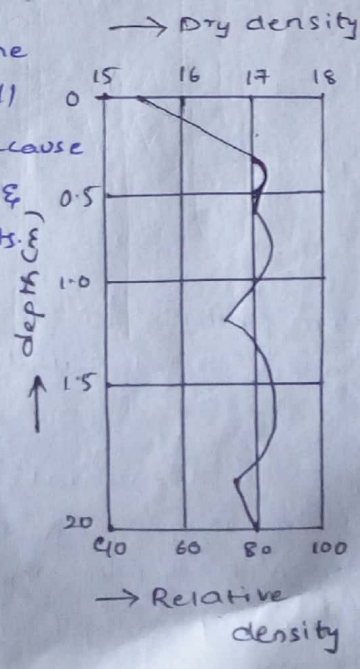
*Vibratory compactors:-

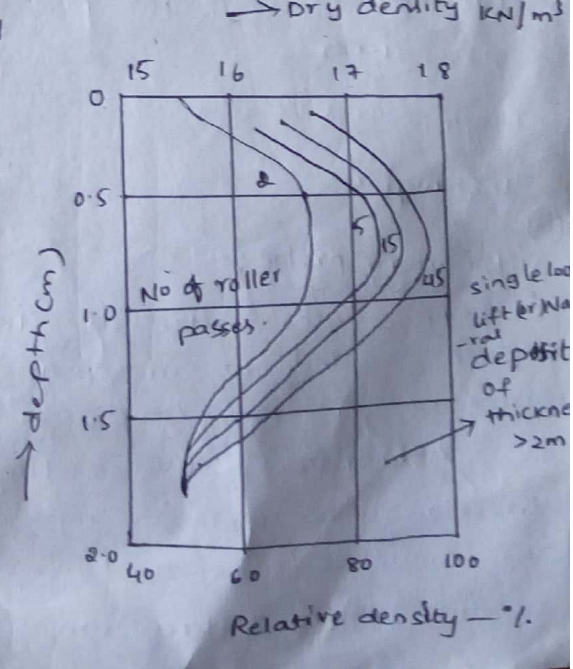
These compactors are available as vibrating drums, Vibratong pneumatic-tire, and vibrating plate equipment. The are operated with a frequency range blw 1500 and 2500cpm. which is within the natural frequency range of most of the soils.

compacting at natural frequency gives the maximum effect because of high amplitude resulting in a more dense arrangement. Good results are achieved when the compactor travels at a slow speed of 6 km/hrs.

Smooth drum and rubber tired vibratory compactors have proven very effective in compacting cohesionless deposits of limited thickness 2 to 3m. Haviest vibratory rollers can densify above 2m depth.

soil nearer to the ground surface will have low density because of over-vibration & lack of confinements. The below fig shows density-depth. densification for a fill placed in successive lifts.





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In order to achieve best results it is essential that lift thickness, roller type and soil type should be matched relative densities as high as 85 to 90% and a lateral earth pressure coefficient of one or more can be achieved if the system is matched properly.

(2)

* Vibro-Displacement compaction:-

These techniques are similar to vibro compaction technique expect that the vibrations are supplemented by active displacement of soil and by back filling the zones from which the soil has been displaced.

Vibro-displacement is a method to improve the density of cohesionless granular soils, Vibro-replacement method is used to improve cohesive soils with deep vibratory methods.

(a)

* DISPLACEMENT PILES:-

The simplest method among the vibro-displacement technique is by driving piles which is very effective in densifying cohesionless sands up to reasonable depths. such piles are referred to as displacement or compaction piles.

When pile are driven into loose solids, sands, The ground surface blw the piles commonly subsides in spite of the displacement of sand by The piles.

Hammer vibration coupled with the displacement force of the pile is ideal for densifying cohesionless soils. But the method is slow and expensive.

Compaction piles can also be used in sandy soils with some cohesion and in existing cohesive fills.

Displacement piles cause densification of sand for distance as large as eight diameters away from the piles. Because of lateral displacement of soil, The horizontal stress acting on the pile increases resulting in large co-effecient of earth pressure at rest value of the stratum being compacted. Timber piles are extensively used for compaction of soils.

(b)

* VIBROFLOTATION:-

Vibroflotation is an efficient technique for densifying cohesionless soils with simultaneous vibration and saturation This technique was originated in Russia in mid thirties.

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The Vibroflotation equipment compreses of a i) Vibroflo
ii) Accompanying power su
iii) water pump
iv) crave
v) Front end leader.

* i) Vibroflot probe:-

Consists of a cylinderical penetrator about 400mm in dia 2m in length with an eccentric weight inside. The cylinder developing a horizontal centrifugal force of about 100kN at 1800 rpm.

A Typical Vibroflot is formed of 2 parts. The lower part is horizontal vibrating unit which connects to upper part, a foollow up pipe, the length of which can be varried dependi on the compaction depth.

The devise provided for water flow from jets at top and bottom at the rate of 225 to 300 lit/min at a pressure of about 400 to 600 kpa. The water jets. The vibroflat into the ground as it is lowered with the crane. The Front-end loader is used to supply the back fill material as the in-situ soils are densified.

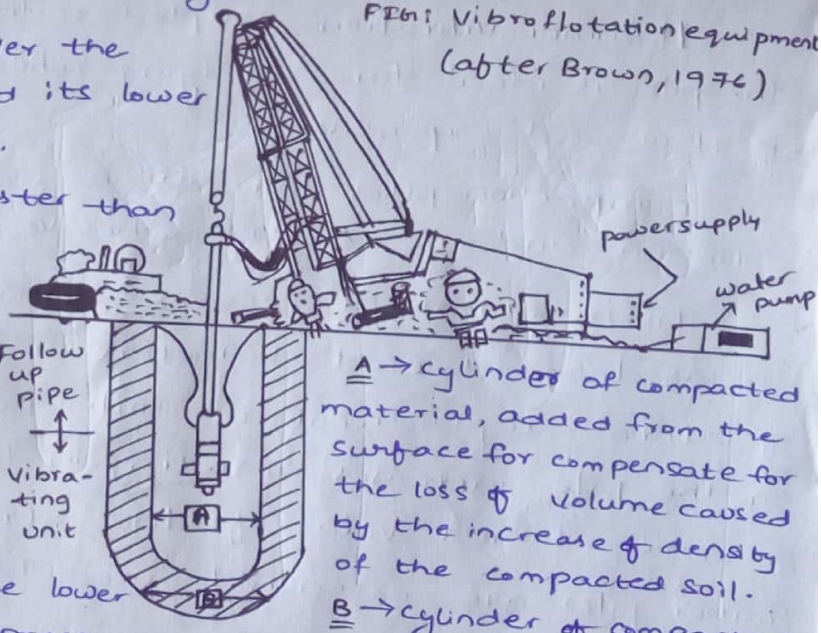
The probe is freely suspended from a crana each compaction sequence has 4 basic steps. They are:-

① Vibroflat is poistioned over the spot to be compacted and its lower jet is then fully opened.

② water is pumped in faster than it can drain away into the subsoil. This creates a momentary "quick" condition beneath the jet which permits the Vibroflot to settle of its own weight & Vibration.

③ water is switched from the lower to the top jets and the pressure is reduced enough to allow water to be returned to the surface, eliminating any arching of backfill material and facilitating the continuous feed of backfill.

Fig: Vibroflotation equipment (after Brown, 1976)



A → cylinder of compacted material, added from the surface for compensate for the loss of volume caused by the increase of density of the compacted soil.

B → cylinder of compacted material, produced by a single vibroflot compaction

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compaction take place during the 0.3m per minute lifts, which return the vibroflot to the surface. First, the vibrator is allow to operate at the bottom of the crater. As the particles densify, they assume their most compact form. By raising the vibrator, step by step and simultaneously back filling with sand, the entire depth of soil is compacted into hard core.

* SAND COMPACTION PILES:-

This method is consists of driving a hallow steel pipe with a data cable bottom plate drawn to desired depth. The driving can be done either by using an impact hammer or vibratory driver sand is introduced in lifts with each lift compacted concurrently with the withdrawl of pipe pile. compressed air is blown down inside the casing to hold the the sand in place. The in-situ soil is densified while pipe is being driven down. The compacted sand pile prevents collapsing of the surrounding soil as the pipe is withdrawn.

During the process of compaction the compacted column expands laterally below the pipe and forming casion pile. This technique is also referred to as vibro-composer method. The installation process is schematically shown below. The required level of relative density can be achieved by varying the diameter of the compaction pile and the spacing. The figure represents the effect of variation of spacing and the size of the compaction piles on relative density.

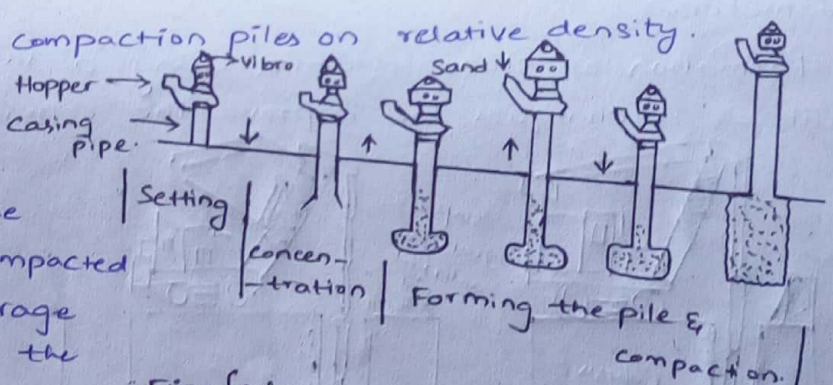


Fig: {After Aboshi & Sumatsu, 1985}

VIBRO-COMPOZER METHOD

The increase in the density may be compacted based on the average settlement and the amount of backfill used. Typical densification of a loose sand surrounding a pile after driving and backfilling. The density increase is characterised in terms of the ratio of final standard penetration resistance to initial penetration resistance.

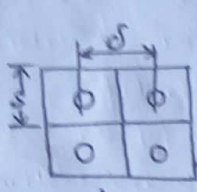
This method is economical for moderate depths upto 15m. and also costlier for deeper deepths. compare to other vibration methods.

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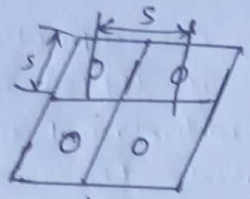
The installation of sand piles cause compaction only in the lateral direction. The pile spacing "s"

$$S = \left[\frac{\pi(1+e_0)}{e_0+e}\right]^{1/2} d \quad \{\text{For square pattern}\}$$

$$S = 1.08\left[\frac{\pi(1+e_0)}{e_0+e}\right]^{1/2} d \quad \{\text{For } \Delta^{le} \text{ pattern}\}$$

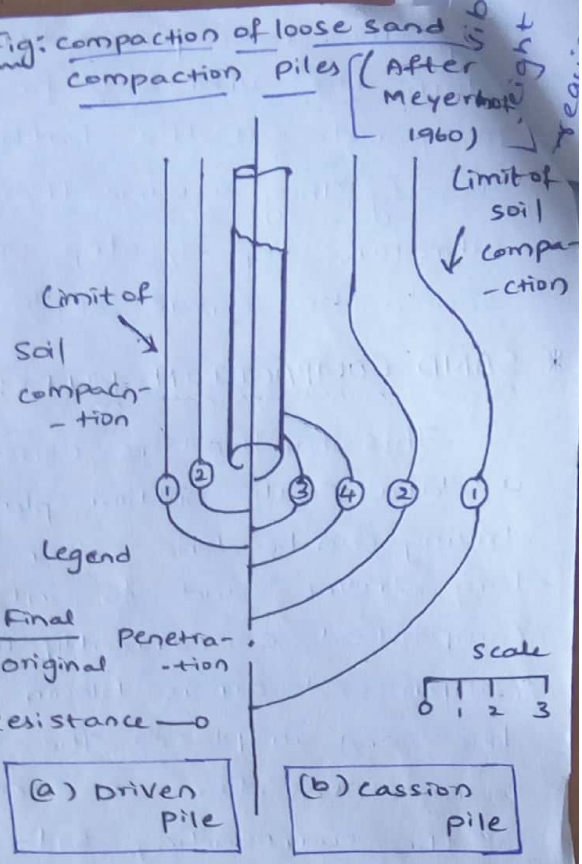


Square arrangement



triangular arrangement

Fig: compaction of loose sand by compaction piles (After Meyerhof 1960)

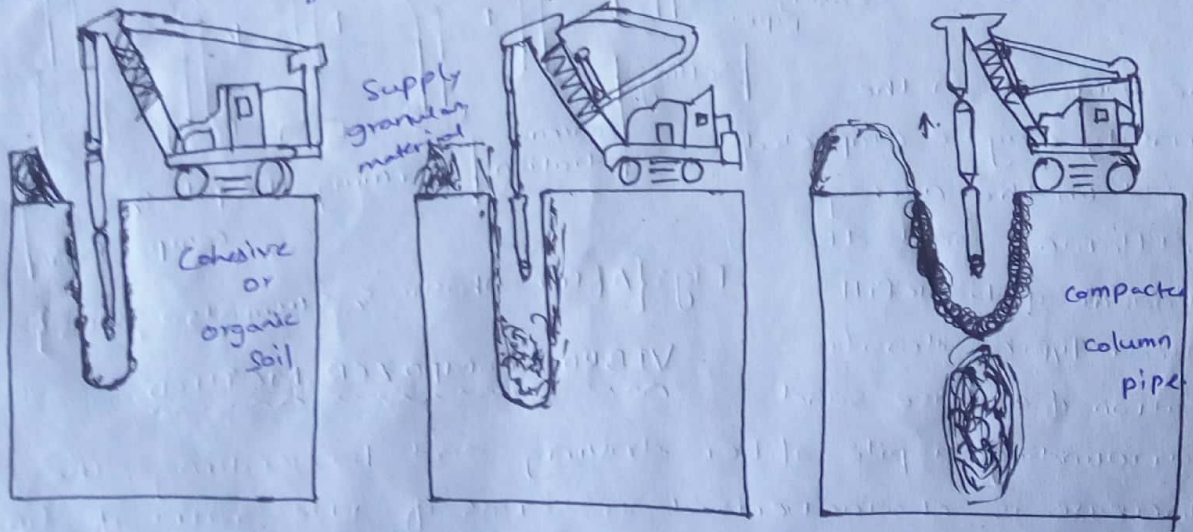


* STONE COLUMNS:-

Stone columns are also called as granular piles. These are used as vibration technique.

A cylindrical vertical hole is made and gravel backfill is placed into the hole in moments and compacted by a suitable device which displaces to the material. This results in a density compacted stone column of certain depth & diameter.

Formation of stone columns using a vibroflot is quite suitable techniques for improve the cohesive soils.



a) Bore hole is formed by sinking vibrator in ground

b) Backfill material into bore hole in stage and compacted

c) Alternate back filling and compacted forms continuous granular piles.

FIG: The vibroreplacement process (After BAUMann & BAUER 1974)

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Vibroflat is allowed to sink into the ground due to its own weight assisted by water or air as a flushing medium upto required depth.

The soil surrounding the Vibroflat is disturbed & Remoulded and softened material can be removed by jetting fluid (water or compressed air)

water is used as a jetting fluid for fully saturated soils while compressed air is used for partially saturated soils. By this process a borehole of larger diameter than the vibroflot is formed once the Vibroflot is withdrawn borehole is back filled with gravel of 12 to 75mm size (or) furnance is lag. With the repenctration of Vibroflot the back fill material is displaced into the sides of borehole and compacting underneath its tip. while backfilling the Vibroflot is raised and lowered.

This procedure is repeated till the hole is completely filled and compacted which forms a cylindrical granularpile.

ALTERNATE METHOD:- (Datye & Nagaraju (1975-1985))

A hammer weighing 15 to 20 kN falling through a height of 1 to 1.5m for compacting stone aggregates placed in pre-bored holes. The resulting stone column and the technique is to be economical than vibrator compaction.

Method-III (Rao 1982)

A simple method using the auger boring equipment and a free fall cast iron hammer. The bore hole is made by spiral auger and the bore hole is cleaned manually by using specially made tools.

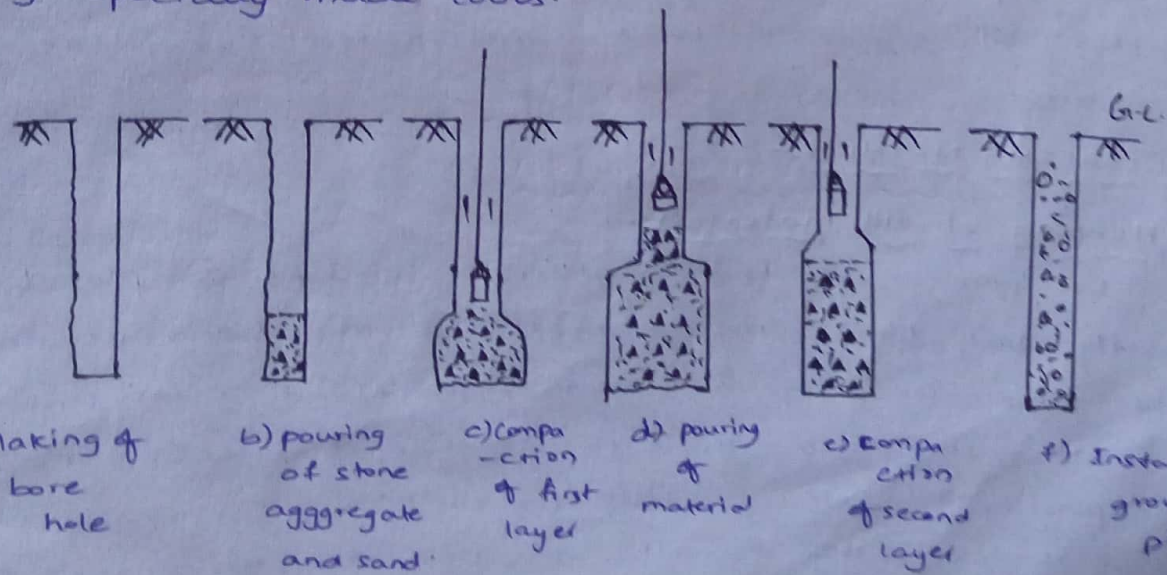


FIG: Granular pile installation method by using Indigenous know how (After Rao 1982)

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* The spacing of stone columns is determined based on settlement tolerances for the loads to be applied and degree of improvement required.

* Stone columns are spaced from 1.2 to about 3m on centre over the site.

The resistance is derived by stone columns only by the peri-meter shear and not by end-bearing. on this basis. The stone column length (L_c) should be greater than

$$L_c \geq \frac{P - A_c(q_{cp+})}{\pi d_c}$$

where
P = total load on stone column
A_c = Average dia of stone column,
c, c_{p+} = side and point cohesion

Allowable bearing capacity of stone columns

$$q_a = \frac{K_p}{SF}(4c + \sigma_r')$$

where $K = \tan^2(45 + \phi'/2)$;
ϕ' = drained angle of internal friction of stone ;
c = either drained cohesion
σ_r' = effective radial stress measured by a pressur meter.
SF = safety factor (1.5 to 2)

* PRE-COMPRESSION PRINCIPLES:-

preloading increases the pore water pressure in the soil and the consolidation process occurs, an increase in effecti stress takes place in the soil. accompained by surface-settlement. The preloading material placed over the ground to be improved in amounts sufficient to produce a stre in the soil equal to that anticipated from the final structure.

* PRELOADING METHODS:-

① Heaping of fill materials:-

In some cases the material is left completely or partly and the removed material may be reutilized in the same project for another preload or for embank-ment construction. There is danger of basefailure in heaping fill material, still this method is generally adopted as it is less costly for all types of structures and loca-tions. Instead of heaping fill the required weight for

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Preloading can also be applied to the ground by constructing a peripheral dyke and filling the enclosed area with water.

Embankement loading:-

In most cases 6 to 8 months are required from the begining of embankement placement to the end when the load is removed. The height of preload is soil heap in most cases is 3 to 8m above the original grade and the minimum and maximum height being 1.5m & 18m respectively.

In situ densification of cohesive soils:-

In-situ densification of cohesive soils are done by pre-loading & Vertical drain technique.

pre-loading:-

It is of a soil, is merely applying an external loading for a long duration to cause desirable changes in the ~~site~~ soil. Conventionally preloading is always carriedout before construction of any structure.

Advantages:-

(1) The cost involved is comparatively less and vary blw 10 to 20% without using vertical drains. and 20 to 40% with the use of Vertical drains.

(2) Especially attractive when the fill material or for site preparation.

(3) simple conventional construction equipment needed for earth moving job is sufficient for the preloading works.

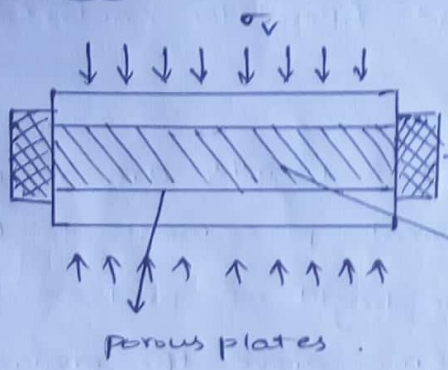
(4) cost of monotoring instrutiments are cheap and time needed for installation is only two (2) 3 weeks.

(5) effect of preloading can be observed periodically from the field-instrumentation. and maices possible future predictions about the behaviour.

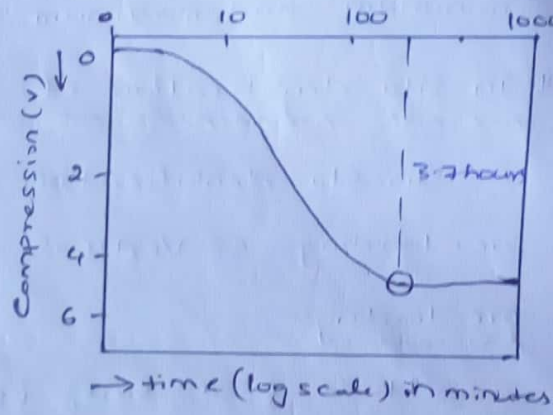
(6) provide uniform improved properties of ground

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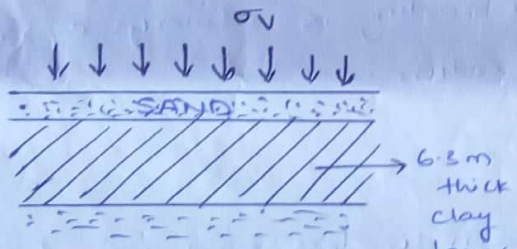
a) Laboratory Consolidation Test results on a 20mm Thick Specimen:-

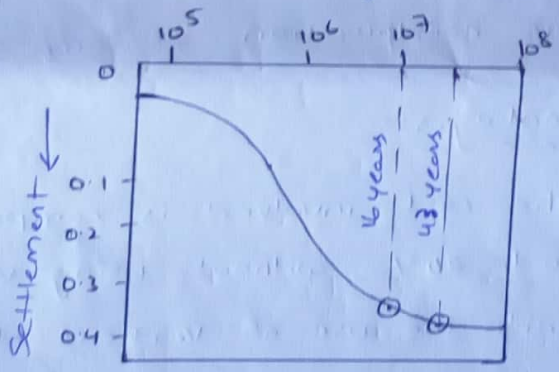


* From the time-compression curve, the time required for primary consolidation is 3.7 hrs.



(b) Time prediction for real problem without Vertical drains





Extraplating from the laboratory result to the real problem of a clay stratum of 6.3m thick. With double drainage time required for 70 and 85% consolidation have been estimated as 16 & 43 years respectively.

Another method of preloading, the final structure is used as vehicle for load application. This method has been extensively applied for liquid storage tanks prior to taking up soil improvement the tank is constructed and then filled with water incrementally. At every stage of additional water loading, the completion of consolidation is ensured. After the final increment of filling and allowing sufficient time for the rate of settlement to

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decrease almost completely.

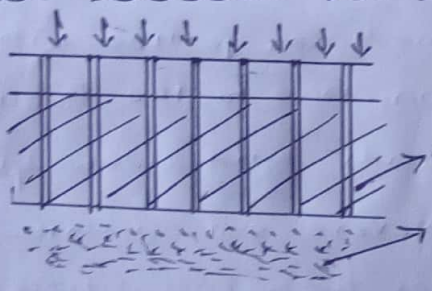
Vertical Drains :-

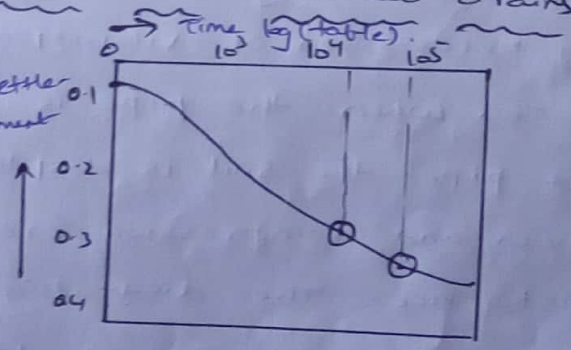
Vertical drains are continuous vertical columns of previous material (sand or fibre) installed in clayey soils. These drains provide the pathway for the pore water to escape from the consolidation soil by travelling a shorter distance than would be necessary without them.

They allow the flow inside the soil to take place along to horizontal which is direction of least resistance. Thus it serves the purpose of collecting and discharging the expelled water faster during the process of consolidation.

Installation of vertical drains in conjuction with preloading brings about the rapid dissipation of excess pore water pressure & there by accelerating the primary consolidation. Vertical drains have no direct effect on the rate of secondary compression leads to the earlier occurance of secondary compression and thus amounting to a total reduction in the time for consolidation.

e) Time prediction for Real problem with Vertical drains





* SAND DRAINS :-

These are the type of vertical drains. They range in diameter from 180 to 450mm. The holes required for sand drains installation should be made with least cost. These are 3 methods of sand drains construction.

→ 1) High-pressure water jetting
2) Displacement of Natural ground
3) Wash Boring

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In all these methods a steel pipe is inserted in the ground and lateral with drawn as sand is poured from the top to fill the hole. All the methods are labour intensive. The spacing of drains varies from 2.5 to 5m.

High pressure water jetting provides forcing water through the bottom of a steel jetting rod at about a rate of 50l/sec or more. The force of water jetting looses up the soil at the bottom of the hole and then the loosened soil along with water is allowed to flow upwards around the jetting rod.

A steel pipe inserted at the ground sinks by its own weight as the hole progresses downward. This method requires a large quantity of water and creats a disposal problem of a soil slurry which may cause an environmental hazard. This method provides very less soil distrbance.

* Displacement Method:-

A closed mandrel consisting of a steel tube closed of the lower end by a loose cap is used. The mandrel is driven by percussion or vibration or sometimes jetted into the place. when the pipe is withdrawn. Due to the forcing of the pipe the soil is displaced upwards and sideways by shear and compression creating a severe soil distribution. distrbance. The distrubance causes high initial porepressure low permeability around the hole and decreases in shear strength. This is a simple in eq expensive method which is very popular.

* WASH BORING:-

In the wash boring method The hole is advanced by circulating water into the hole at a rate of 1 to 2 l/sec The soil slurry from the hole are allowed to settle and from water is siphoned back into the circuit. This

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Method causes less soil disturbance and it can be performed with simple subsurface investigation equipment. This method is slower & more expensive than previous two methods.

* Geo drains:-

The plastic drains have been widely used & showed relatively little disturbance & could sustain large settlement without break of drain continuity

Geodrains have been divided into following ways Advantages

→ low cost
→ Fast installation
→ Ensure drain continuity
→ clean site
→ light weight
→ High permeability
→ negligible subsoil disturbance.
→ positive drainage.

Common types of plastic drains (90 to 100mm wide by 3 to 5mm thick) are usually installed by a lance about 140mm in cross section.

open or closed mandrel are fitted to rings A down-ward force of 200kN can be executed by the rings upto 4 wicks at a time.

Installation speed is of the order of 0.2 to 0.6 m/sec and driving depth could be upto 45m plastic drains are wound around reels and as the mandrel is lowered into the ground, the band is released by unwinding. The Spacing is commonly in the order of one and a half to two wicks drains per one sand drains

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Fig: Cross-section of cardboard drain & insertion Mandrel.

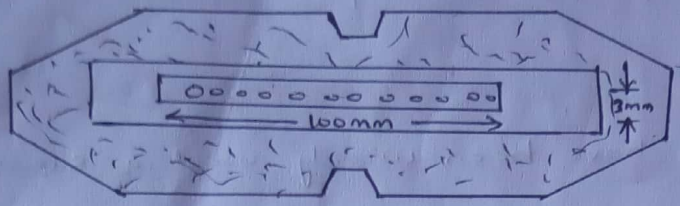
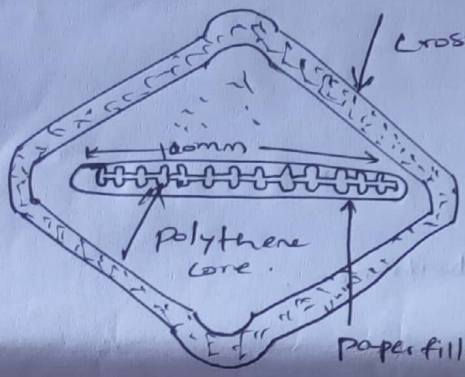


Fig:- Crossed section of plastic geodrain & insertion Mandrel.



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