Unit - I Problematic Soil & Improvement Techniques.

Role of ground improvement in foundation Engineering.

Ground Improvement :

The process in which the insitu soils are developed for supporting the foundation is called ground improvement.

Need :

* To increase the BC of soil to support the foundation.
* To provide stability to structure.
* To reduce settlements.
* To avoid liquefaction in seismic prone areas.
* To avoid deep foundations.
* To avoid soil replacement.

factors :

* Type and degree of improvement required
* Type of soil, geological structure, seepage conditions.
* Availability of equipment & materials for adopting a particular ground improvement technique.

- Cost and construction time
- Possible damage to other structures.

pollution of ground water

Reclaimed soils :

The term reclaimed soil comprises of all materials deposited on site using various methods for different purposes. Following are the list of reclamation materials,

- Fairly clean sand
- clayey sand
- Soft cohesive soils
- Paper sludge
- Fly ash
- Slag from furnace
- Sanitary fill.

Importance

In the early times before the geotechnical engineering, advancement in the foundation engineer~~ing~~s the only chance for the foundation matching to was to design the foundation the sub

15 set

Unit - I

Site Investigation and Selection of foundation

The knowledge of subsoil conditions at a site is important for safe & economical design of substructure elements. The field & laboratory studies carried out for obtaining the necessary information about the subsoil characteristics including the position of ground water table are termed as soil exploration.

Purpose and Scope:

- Provide information
- Reveals the need for further investigations.
- Indicates changes in design (or) confirms assumptions.
- Cost savings.
- Analysis of failure of existing structure.

Objectives of Soil (or) Site exploration.

1) To select the type & depth of foundation.
2) To determine the bearing capacity of the soil.
3) To estimate the probable maximum and differential settlement.
4) To establish the groundwater level and to determine the properties of water.
5) To find soil and rock profile.
6) To select the suitable construction techniques.
7) To obtain Geological features.

Site Investigation:

Three stages involved in exploration

1) Reconnaissance
2) Preliminary Exploration.
3) Detailed Exploration.

1) Reconnaissance

It includes,

- Site inspection → To visit the site.
- Library study:
  - Geological maps
  - Aerial photographs.
  - Toposheets.
  - Soil maps.

2) Preliminary investigation:

→ To find the depth, (t) & composition of each soil strata.

→ To locate the boundaries of different strata.

- Test pits & Trenches.
- Soundings or Probings.
- Geophysical investigations.

3) Detailed exploration:

→ To find engg. properties.

- Deep boring
- Sampling
- Field testing
- Laboratory testing

Methods of Exploration (or) Investigations.

1) Open excavation
   - → Test Pits
   - → Trenches.
2) Borings
   - → Auger boring
   - → Auger & Shell boring
   - → Wash boring
   - → Rotary Drilling
   - → Percussion Drilling.
   - →
3) Subsurface soundings
4) Geophysical method (or) Averaging.
   - (a) Seismic refraction method
   - (b) Electrical resistivity method
   - (c) Gravitational method.
   - (d) Magnetic method.

1) Open excavation:

a) Test pits:

- Economical
- Size of 1.2 m x 1.2 m
- Max. depth of exploration – 5 m
- Useful for plate load testing
- Water should be pumped out.

Data gathered:

- Physical & Engineering properties
- Stratification.

Limitations:

- Cost increases with depth
- Unsuitable for pervious soils.
- Difficulty with water table.

b) Trenches:

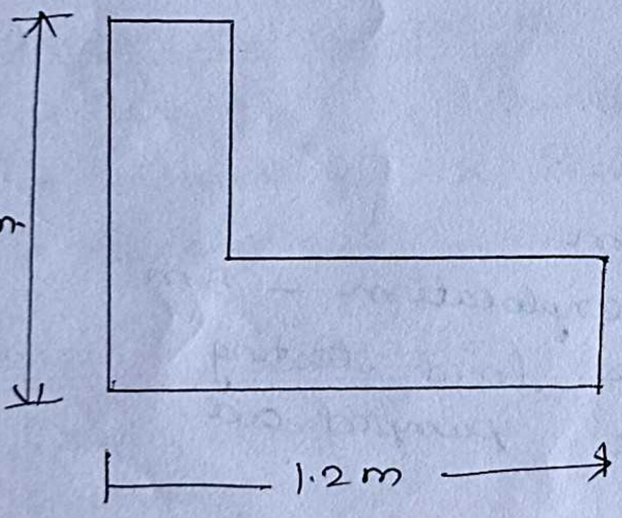
- Continuous length
- Useful for slope exploration

Advantages:

- Stratification can be seen easily
- Fast and inexpensive method
- Reliable in field sampling & Testing.

Limitations:

- Limited depth of exploration
- Exploration difficult under water table
- Increased cost.
- Back filling may be non-uniform.



Test pit.

Boring:

Boring may be defined as the process of advancing a horizontal, vertical (or) inclined hole in the soil to obtain samples and in the process determine its engineering properties.

Methods of boring:
(1) Auger boring (2) Auger and shell boring
(3) Wash boring (4) Percussion boring (5) Rotary drilling

(1) Auger Boring: (Disturbed sample).

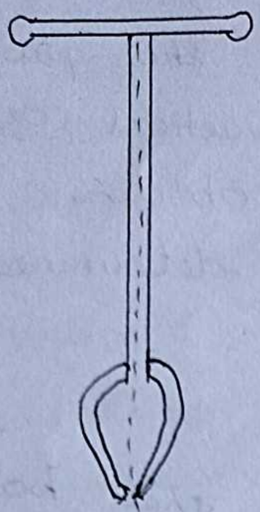
- * Bore hole advanced by auger.
- * Augers are used in cohesive & other soft soils above water table.
- * Types of auger → Hand auger dia (15-20 cm) – upto 6m (dep)
  → Mechanical (or) Power – greater depth. (Gravel soil).
- * Post hole auger & Helical auger.
- * The soil samples are collected on the sides of augers & it is taken out.
- * Used in Highway & railway construction.

Advantages:

1. Useful for shallow exploration.
2. Inexpensive method
3. Useful in case of transportation projects.

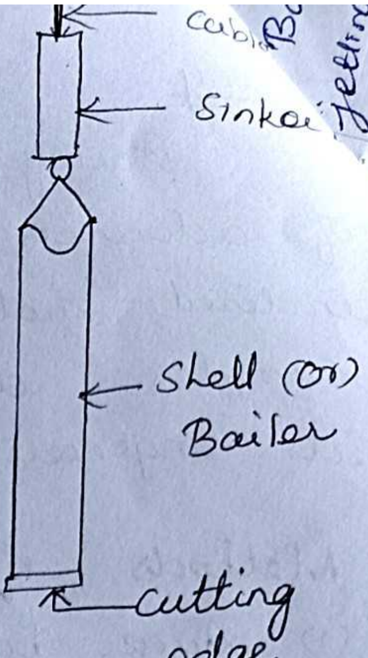
Limitations:

- * cannot be used in gravel
- * Difficulty with water table
- * change of stratum cannot be identified due to mixing of soil.



Auger Boring

Helical Auger



Auger & Shell boring.

2) Auger & Shell boring (or) Sand bailer:

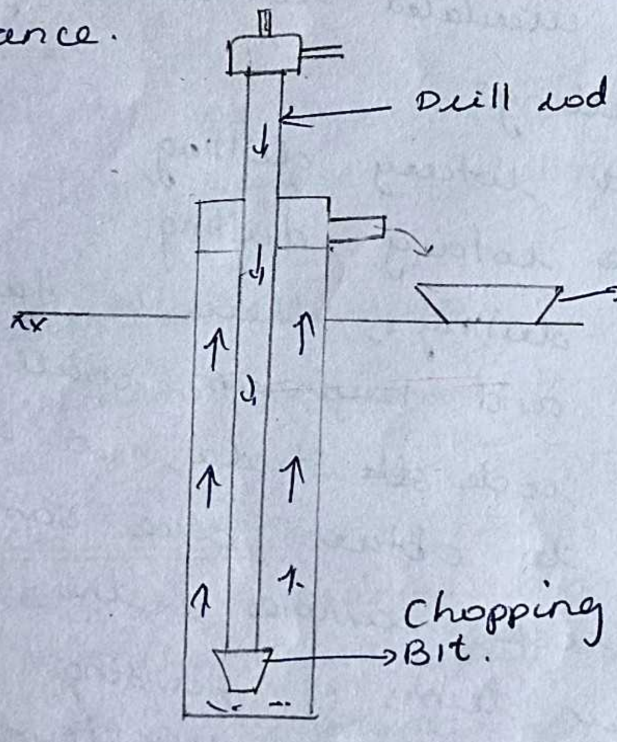
- A shell also called bailer, is a heavy pipe with a cutting edge.
- Sinker bars are used to add weight to the shell.
- The shell is raised & let fall in a hole through the cable.
- Depths upto 50 m can be achieved

3. Wash Boring (or) Water Boring:

- It is used for exploration bblow water Table.
- It is used for where the auger method is unsuitable.
- It is used for all types of soils except those mixed with gravel and boulders.

Bore hole is advanced by dropping and jetting of water at high pressure.

- * Soil is reduced to small fragments called cuttings.
- * Water is pumped down through drill rod, water enters to the soil through the small openings in a chopping bit.
- * Cuttings is brought to surface by wash water and collected in sump.
- * Change in colour of water indicates change in stratum.
- * Soil is extremely disturbed, so method is adopted only to advance the hole.
- * Driving resistance gives an indication of soil resistance.



Wash boring.

Advantages.	Limitations.
* Fast and inexpensive method.	* Cannot be used in
* Easy and simple operation	* Highly disturbed samples.
* Unskilled supervision	* Disintegration of soil particles
* change in stratum can be seen	* High water content at bottom

3. <u>Rotary Drilling</u>:

* Hole is advanced by a rotating string consisting of hollow drill rods to which a cutting bit or coring or core barrel is attached.

* Downward pressure is applied for movement

* Drilling fluid is circulated to cool the bit and to remove the cuttings.

Types → Straight rotary drilling
→ Reverse rotary drilling.

In reverse rotary drilling, there is faster removal of cuttings and minimum wall disturbance.

When drilling in rock ~~stt~~ Strata, a diamond core barrel is used to obtain core samples of rock.

When obtaining rock samples, the quality of rock samples in terms of jointing and fracturing is designated by the term RQD (Rock Quality Designation). (ie) It is a rough measure of the degree of jointing (or) fracturing in rocks

$$RQD = \left(\frac{l_{sum} \text{ of } 100}{l_{tot} \text{ core run}} \right) \times 100\%$$

RQD	Rock mass quality.
< 25%	Very poor.
25-50	poor
50-75	fair
75-90	Good
90-100	Excellent.

Advantages:

1) Used for all type of soil
2) Bore hole of dia 50mm-200mm can be achieved.

Limitations:

1) Not used in pervious stratum due to high usage of drilling fluid
2) Highly disturbed samples
3) Skilled supervision required.

4) Percussion Boring:

* Borehole is advanced by raising and dropping action of the drill pit
* Cuttings are removed in the form of slurry by adding water.
* Sand pumps (or) bailers are used for removal of cuttings.

Advantages

1. Can be used for any types of soil
2. Used for drilling tube wells
3. Rapid method
4. Suitable for glacial tills.

Limitations.

- * Disturbance of soil a to impact..
- * Cannot used for loose sand
- * Operations require casing
- * More expensive.
- * Changes in stratum difficult to determine.

Sounding Methods: (or) Penetration Methods.

Sounding means pushing (or) driving by hammer, a steel rod or pipe into the ground, to determine the resistance to penetration (or) depth of hard stratum.

The devices are used to determine the penetration resistance called as 'penetrometer'.

Tests (or) Methods:

1. Standard penetration Tests (SPT)
2. Static Cone (or) Dutch cone penetration tests (SCPT)
3. Dynamic cone penetration Tests (DCPT).

Geophysical Method:

- * Seismic refraction, Reflection methods
- * Electrical Resistivity methods.
- * Gravitational method
- * Magnetic method.

Objectives:

- Thickness of layers.
- Boundaries of layer
- Depth of water-table
- Location of gravel deposits.
- Location of organic deposits.
- Bed rock profiling.

1. Seismic Method:

Principle:

It states that shear waves travel with different velocities in different types of materials.

In this method, a shock waves are created into the soil at their ground level by striking a plate on the soil with a hammer.

Shock waves produced are picked up geophones 1, 2, 3 ... placed at regular intervals $d_1, d_2, d_3 \ldots$ at time $t_1, t_2 t_3 \ldots$

The arrival times are recorded in the recorders.

As the distance b/w the shock point and geophone increases, the travel time of waves get reduced.

* Time Vs distance is plotted which the intersection of two straight lines at distance D.

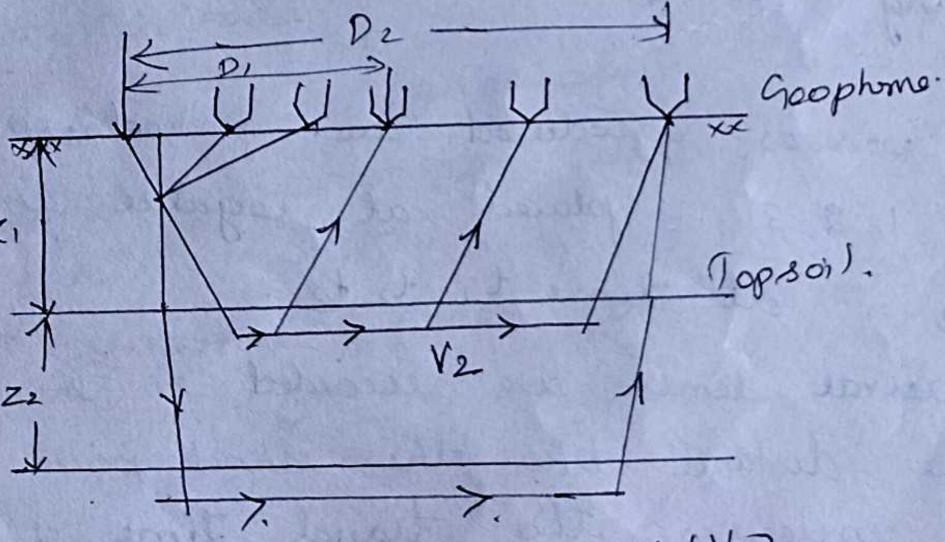
Depth of rock $H = \frac{D}{2}\left[\sqrt{\frac{(V_2 - V_1)}{V_2 + V_1}}\right]$.

Advantages.

1. Rapid Method
2. Lots of additional information
3. Alternative alignments can be studies.
4. Borrow areas can be explored

Limitations

* Soil may not be homogeneous and isotropic
* Thickness of layer should be at least 1/4 th of the depth of occurrence
* Varying boundaries.
* Range of velocities
* costly.



Refracted waves. (V_3)

Electrical Resistivity method:

Principle:

Based on the fact that different materials offer different resistances to the passage of electricity.

Resistivity depends upon;

Water content, voids ratio, Particle size, Temperature, stratification.

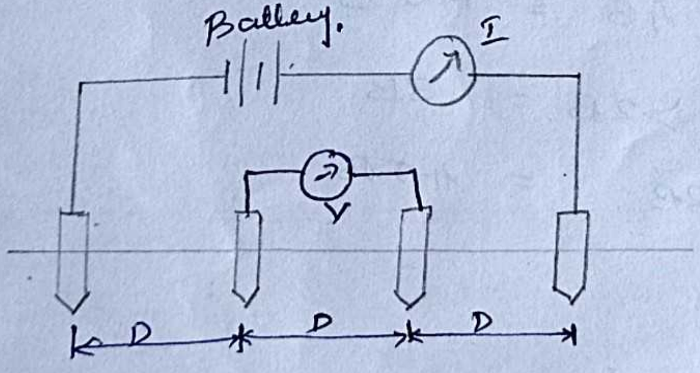
Equipments

① 4 electrodes ② Potentiometer ③ Multimeter

④ Battery.

Method:

* Electricity (I) is passed into the ground through the end electrodes
* The potential difference is measured between the inner electrodes.
* The spacing is changed and the procedure is repeated.
* Marked change in potential indicates presence of layers of different resistivity.



$\rho = \frac{2\pi D E}{I}$ ρ → Resistivity (ohm-cm)

D - Distance b/w electrodes   E → Potential drop. (v)

I — Current

Advantages	Limitations.
1. Can detect sea water intrusion, organic deposits aquifers, ore bodies.	* Wide range and overlapping of resis make interpretation difficult.
2. Can differentiate pervious alluvium from clay	* Readings are easily affected by surface anomalies.

Depth and spacing :

Isolated footing – 1.5 to 2B

Strip footing – 3 to 3.5 B

Dam – greater of H (or) B/2

Narrow cuts – H

Broad cuts – B

Group of piles – 1.5 to 2B

Group of footing :

$A >= 4B = 1.5B$

$4B > A > 2B = 3B$

$A <= 2B = 4.5B.$

sed for grain size analysis, consistency and proctor tests.

Non - representative samples:-

These samples are mixture of materials from various soil (or) rock strata from which some mineral constituents have been lost or got mixed up.

Undisturbed samples:

Samples which are more (or) less intact obtained from bore holes by means of tube sampling.

Used to obtain data on shear strength, permeability, consolidation & stress - strain behaviour.

Chunk samples:

* Chunk samples are the least disturbed of all sampling methods.
* Obtained by means of open excavation.
* Samples are used for all types of tests.
* They cannot be obtained below water table.

Sampling:

The process of Obtaining a small qu of soil from a soil deposit in the field for the purpose of study (or) tests to know about the soil deposit in the field.

The quantum of soil obtained for the purpose is called a sample.

- Types
  - Disturbed sample
    - Representative sample
    - Non-Representative sample.
  - Non-Disturbed sample

Disturbed Sample:

These are the samples in which the natural structure of the soil gets disturbed during sampling. But these samples represent the composition and the mineral content of the soil.

* These samples can be used to determine the index properties of the soil such as grain size, plasticity characteristics, specific gravity etc.

Representative samples:

* These are disturbed samples in which the structure of the soil is lost but water content and density parameters are preserved.

* Obtained by direct excavation, augering (or) Split spoon sampling.

mpling methods:

Soil Sampler:

Depends on thick ness.

- Thick wall sampler
  - Area ratio > 10 to 25%.
  - Split spoon sampler
  - Thickness greater than 4mm.
- Thin wall sampler
  - Area ratio < 10%.
  - Shelby sampler
  - Thickness less than 4mm.

Depends on mode of operation.

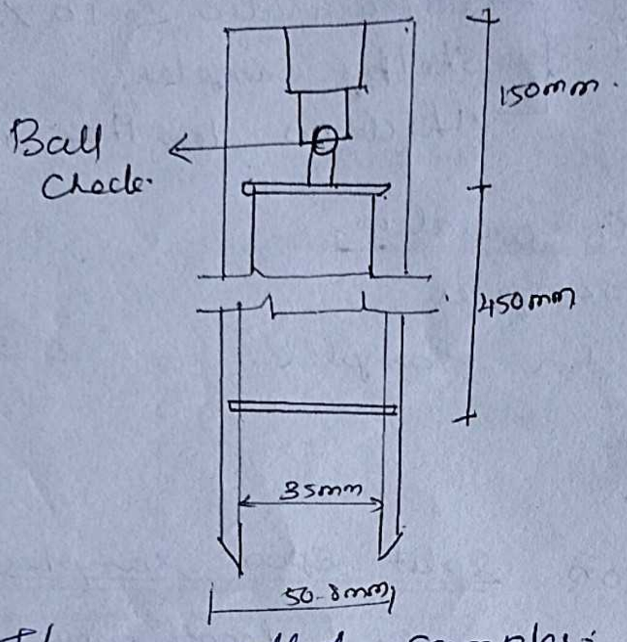
- Open drive sampler
- Stationary piston sampler.
- Rotary sampler.

1. **Thick wall sampler** (or) **Split spoon sampler**

- Thick walled tube, split length wise.
- A drive shoe attached to the lower end serves as the cutting edge.
- 35mm internal and 50.8 mm external dia & 600 mm long.
- The sampler is lowered to the bottom of the bore hole
- The sampler is driven by forcing it into the soil by using hammer.
- The assembly of the sampler is then extracted from the hole.
- The two halves of the barrel are seperated and the sample is exposed. The sample may be placed in a glass jar and sealed after visual examination.

* The Ball check value is provided for the purpose of drilling a fluid (or water into the soil.

Standard split spoon Sampler.



2) Thin walled sampler:

* Smooth, thin seamless tubes provided with tapered cutting edges at the bottom and coupling at the top.
* Area ratio is 13%.
* Sample is retained by friction.
* Made up of Steel (or brass (or Aluminium.
* Procedure is same as that of split spoon.
* The use of steel for the sampler is the danger of corrosion.
* It can lead to the development of adhesion b/w the soil and the tube, making it difficult to remove the sample.
* Chemicals change the engg. properties of soil.

...all by tube:

- * Outside dia varies b/w 40 to 125 mm.
- * the bottom of the tube is sharpened.
- * Area ratio is less than 15%.
- * Inside clearance is b/w 0.5 to 3%.
- * Thickness 1.25 To 3.15 mm

3. Open drive sampler:

* Thick wall type as well as thin wall type.

* The tube may be split in two parts.

* The head of the sampler is provided with valves to permit water and air to escape during driving.

4. Piston sampler:

* It consists of a sampler with a piston attached to a long piston rod

* It is used to prevent water and unwanted loose soil from entering into the sampler.

* The sampler is pushed to the desired depth with the piston closing the bottom end

* Then piston is released and the sampler is pushed into the soil

* The piston remains at the top while the sampler is driven.

* When sampler is fully driven, the piston is locked in its top position & the sampler is withdrawn.

* Piston sampler with used in soft & sens

4) Rotary sampler:

* Combined drilling and sampling operation.
* Consists of two concentric tubes, the inner one acting as sampler and outer one acting as cutter.
* After reaching the desired depth. the inner tube is pushed into the soil and the outer tube is rotated around it to advance it downward.
* when sufficient depth is drilled, the inner tube is raised to the ground level.
* Used for stiff clayey soils.

) Foil sampler:

* Provided with a thin lining of metal foil between sampler & soil to reduce the friction.
* Lining consists of thin vertical strips that enclose the sample.
* 20 m long sample can be obtained.

ndard Penetration Tests :- (SPT).

* SPT is used to determine the parameters of the insitu soil.

* SPT is suitable for cohesionless soils.

Equipments used :

- Split spoon sampler
- Hammer (65 kg weight, free fall of 300 mm)
- Drive rods.
- Equipment for drilling and boring.
- Boring rig.

Method :

1) The test consists of driving split-spoon sampler into the soil through a bore hole of 55 to 150mm dia. at the desired depth.
2) A hammer of 65 kg wt with a free fall of 300mm is used to drive the sampler.
3) The number of blows for a penetration of 300mm is designated as the Standard penetration Value (or) number 'N'.
4. Drive the casing
5. Complete wash boring and clean bore hole.
6. Replace drill bit with split spoon sampler
7. Check whether the sampler penetrates under self weight.
8. If not, drive sampler using hammer.
9. Count the number of blows (N) for every 150mm drive
0 Driving is discontinued if N >= 100 for 30cm penetration.

11. The top seating drive value of N
considered for design purpose.

* Loose soil from the sides may ha
fallen on the bottom.
* The bottom soil may have been driven
by driving.

12. The number of blows required for 300 mm of penetration is recorded as the SPT Value.

13. Lift sampler and extract sample.

14. The spacing b/w subsequent sampling should not be < 0.5 m. It is normally carried out every 0.75 m.

16.

15. Base depth. (or) Change in Strata

0 to 5 m — 0.75 m
5 to 10 m — 1 m
> 10 m — 1.5 m.

Problems with recorded N-Value:

* Hammer efficiency may vary.
* The height of drop may vary due to manual error.
* The bore hole dia may be different
* Sampler may (or) may not be lined.

Corrections:

The observed value of N is corrected for

* Correction for overburden pressure
* Submergence (or) dilatancy correction.
* Gibbs corrections.

ubmergance. correction:

In the case of fine sand (or) silt below water table, high value may be noted for N. In such cases, the following correction is recomenended.

$$C_N = 15 + \frac{1}{2}(N' - 15)$$

N' - Observed SPT Value

C_N → corrected SPT value.

* Over burden pressure correction:

$$C_N = 0.77 \log_{10}\left(\frac{2000}{\sigma'}\right)$$

σ' = Effective over burden pressure = γD (kN/m²)

* Gibbs correction.

$$C_N = \frac{50}{1.42\sigma' + 10.}$$

2) Static cone penetration test (SCPT)

Dutch cone test.

- Used in place of SPT, particularly soft clays + silts and fine to medium sand deposits.

Equipment

1) Cone

Mechanical Cone → Dutch cone (3.57 cm dia + 60° cone area 10 cm²)
→ Peckmann friction jacket cone.

Electrical Cone → Piezo Cone.

2) Sounding rod – 1 m long, 15 mm dia.

3) Steel or Mantle tube – $d_i = 16$ mm, $d_o = 36$ mm, L = 1 m.

4) Cone driving equipment.

Method:

1) The equipment is anchored firmly ~~f~~ on the ground.

2) Cone with sounding rod is inserted into the required depth.

3) Apply pressure to take the cone to the required depth.

4) Obtain cone resistance by pushing the cone at the rate of 10-20 mm/s to a depth of 50 mm by pushing the sounding rods.

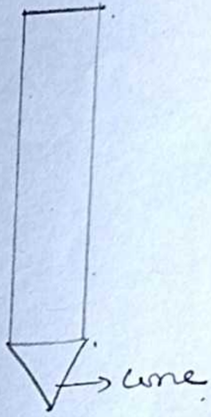
5) The test is conducted in increments of not greater than 200 mm

6) In case of friction jacket cone, cone resistance is obtained by pushing the cone by 50 mm and then the friction jacket is pushed along with cone to get cone & friction resistance

$$\text{Cone resistance } (q_c) = \frac{\text{Load applied on cone}}{\text{Cone area.}}$$

$$\text{Unit friction } (f_s) = \frac{\text{Frictional resistance} \times \text{cone area}}{\text{Surface area of friction jacket.}}$$

$$\text{Friction ratio} = \frac{f_s}{q_c} \times 100.$$



Applications of SCPT:

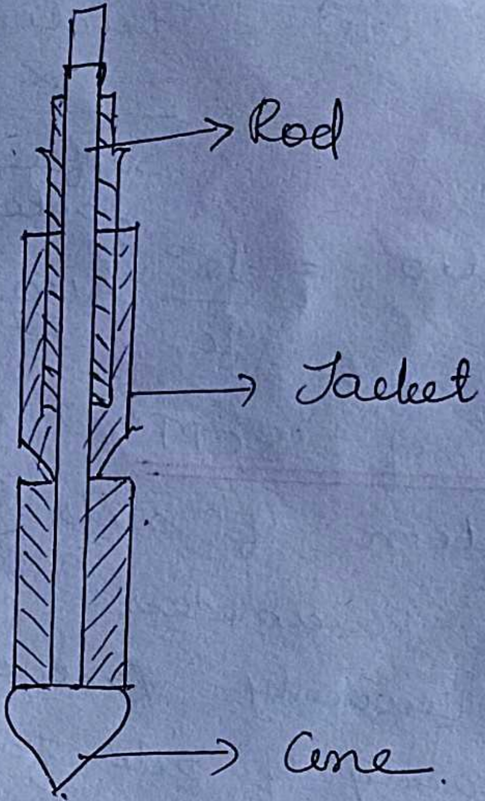
- classification of soils
- Strength parameters.
- Bearing capacity factors.
- Load capacity of pile foundation.
- Settlement of foundations.

Merits

1. Tests can be done on soil with low bearing capacity.
2. Tests can be performed at smaller intervals
3. Thin layers strength can be determined

Demerits.

- Soil in which test is performed cannot be determined
- Seperate rig is required for testing
- Cone penetration values are unrealiable when particle size is beyond particular size.


Rod
Jacket
Cone.

Soil log report (or) Subsoil investigation report:

It is a report (or) record of the soil data that has been obtained from a particular bore hole:

Uses:

A soil exploration report generally consists of the following:

1) Introduction, which gives the scope of the investigation.
2) Description of the proposed Structure, the location and the geological conditions at the site.
3) It indicates the number of borings, their location & depths.
4) Details of the method of exploration.
5) Bore hole logs.
6) General description of sub soil conditions as obtained from in-situ tests such as Standard penetration test and CPT.
7) Details of laboratory test
8) Depth of ground water table and changes in water levels.
9) Discussion (or) Analysis of results.
10) Recommendation about the types of foundation.

BOREHOLE LOG

BOREHOLE No **CP01**

Princedale Road

	Date	Ground Level (m)	Co-Ordinates (m)	Sheet
G/28250A	22-08-17	9.60		1 of 2

Academy Holland Park Ltd

SAMPLES & TESTS

Depth	Type No	Test Result	Water
[illegible]	B		
[illegible]	B		
[illegible]	B D SPT	N6	
	U		
[illegible]	B		
[illegible]	B D SPT	N6	
[illegible]	U		
	B		
[illegible]	B D SPT	N10	
[illegible]	B D SPT	N9	
			1 ▽
			1 ▼
[illegible]	B D SPT	N12	
[illegible]	B D SPT	N15	

STRATA

Reduced Level	Legend	Depth (m) (Thickness)	DESCRIPTION
9.40	▩	0.20	Hardstanding over dark blackish grey medium to coarse sand and fine to coarse angular gravel of mixed lithologies comprising tarmac fragments [MADE GROUND]
9.10	▩	0.50	Dark brownish grey sandy fine to coarse angular gravel comprising brick and mortar fragments. [MADE GROUND]
9.00	▩	0.60	Greyish brown gravelly medium to coarse sand. Gravel is fine to coarse angular of mixed lithologies incuding brick, mortar and tarmac fragments. [MADE GROUND]
8.80	▩	0.80	Weak concrete slab. No rebar noted. [CONCRETE]
7.60	▩	(1.20) 2.00	Mottled greyish brown and brown sandy gravelly clay. Sand is medium to coarse. Gravel is fine to coarse angular (anthropogenic materials) to subrounded (natural materials) of mixed lithologies including brick fragments. [MADE GROUND]
6.60	≡	(1.00) 3.00	Firm to stiff mottled brown and orangish brown CLAY. Occasional rootlets. [LANGLEY SILT MEMBER]
5.10	≡	(1.50) 4.50	Soft to firm orangish brown sandy to very sandy CLAY. Sand is fine. Occasional organic matter content. [LANGLEY SILT MEMBER]
1.10	⁘	(4.00) 8.50	Loose to medium dense orangish brown clayey fine to coarse SAND [KEMPTON PARK GRAVELS] 5.10 becoming slightly clayey. 6.00 becoming medium to coarse sand.
0.00	○	(1.10) 9.60	Medium dense orangish brown slightly silty coarse SAND and fine to coarse subrounded GRAVEL of mixed lithologies including flint, mudstone and sandstone. [KEMPTON PARK GRAVELS]
	≡		Stiff bluish grey CLAY. [LONDON CLAY FORMATION]

Boring Progress and Water Observations

Comment	Strike Depth	Casing Depth	Casing Dia. mm	Standing Depth
	7.65	7.50		7.25

General Remarks

1. A hand dug inspection pit was undertaken from ground level to 1.20m bgl.
2. D - Disturbed sample; ES - Environmental sample; B - Bulk sample; U - U100.
3. Densities and soil consistencies are based on insitu tests.
4. No visual or olfactory evidence of contamination observed.
5. Groundwater was encountered at 7.65m bgl.
6. SPT - Standard penetration test; N - Number of blows.
7. Installation details: 50mm plain pipe with bentonite seal between 0.00m bgl and 6.00m bgl; 50mm slotted pipe with gravel between 6.00m bgl and 10.00m bgl; bentonite backfill between 10.00m bgl and 15.45m bgl; flushed cover installed and ground reinstated.
8. Ground level taken from local spot height.

	Field Crew	Logged By	Checked By
Dando 2000	BBL	APC	JJM

Geotechnical problems in Alluvial, laterite & black cotton soil

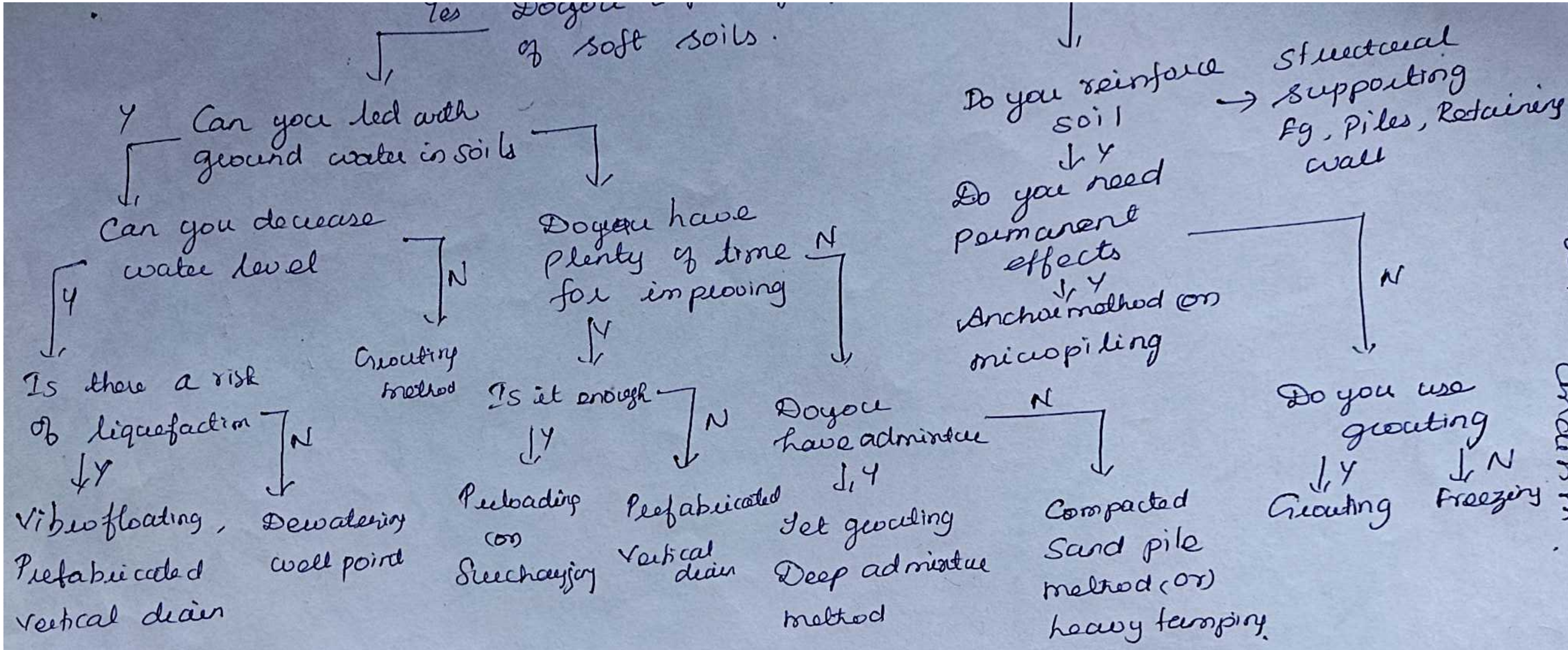
Items	Alluvial soil	Laterite Soil	Black cotton soil.
i) Formation	Formed by deposits of loose unconsolidated sediments which has been eroded, reshape by water flowing over flood plains.	Formed by decomposition of rock, removal of bases, silica from ground by oxidation.	Formed from rocks like bassalt & contain clay mineral.
) Composition.	Composed of silt sand clay & gravel in alternate ways. * High silica content * Pottash lime * Nitrogen	* Hydrated oxides of aluminium & iron * MgO * Deficient in pottash phosphoric acid & lime.	* Mg, calcium. * Deficient in N, phosphoric acid & organic matter. * Montmorillonite

Appearance	* These soiles are fine grain & it is the most fertile. * Colour varies from light olive brown to dark brown.	* Thin & gravelly in higher altitudes & heavy loam in lower layer. * Soft at early stage * Harden with age. * Reddish pink colour	* Loamy to clayey in appearance * High degree of fertility * Black colour.
Characteristics	* Fertile in nature * pH = 7.5 (Surface) pH = 9.15 (last layer)	* Rich in nutrients & Organic matter * pH = 3.5 to 4	* High content of montmorillonite. * pH = 8.5 to 9.
Soil distribution	Indo gangetic, brahamaputra plains. East - Assam West - Punjab. River - Ganges.	Orissa Assam Kerala Karnataka West Bengal	Mathiya Pradesh Andhra Pradesh Tamil Nadu.

	During this strong shaking, the soil transforms into liquid state finally using its strength & bearing capacity * Soil is subjected to settlement. *	* Coarse in nature and hence posses medium to high workability. * No swelling & foundation filling. * Resistant to moisture * It is infeasible dusty in natures during cool weather which clogs the drainage system.	
Control.	Using suitable ground improvement techniques.	Use of stabilizing agents improves for the strength	* By surcharging * By using stablizing agen like cement, lime, asphalt & sand.

	According to age, 1) Old alluvium 2) New " According to stage depth → Minimal → Maximal → Medial	1) Primary laterite 2) Secondary laterite	According to region. 1) dry & heavy 2) medium & light According to profile * Shallow with gypsum * Shallow without gypsum * deep with gypsum * deep without gypsum.
Problems:	* Liquifaction problem * Increase in silt & clay content increases the fines & fraction which is limited to some percentage * Alluvial soils amplify the seismic waves through them	* No difficulty as foundation material & retained these slopes. * Posses high bearing capacity & hence can be choosen as construction material in foundation.	* It contains clay mineral. * Swelling & shrinkage. * Used in highway & air field construction.

Selection of ground improvement tenchnique based on soil condition.



Unit - II Drainage & Dewatering

Drainage techniques - Well points - Vaccum and electroosmotic methods - Seepage analyses for 2D flow - fully & partially penetrating slots in homogeneous deposits.

Drainage & Dewatering :

Dewatering systems consists of lowering water table to a required level by collecting the water using collected like wells, galleries, sumps and ditches and removing the water using pumps and pipes. Continuous dewatering may be costly and endanger the stability of adjacent structures.

Drains are provided to control the flow, reducing the pore pressure & seepage forces.

Advantages :

- To control seepage & lowering of water table
- To stabilize banks of excavation thus providing slope stability.
- To keep the bottom of excavation dry.
- Reduces danger of frost action.

Disadvantages :

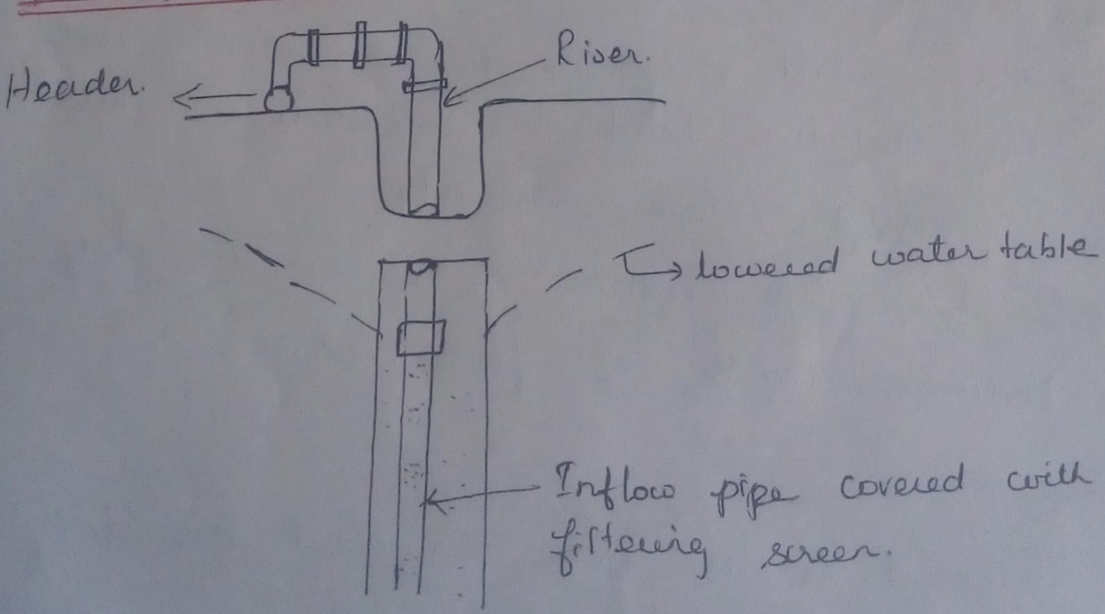
- Ground water gets lowered causing environmental impact.

- Requires proper installation and maintenance.
- Dewatering effects nearby structures like buildings, roads, embankments due to vibrations that arise during dewatering.
- Extraction of fines in addition to water cause serious effects of local settlement, erosion & instability of structure.

Dewatering Methods :

1) Well points.
2) Vaccum dewatering systems.
3) Electro-osmosis.

1) Well points :



Well points are a commonly used dewatering method as they are applicable to a wide range of a ground water conditions.

Well points are perforated pipes about 0.5 m to 1 m long and 5 to 8 cm dia covered by small well screens.

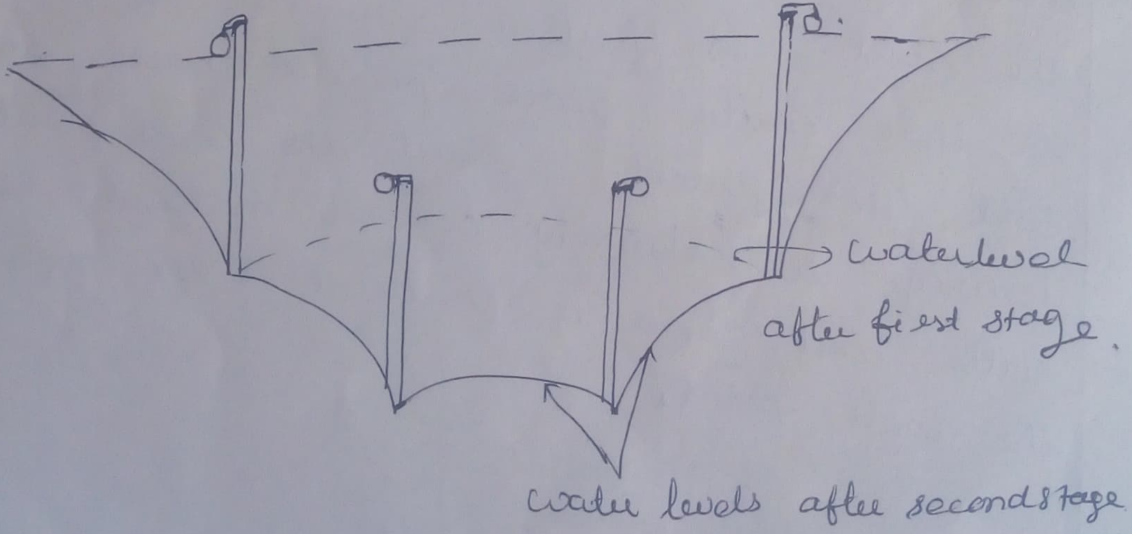
These well points are either of closed end or self jetting type. The screens are made of brass or stainless steel mesh, slotted brass or plastic pipe (or) trapezoidal shaped wire wrapped on rods.

Incase of well points with closed ends, pre-drilling is required and incase of well points of self jetting type, jetting of water helps in driving the well points into the soil. A further advantage of jetting is that water under pressure washes away soil fines present around the well point leaving a relatively coarser material to settle and form a natural filter over the well point.

The well point is connected to a header pipe by means of a riser pipe so that the collected water can be pumped out. When suction commences, water enters into the well through the screens and drawn through the riser pipe and it reaches the surface.

The capacity of a single well point with 50 mm riser is about 10 litres/m and the water table can be lowered to a depth of 6m.

Spacing of well points can be kept b/w 0.75m to 1m in fine to coarse sand & sandy gravel. A spacing of 1.5m is necessary for silty sand & 0.3m is enough for coarser gravels.



For dewatering excavation for more than 6m to the water table, a multi stage well point system is used. In multi stage well point system, the ground is first stripped to a natural water level where the first stage of well points is installed.

After excavating about 5m, second stage is installed to further lower the water table for advancing excavations per well point is small, a jet well point may be used in place of multi stage well point system. Each well point is installed in the bottom of cased hole.

The well point is attached to the bottom of jet eductor pump which is in-turn connected to the surface by two pipes; one for incoming high pressure water that operates the pump and the other for return water including the water that has to be pumped or removed from the well point.

It has low efficiency.

Draw down of Ground water is not limited in depth.

2) Vaccum Dewatering Systems:

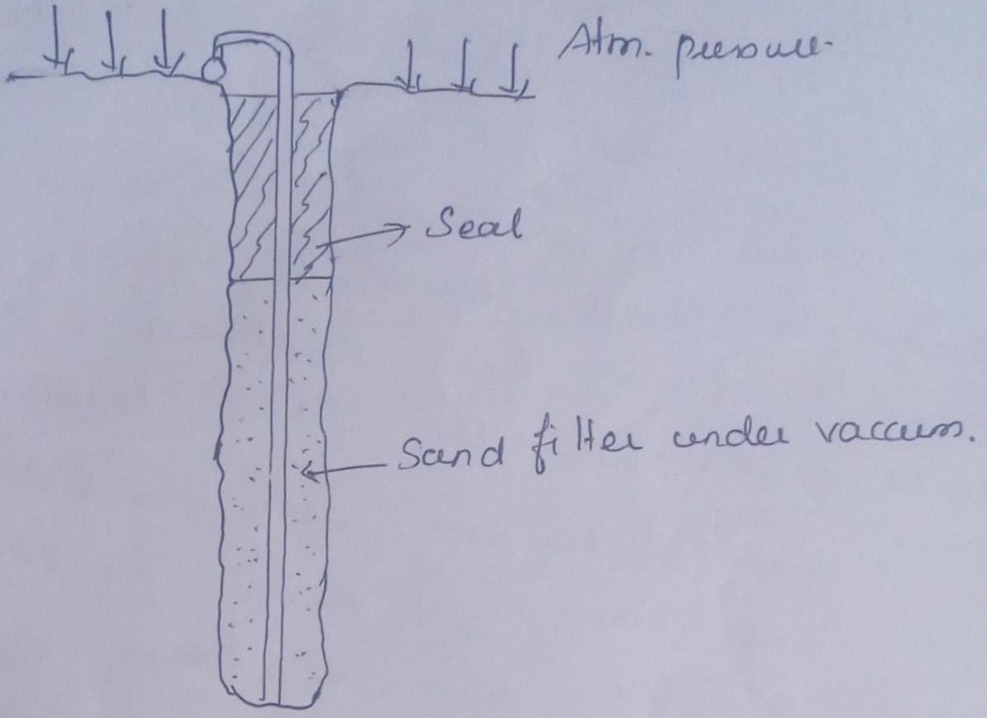
In fine grained non-cohesive soils such as silty sands, the vaccum method of dewatering is used. In such soils with low permeability of the order 10^{-3} & 10^{-5} cm/s it is necessary to apply a vaccum to the piping system.

The vaccum Dewatering System requires that the well point system & the riser pipes are surrounded with filter sand & that is sealed at top with an impervious material. By means of a vaccum pump, vaccum is maintained in the well points & surrounding water.

∴ The pressure around the well point is reduced whereas the ground surface is acted upon by the atm pressure.

The unbalanced atm pressure drags the water in pores to the well point & hence to the ground consolidating the subsoil.

Ht of lift is 3 to 6 m.



Advantage:

- Increased dewatering rate
- Reduced no of well points are required
- Effective source removal at low permeability soils.

Disadvantage.

- Higher operation & maintenance cost
- Applicable to limited places or zones.

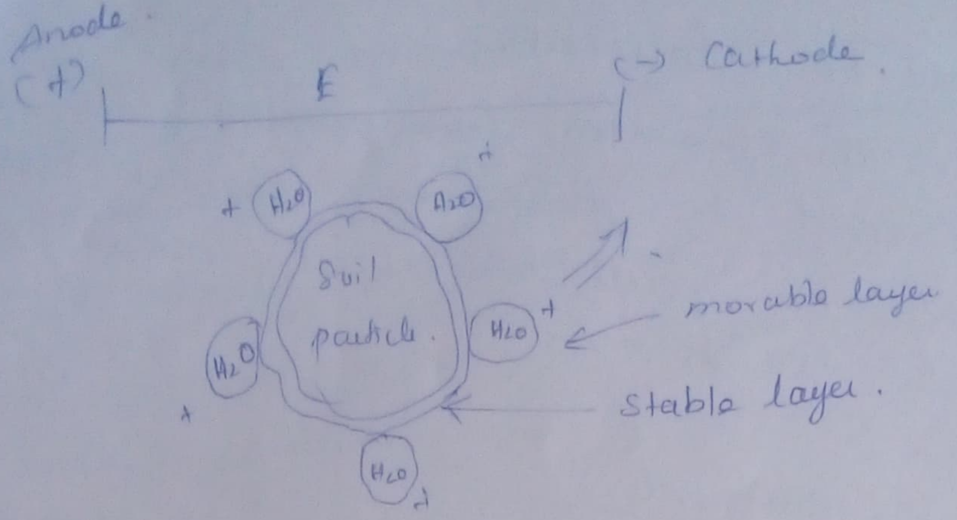
Electro- osmosis

* It is suitable for fine grained non- cohesive soil.

* When a electromotive force is applied across a solid - liquid interface, the movable layer is displaced tangentially with respect to the fixed layer.

* Two electrodes are inserted into the saturated soil mass. The cathode is made in the form of a well point. Anode is of a steel rod, a pipe or sheet pile layer consist of a net positively charged water particles which serves as the movable layer while the inner layer is soil particles which are -ve ly charged.

When an electric potential is applied to the electrodes, the outer layer of +ve ly charged water particles are moved towards the cathode & gets collected while the inner layer composed of soil particles remain stable. The water collected in the cathode well can be pumped out.



$$V_e = k_e - i_e$$

where

k_e → Electro osmotic coeff of permeability.

i_e → Electric gradient which is equal to the applied electric potential divided by the distance b/w the electrodes.

$$k_e = 0.5 \times 10^{-4} \text{ cm/s}.$$

Electric potential ranges b/w 40 to 180 V for a distance of 4 to 5 m b/w the electrodes.

Safety measures:

- Only persons wearing rubber boots should be admitted the electrodes.
- While working b/w anode & cathode neither the electrode nor the wiring

should be touched.

* While the excavation for placing the elec is carried by machinery, special attention should be paid to avoid occur of short circuits.

Filter requirements:

In any drainage and dewatering systems, conduits and perforated pipes are used. The space b/w the natural soil & pipes are filled with coarse grained material called filter.

If the voids of the filter are larger than the grain size of soil particles, there is a possibility of these fine particles to fill the voids and block the flow.

On the other hand, if the voids of filler are smaller than the grain size of soil particles, the filter material get washed off. Both these are undesired conditions a filter material that over comes above two conditions is called filter.

- The filter material should be fine & so graded prevent base material from penetrating the filter.
- It should be coarse & pervious.
- It should be coarse not to be carried away through the clearance openings.
- It should be thick enough to carry the seepage discharge from base material to the well.

$$\frac{D_{15} \text{ of filter}}{D_{85} \text{ of base material}} < 4 \text{ to } 5$$

- The D_{15} size of filter material must be at least 4 to 5 times the D_{15} size of base material..

This keeps the seepage forces within the filter to permissible soil magnitude.

$$\frac{D_{15} \text{ of filter}}{D_{15} \text{ of base material}} > 4 \text{ to } 5$$

Design for simple case.

Design steps for dewatering system

1) Sub soil Investigation.
2) Source & water table details
3) Effective well Radius (r_w)
4) Discharge computations.
5) Design of filters.
6) Design of selection of well screens.
7) Selection of Pumps & Accessories.
8) Centro of surface water.

1) Sub soil Investigation

Depends on permeability, grain size distribution, thickness of layer.

$$K = C_1 D_{10}^2$$

D_{10} → effective size of particle.

C_1 → Constant (100 to 150).

K → Coeff of permeability.

2) Source.

Depends on geological features of the area, aquifers, degree of imperviousness of soil, Amt of drawdown etc.

Case(i) Aquifer:

$$R = C_1 (H - h_w) \sqrt{k}$$

R → radius of influence

C_1 → Constant = 0.9

H → Depth of natural wT.

h_w → Head of the well

$\sqrt{k}$ → coeff of permeability.

Case(ii) River:

→ D/s between the river & well.

3) Effective well radius: (r_w)

$r_w = \frac{1}{2}$ (out side dia of the well screen).
(w/o filter).

$r_w = \frac{1}{2}$ (out side dia of filter) (with filter).

4) Dicharge:

$$Q = \pi k \left(\frac{H^2 - h^2}{2.303 \log_{10}\left(\frac{R}{r}\right)} \right).$$

Q → Discharge

H → Depth of strata

k → Permeability.

R → Radius of influence.

h → Ht of wT

r → radius of well point

Design of filter:

	Ratio R50	R15
Cu (3 to 4) =	5 to 10	—
well graded to poorly graded. rounded grains =	12 to 58	12 to 40
" " angular particles =	9 to 30	6 to 18

Design of well screens:

- resist corrosion.
- < D70 & D80.
- made of steel (or) wood pipe, galvanized trapezoidal wire pipe.

Pump.

- High capacity
- fuel economy.
- Operation & maintenance.
- Centrifugal pumps are used.
- head pipe is of 15 to 30 cm dia & made of light weight steel or plastic.

Control of surface water:

The surface water flow can controlled by providing dikes, ditches, sumps and by seeding.

Seepage:

It is the movement of liquid through porous material (or) small holes.

Seepage pressure

It is the pressure exerted by the water on the soil through which it percolates.

$$P_s = h\gamma_w = iz\gamma_w$$

$i \rightarrow$ hydraulic gradient $= \frac{h}{L}$

$\gamma_w \rightarrow$ Unit wt of water.

Seepage force (J)

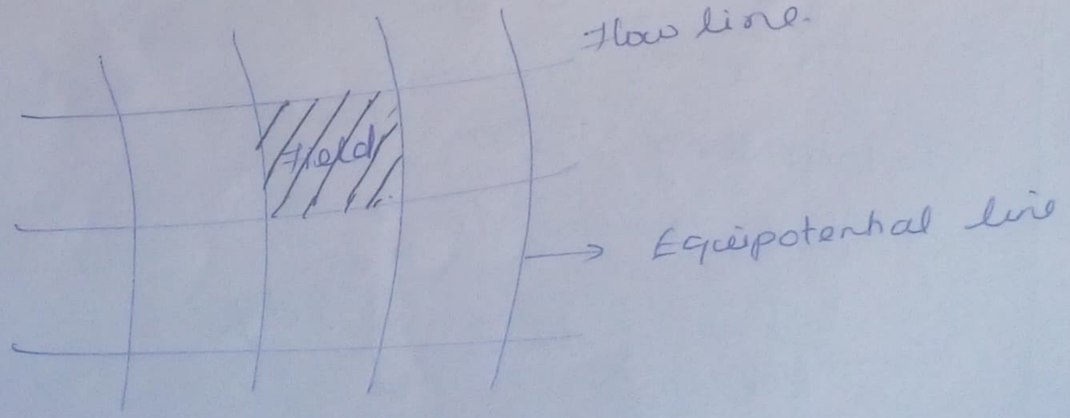
$$J = P_s . A = iz\gamma_w A$$

Seepage force per unit volume (j)

$$j = \frac{iz\gamma_w A}{zA} = i\gamma_w$$

Flow net:

It is the graphical representation of flow through the medium.



Properties:

- * Flowlines $\perp^{re}$ to equipotential line.
- * Fields are square.
- * Discharge is same.
- * Smaller the dimensions of the field, greater will be the hydraulic gradient & velocity of flow through it.

Seepage Analyses:

Assumptions:

- * Flow is laminar
- * Darcy's law is valid.
- * Soil to be dewatered is homogeneous and isotropic.

Fully penetrating soil.

$$q = k i A$$

$$= k \frac{dy}{dx} (y \times a)$$

$$\frac{q\,dx}{ka} = y\,dy$$

Integrating b/w limits $y = h_0$ to $y = H$ and $x = 0$ to $x = L$.

$$\frac{q}{ka} \int_0^L dx = \int_{h_0}^{H} y\,dy$$

$$q = \frac{ka}{2L}\left[H^2 - h_0^2\right]$$

Fully penetrating confined flow.

$$q_p = \frac{kab(H - h_0)}{L + E_A}.$$

q_p -> Dischaege of partially penetrating well.

E_A = Extra length factoe which is a function of slot penetration 'p' to the thickness of permeable strata 'b'.

Unit - II Insitu Soil treatment of cohesionless & cohesi

Methods of ground improvement.

1) Compaction / Densification
   - → Dynamic compaction
   - → Vibro compaction (or) Vibro flotation.

2) Consolidation → Preloading & Prefabricated Vertical drain.

3) Reinforcement
   - Stone columns.
   - Soil Nailing
   - Micropiles
   - Vibro Concrete Columns.

4) Grouting
   - Permeation Grouting
   - Compaction Grouting.
   - Jet Grouting.

5) Deep soil mining
   - → Wet mining
   - → Dry mining.

Densification : (Cohesionless soil. (Shallow & Deep).

Soil densification is done by applying a shock or vibration to the subsoil and thereby causing a rearrangement of the soil structure from a loose to dense state. This technique is applicable to non cohesive soils.

a) Dynamic compaction:

Dynamic compaction involves dropping a heavy weight on the surface of the ground to compact soils to a depth greater as 40ft (or) 12.5m. This method is used to reduce foundation, settlements - reduce liquifaction.

Procedure:

A heavy duty crane is used to drop the weight. The cranes should be in good condition and carefully maintained and inspected during performance of work to maintain safe working environment.

The procedure involves lifting a heavy weight using a crane and dropping it from a height of 50 to 100ft (15.4 to 30.8m).

The weight has a capacity of 10 to 30 tons (90 to 270kN) and made of steel.

The weight ~~has~~ ~~a~~ capo should be capable of withstanding dynamic impact.

The weight must be dropped in a single line to allow the weight to fall freely maximizing the energy when striking the ground.

The degree of densification depends on

Stage 1:

The equipment consists of vibrofloat hung by a crane. A tremie pipe is attached to the vibrofloat, through which concrete can be pumped through a hose. Vibrations are initiated and the vibrofloat reaches the required depth.

Stage 2:

As the vibrofloat reaches the required depth, concrete is pumped and the vibrofloat is repeatedly raised and lowered for a height of about 2ft (0.75m) to create an expanded base

Stage 3:

The concrete is pumped and the vibrofloat is raised simultaneously to the surface. At the ground surface, the vibrofloat is again raised and lowered several times to form an expanded top.

Advantages:

* A good and permanent alternative to stone column.
* Suitable for soft/weak soils
* Shorter and less concrete requirement when compared to piles.
* Minimum noise and vibration during installation.

Application :

- * Used in strengthening foundations of rail embankments, industrial and commercial structures, warehouses.
- * Can be used for very soft soils.

4) Permeation Grouting :

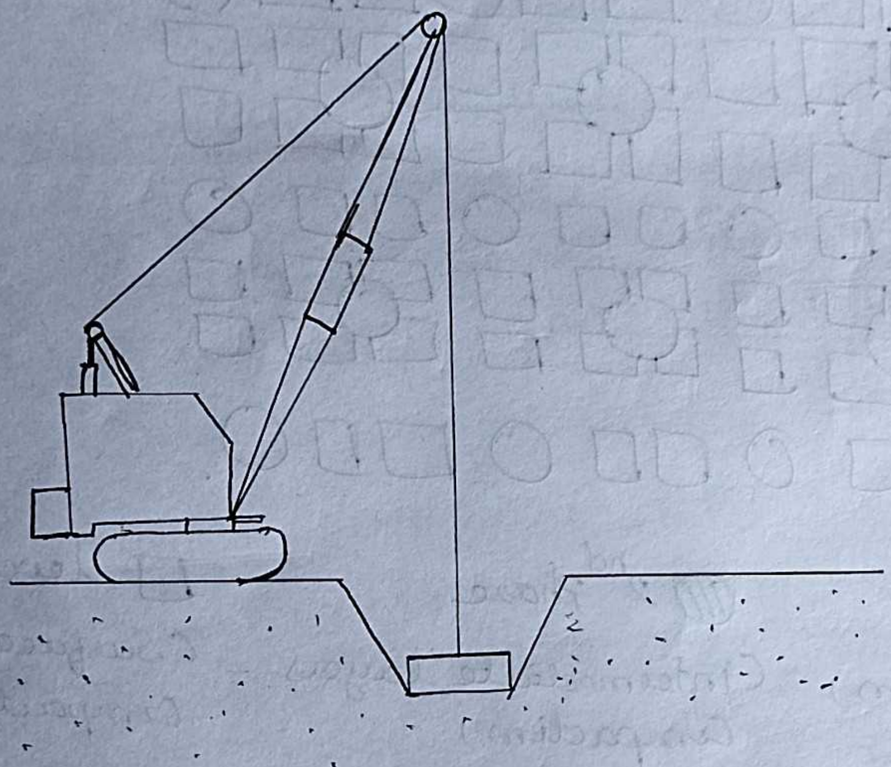
It is the injection of grout in colloidal or solution form into a highly permeable granular soil. This process creates a stabilized and compact soil mass.

The grout can be batch mixed or stream mixed. Batch mixing involves mixing a selected volume of grout materials and then injecting it before next batch is mixed. Steam mixing involves storing the grout components in a tank and then pumping then through separate hoses and combining them before the grout reaches the injection pipe.

If the geometry of grouted mass is not important, the grout can be pumped through the injection pipe inserted into the soil. Then the pipe is raised to a height of 1 to 3ft (0.3 to 0.9m) and the injection process is repeated untill the entire depth is filled with grout.

the weight & height of drop, saturation level of ground, fines content, permeability of soil.

The cavity formed due to the drops called as 'crater', should be filled with granular material after the crater depth reaches 3 to 4ft (1m).

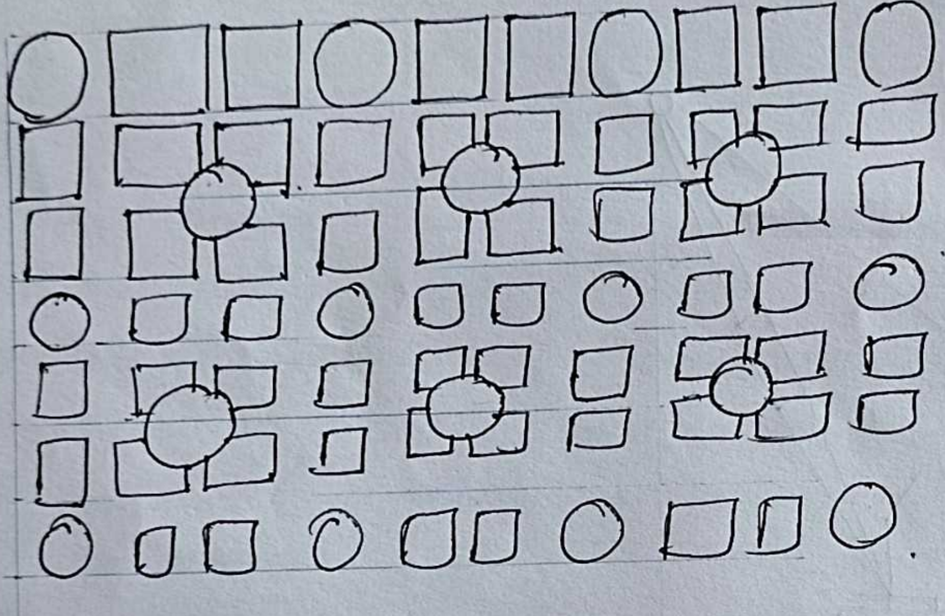


Phasing:

Dynamic compaction is performed in phases in order to achieve full densification of soil.

Appl *

The first phase consists of compacting widely spaced grids deeply. After completion of compaction at grids spaced widely, grids are established at closer spacing and such grids are compacted for an particular depth. Finally in the levelling phase the remaining grids are subjected to surface compaction.



○ 1st phase (deep compaction)

▨ 2nd Phase (intermediate layers compaction)

☐ levelling phase (Surface layer compaction).

Advantages:

- Compacts large areas of loose granular fills.
- Increases insitu density and collapses voids
- Increases bearing capacity of soil
- Reduce settlement.

Application :

* Used for improving ground of the following.

Constructions .

- * Port and Airport platforms
- * Land fill sites
- * Heavy storage tanks.
- * Industrial warehouses .

2) Vibrofloatation (or) Vibrocompaction .

This process involves compacting the soil by using vibrofloats or Vibroprobes. Vibrofloat consists of cylindrical shell with an interior electric or hydraulic motor which spins an eccentric weight .

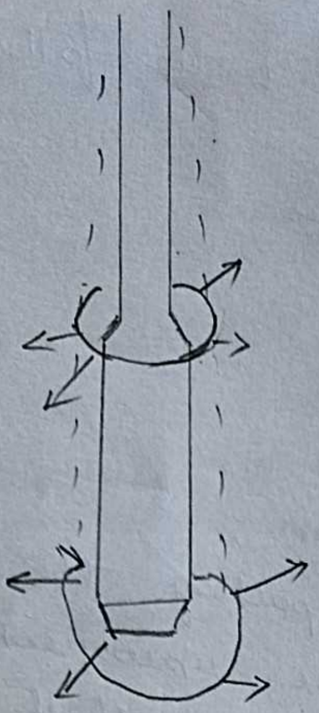
* The dimension of the vibrofloat is 10ft (3.1m) in length and 1.5 ft (0.5m) in dia.

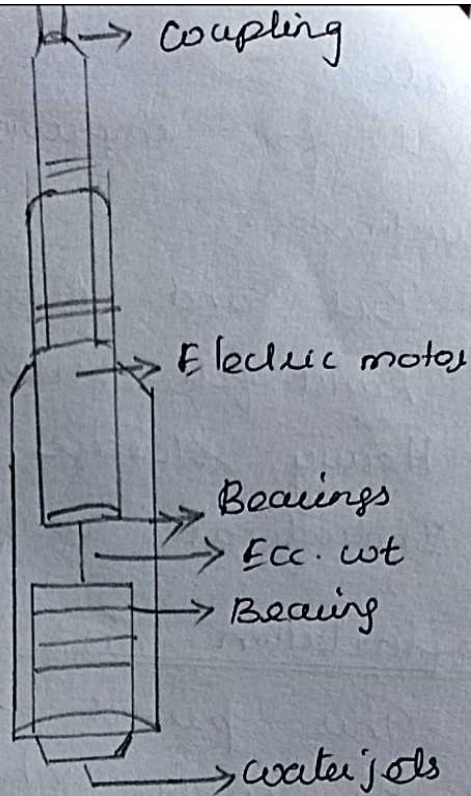
* Vibrofloats vary in power from about 300 HP .

* Typically the vibrofloat is hung from crane .

* Extension tubes are bolted at top of vibrator so that the vibrator can be lowered to necessary depth.

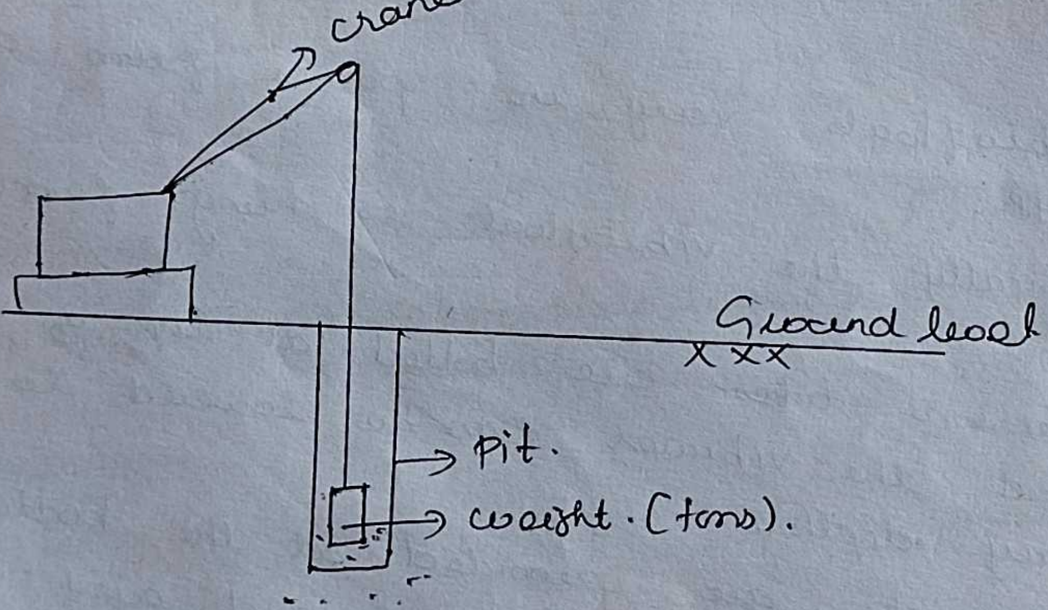
* Water jets are provided at the bottom of vibrofloat in order to aid easy movement of vibrofloat into ground .

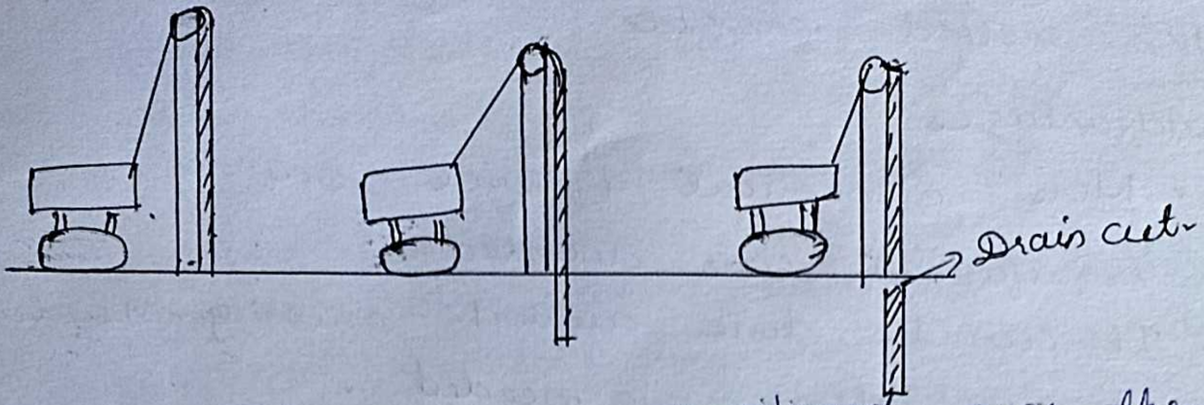




Procedure :

Following are the stages involved in the process of vibroflotation.





Stage 1: Vibrofloat is positioned over the point of compaction.

Stage 2: Water is flushed through the bottom of vibro probe and vibration is initiated. As a result of jetting water, the soil gets liquified and hence the vibrator penetrates the soil under its own weight. If penetration is difficult, pre drilling is required.
Sand is stacked at the top.

Stage 3: After vibrofloat reaches sufficient depth, flushing of water is stopped. Soil is densified by vibration induced from vibrofloat by repeatedly raising and lowering the vibrofloat sand gets filled compensating the volume reduction. The raising and lowering is repeated until the sand gets filled upto the top.

The surrounding granular soils are rearranged into a denser state achieving relative densities of 70 to 85%. Treatment can be done to a depth of 120ft (37

This method can be

Advantages:

* More economical & time saving
* Liquifaction was avoided
* It can be done around existing structures.
* No excavations are needed.

Applications:

* Improvement of hydraulic fills and dredged fills for platforms, embankment & foundation.
* Anti-liquefaction treatment of soils.

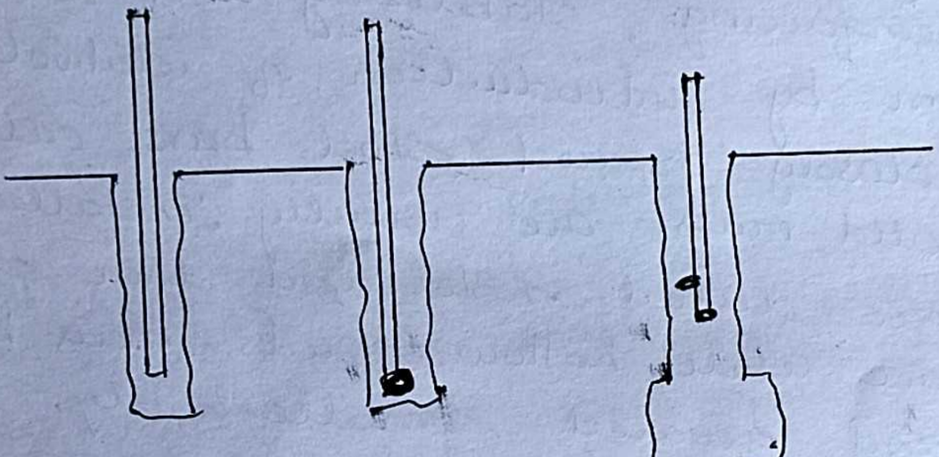
3) Preloading & Prefabricated vertical Drains/consolidation

Preloading consists of placing a temporary load (generally soil fill) to preconsolidate the soil prior to constructing the planned structure. The process improves the soil by compressing the soil, increasing stiffness and shear strength.

In partially or fully saturated soils prefabricated vertical drains are used to drain the excess water, thereby accelerating the compaction process. Prefabricated vertical drains are generally made of flat (rectangular) or cylindrical plastic are wrapped in geotechnical fabric. The PVD's are typically available

Jet grouting :-

Jet grouting is a grouting process that uses high pressure and high velocity erosive jets of water and / or grout to loosen soil and replace them with a grouted column of soil formed by mixing of soil and grout. The resulting grouted column of soil is called as soil crete.



Stage 1 : Drilling - Jet grout is a bottom up process. The drilling is done up ~~to~~ the bottom and the monitor is inserted to the battom of treatment zone.

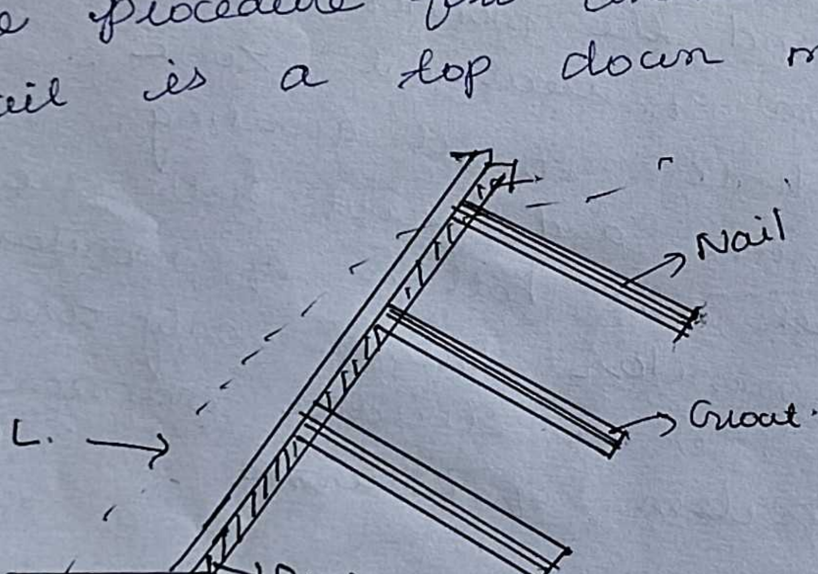
Stage 2 ÷ Initiation of jet grouting.

The erosion and grout jets are flushed through the bottom of monitor. Rotating the monitor through only the bottom potions in a circular manner creates a portion of column.

Stage 3 - Construction of soilcrete column. Rotating the monitor, mixes the soil with water and grout creating a column. As the monitor is moved up, a soilcrete column is formed.

Soil Nailing:

It is a in situ technique used for reinforcing, stabilizing and retaining excavation by introduction of relatively small, closely spaced steel bars called nails. Solid nails are usually installed into pre drilled holes and then grouted. into place while hollow nails may be drilled and grouted simultaneously. Soil nails are usually installed at an inclination of 10 to 20 degrees with horizontal the procedure for constructing a soil nail is a top down method.



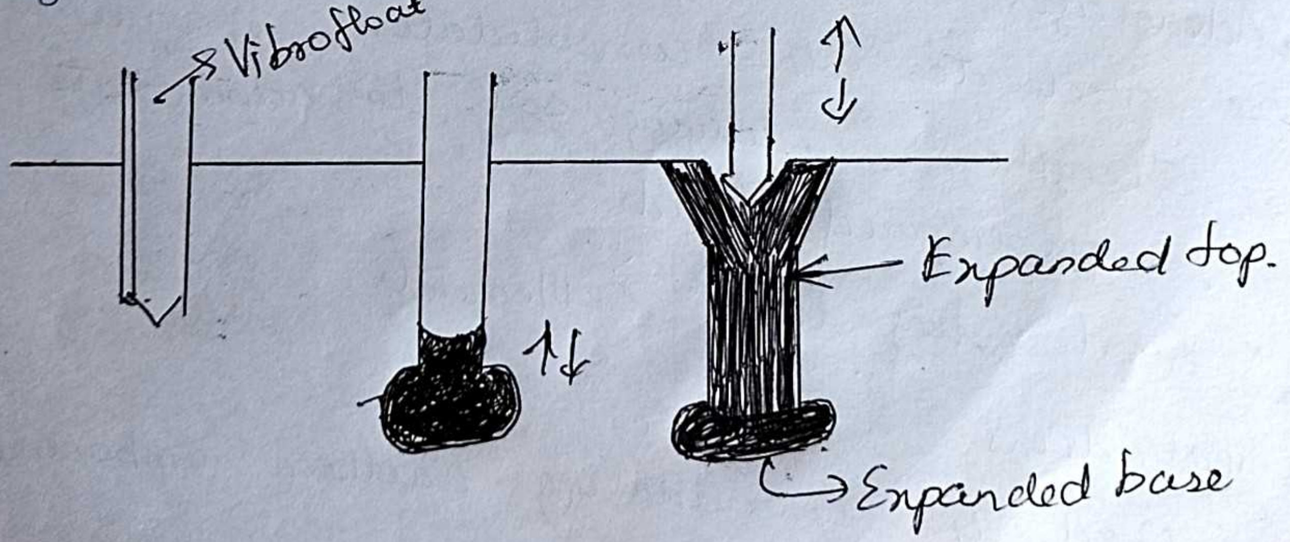
Stone Columns (or) Vibro Replacement:

Stone columns refers to compacted gravel size stone particles constructed vertically in the ground to improve the performance of loose or soft soils. Stone column is capable of transferring the load from the surface to deeper strata.

This process can be also called as vibro replacement as the sand fill is replaced with stone columns and this can be of wet feed (or) dry process

Vibro concrete columns:

Vibro concrete column involve constructing insitu concrete columns used in areas that require higher loads and are installed through very soft soils inorder to transfer the load to the load bearing strata through soft soils. These vibro concrete columns are constructed using a vibro float connected to a tremie pipe through which concrete is pumped.



in rolls of 1000 ft (308 m). The PVD's are housed inside a mandrel attached to a crane.

Stage 1 – Initially the mandrel is kept touching the ground with the help of crane. The drain kept inside the mandrel is provided with an anchor plate at bottom.

Stage 2 – The mandrel is pushed inside the ground. The anchor plate attached to the bottom of the PVD holds into the place on the soil.

Stage 3 – When the drain gets fixed to the ground through the anchor plate, the mandrel is driven out and the PVD is cut off at its top. The process is repeated to place other drains.

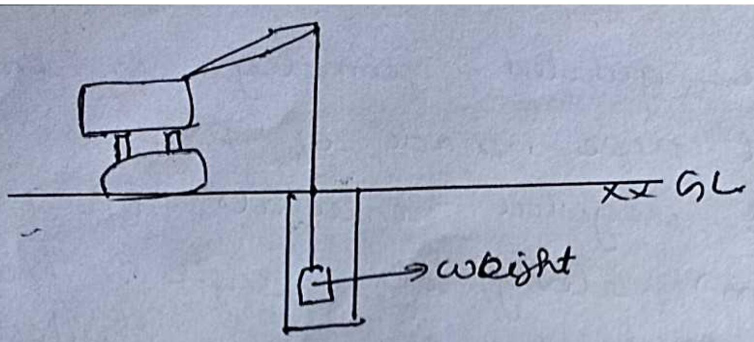
Once the drains are placed, preloading is done by placing temporary load on the surface by means of a truck or dozer.

Advantages:

- Accelerate the consolidation of ground soils.
- Strengthens underlying soil to accomodate superimposed loads.
- Limits long term settlements.

Applications:

Used in consolidating earthen embankments



Stage 1 - Installation of grout pipe - The grout pipe is installed by means of drilling or by hammer depending on the soil & treatment

Stage 2 : Initiation of grouting - The grout paste is prepared by mixing and pumped into the grout pipe. By gradually raising, and lowering the grout pipe, individual grout bulbs are formed which compacts the soil.

Stage 3 : Continuation of grouting - In order to acheive uniform compaction, the grouting process is continued till the surface

Advantages :

- * Pin point treatment
- * Speed of installation
- * Can be performed in restricted access
- * Economic + no wasteage.

If the grouted geometry is important sleeve port pipe made of PVC or steel are inserted at regular intervals of 1 to 3 ft (0.5 to 0.9m) along its length. These pipes are inserted into the PVC drilled holes.

If the grouted geometry is important, sleeve port pipes made of PVC or steel is used. A hole is drilled in soil and the sides of hole is filled with weak, brittle grout. Similarly other sleeve port pipes are inserted at regular intervals of 1 to 3ft (0.3 to 0.9 m). Once the weak grout has hardened, grout injection pipe is inserted through the sleeve port pipe and the grout is injected.

8) Compaction Grouting:

This technique densifies soil by injection of low mobility, low slump cement grout under pressure into the soil mass. The injected grout forms the shape of a bulb which on further expansion compacts the surrounding soils. Upon completion of grouting, the resulting grout column reinforces the soil mass reducing further settlement and increasing shear strength. Compaction grouting is most effective in free draining granular soils.

Stage 1

In this stage the vibrator is set up at the ground level. A stone tube is attached to the vibrator through which stone can be fed by a hopper arrangement the skip is charged with stone by the help of a truck or dozer.

Stage 2:

Vibrator penetrates the weak soils to the design depth with the help of vibrators.

Stage 3:

As the required depth is reached, the stone is released and compacted by small upward and downward movements of vibrator. By repeating this process upto ground level, stone column is formed.

Advantages:

- Increased bearing capacity
- Reduced settlements
- Reduced liquefaction.

Applications:

- For strengthening soil retaining walls.
- Road & rail embankments.

Unit - IV Earth Reinforcement

Reinforced earth consists of compacted soil mass within which reinforcing elements in the form of h2l metal strips, rods of metal, fiber/glass strips, bamboos and geosynthetics are embedded.

Principle:

When soil is loaded, shearing stresses are induced in it. When the shear stress reaches a limiting value, shear deformation takes place leading to failure of the soil.

Shear stress.

$$\tau = \frac{\sigma_1 - \sigma_3}{2} \sin 2\theta .$$

σ_1 → Major principal stress

σ_2 → Minor principal stress.

Concept of reinforcement & its types.

Enhancing the shear strength by reinforcement.

Relative sliding occurs b/w the particles when subjected to shear stress. As a result of these sliding, more number of contact points is developed.

At these points of contact friction exists and the particles tends to come towards each other causing the shear resistance to increase.

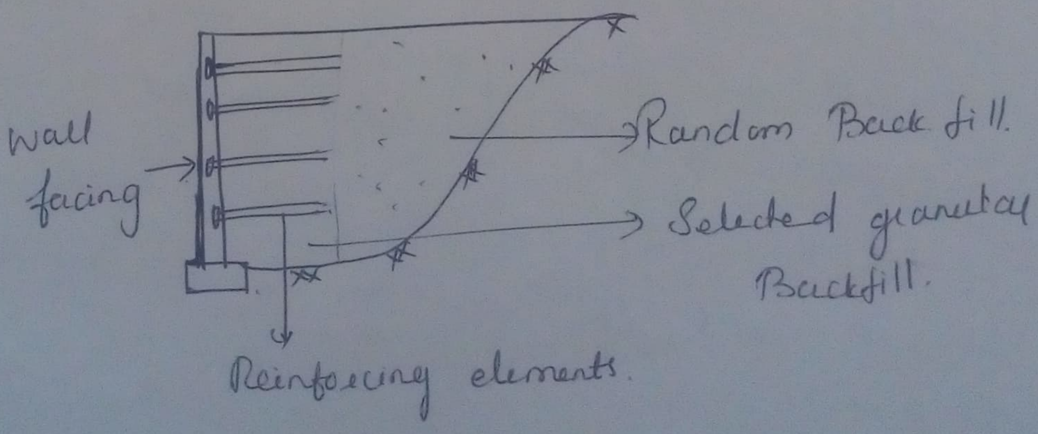
- Provides enough axial stiffness against the shear force.
- Large number of contact point is developed at the steel reinforcement providing more frictional resistance against the applied shear force.
- Movement of soil, relative to reinforcement will generate shear stress at soil/reinforcement interface which gets redistributed into the soil in the form of internal confining stress.

Reinforced earth wall:

Components & mechanism

Reinforced earth structure consists of

- Wall facing elements
- Reinforcing elements
- Compacted back fill.



1) Wall facing elements are provided at free boundary of the reinforced earth wall. These elements are known as skin & can be either flexible or stiff. These elements should be strong enough to hold the backfill. and should allow fastening of reinforcing elements.

Wall facing elements are generally made of steel, plastic, fibre, glass (or) reinforced concrete.

Generally the facing units are prefabricated to provide units small, light & easier for transportation. Facings can be of hard or soft nature.

2) Reinforcing elements:

H21 metal strips:

They are metal like galvanized steel, stainless steel, aluminium. They are 50 to 100mm wide & upto 9mm thick, several metres in length.

Rods of metal.

They are made of galvanized steel.

Fibre/Glass strips:

Used in combination called glass-fibre reinforced plastic (GRP)

Bamboos: A natural reinforcing elements.

Geosynthetics: like geotextiles, geomembranes, geogrids, geocomposites.

3) Compacted back fill:

* The soil used for the backfill should be predominately coarse grained not more than 10% of the particles should pass 63μ sieve.

x Cohesionless soil.

x Angle of internal friction not be less than 30°.

* First layer - Reinforcement

* Back filling - granular soil.

Construction steps:

* Laying of geotextile sheet.
* Back filling over this sheet with soil.
* Granular soil → 30% silt
  5% clay.
* When the first layer is folded, the process is repeated by placing

by placing the second layer of geotextile with temporary wooden facing extended. The back filling is made.

- This process is repeated till then wall reaches intended height. Finally the facing may or maynot be removed.

Requirements :

- High strength & stability & low creep
- Ease of handling & durability.
- High coeff of friction & adherence with soil.
- Ready availability.

Advantages of reinforced earth structures.

- It is flexible & can withstand foundation settlements.
- It can withstand earthquake force.
- It is more economical.
- It is easily available, transported, stored and handled.

Advantages of reinforcing the soil.

- Increase in tensile strength
- Increase in shear resistance at the soil-reinforcement interface.
- Reinforced soil can be used as a replacement for conventional concrete structures

Geotextile :

Geosynthetics :

It is the fabric manufactured from synthetic materials like polypropylene.

Materials :

- Polypropylene
- Polyester
- Polyamide
- Polyvinyl Chloride.

Basic types :

- Woven type
- Non oven type
- Knitted
- Natural fibres.
- Geosynthetic nets and grids.
- Geomembrane.

Commercial types

- Geotextiles
- Geogrids.
- Geonets
- Geomembranes.
- Geo composites.

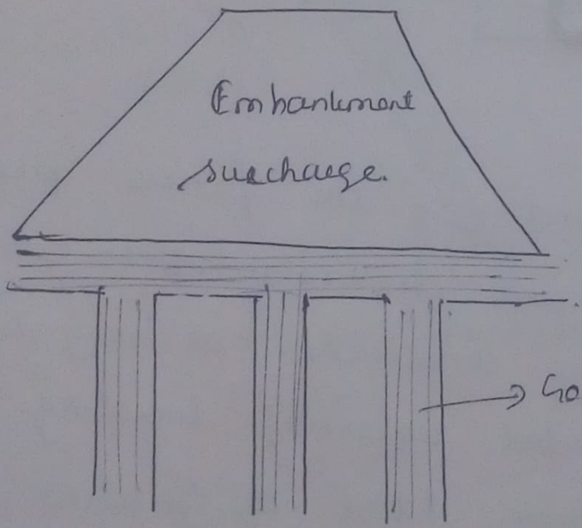
- Geosynthetic clay liners
- Geofoam.

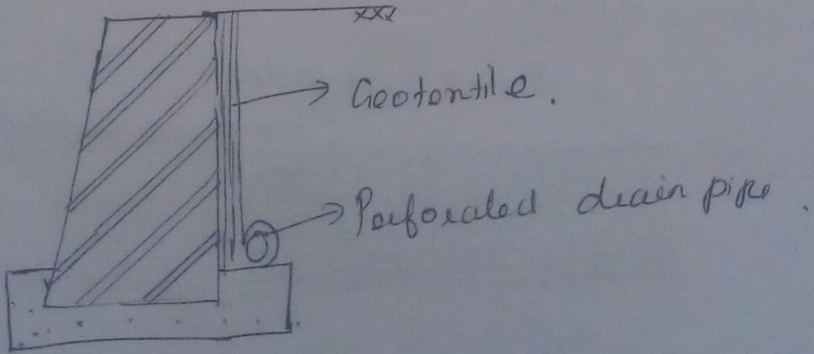
Functions of Geosynthetics :

Drainage :

Collecting & redirecting seepage water within a soil mass (or adjacent to retaining walls culverts & tunnel linings.

Vertical & Hzl drainage.



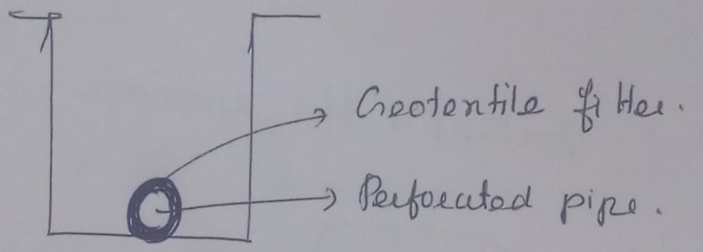


Drainage behind wall.

Filtration.

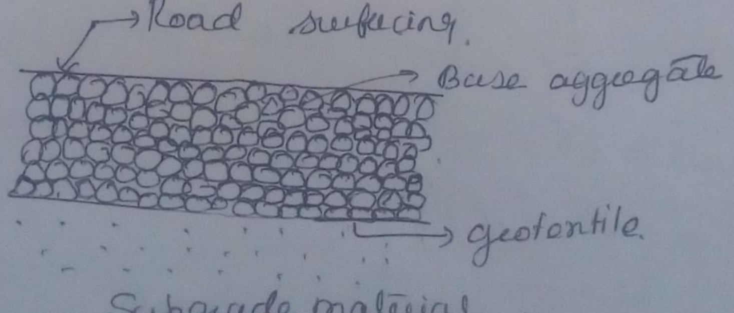
Geotextiles acts as a filter if it allows seepage from a water bearing layer while preventing most soil particles from being carried away by the water flow.

Filter around perforated pipe.



Seperation :

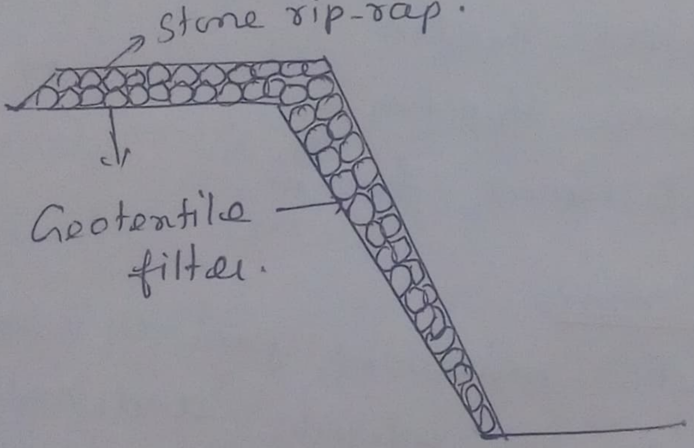
It is achieved if the fabric prevents mixing of adjacent dissimilar soils which may occur during construction or may be caused by repeated external loading of a soil layer system. Most of fabrics can act as seperators provided they have adequate strength.



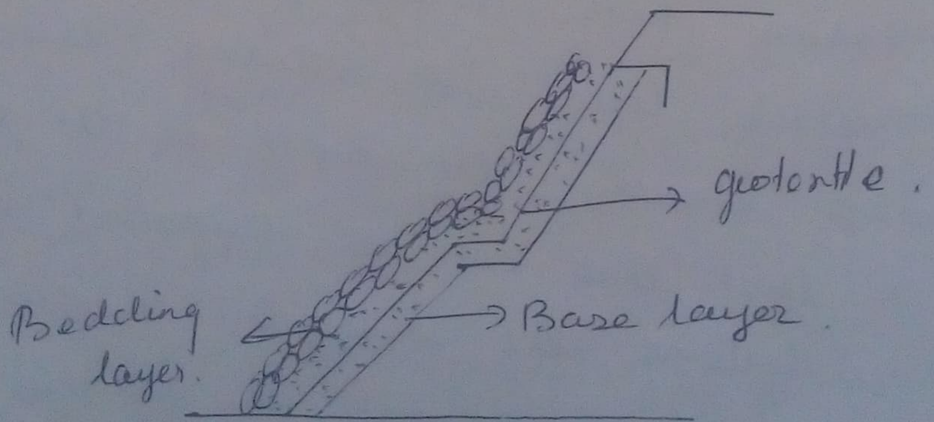
Seperation of materials.

Reinforcement:

It means the inclusion of the fabric to provide tensile strength, redistribution of stresses and/or confinement, thereby increasing the stability of a soil mass, reducing earth pressures or decreasing deformation or susceptibility to cracking.



Erosion control.



Slope protection.

Use of Geosythetics in Road works :

- Time saving - no prior stripping of natural soil
- Economy of aggregate
- Reduction of differential settings.
- Speed consolidation of fills.

Functions.

1) Seperator Function
2) Drainage Function.
3) Reinforcement Function.

1) Seperator function.

Geosynthetic materials provide seperation, which preserves the integrity and extends the life of the road surface layer. Roadway pavements are basically structures for taking high contact pressures from the vehicle tires and reducing this pressure through the depth of the pavement to a level that can be supported by the underlying soil subgrade. Pressure is dissipated down through the various layers of materials within the pavement.

If geosynthetic is not provided at the interface b/w subgrade & the aggregate base, the vehicle pressure, over-time, cause subgrade soils to migrate into the aggregate base of the pavement section.

Contamination of the agg. base by the subgrade results in reduction of the effective base thickness by which there is a decrease in the load carrying capacity of the aggregate base & consequent reduction in pavement life.

Geo sythetics as a seperator which,

* Prevents the inter penetration of the natural soil & aggreages.

* Fully preserves the properties of road making materials.

* Allows vehicles to circulate on foundation course while work is in progress & protects the foundation course from contamination.

Drainage function :

Also using it to its drainage function, geosynthetic road edge drains can be laid to provide drainage of roads & hence improving them.

When a road embankment is to be constructed on compressible soil, the consolidation of the subgrade soil, over a period of time will cause cracks and pot holes in the road surface.

In order to avoid this, usual procedure is to provide sand drains which accelerates the consolidation process.

Reinforcement function :

In a road embankment, geosynthetic is placed in layers across the potential rotational failure plane to carry the tensile forces that cannot be carried by an unreinforced soil mass of embankment.

Use of geo synthetics in Railways:

- Seperator function
- Drainage "
- Reinforcement "

Seperator function:

In track foundation, geosynthetics seperate ballast & subgrade at interface and prevents intermixing of the two materials under dynamic loads.

It also checks mud pumping & prevents ballast fouling and thus extends deep screening by several years.

Drainage function:

Geosynthetics provides surface & subsurface drainage by wicking action under train loads, where by water is squeezed and conveyed laterally out of track foundation.

This action dries the subgrade, which in turn improve the shear parameters, thus enhancing the soil supporting strength.

Reinforcement function :

Geo synthetic provides reinforcement through both tensioned membrane & tensile member function.

It acts as reinforcement ensures load distribution especially for heavy weight and high modulus fabrics.

In addition, it provides lateral restraint allowing the ballast to act as an elastic beam.

The deformation under dynamic loads induces tension in the fabric and due to the membrane action acts as a reinforcement.

It keeps the stress level low on subgrade due to h2l shear stresses mobilized by vertical loads.

Fabrics is placed under tension & it spreads the load in wider area & there-by decreases its intensity

Unit - V Grout Techniques:

Grouting:

It is the process of improving ground by injecting fluidized materials into the voids or cavities in soil (or) rock.

Groutability:

It is the satisfactory performance of a grout in decreasing the permeability of soil and improvement in its shear strength upon its addition. The groutability of soil with particular grouting is evaluated based on groutability radio (GR).

$$GR = \frac{D_{15}\ (\text{Formation (or) soil})}{D_{85}\ (\text{grout})} > 20$$

If GR > 20, grouting is possible

where D_{15} – particle size at which 15% of is finer

D_{85} → particle size at which 85% of grout is finer.

Types of grouts :

1) Suspension grouts

2) Solution grouts.

1) **Suspension grouts** : (particulate grouts)

It is a multi phase system (ie) small particles of solids distributed in liquid medium.

(eg) Cement, lime in water.

1) **Grouting with soil** :

- Soel is used to fill up the voids of coarse grained soils.
- Soil should be very fine grained (eg) fine sand.
- Clay with particles less than 0.002mm is suitable for injection into medium coarse sands with permeability of order 0.1 to 1mm/s. It behaves as a Bingham fluid.
- Kaolinite or illinite based clays have low visuasities and hence used as filler grouts.

Grouting with cement mixes:

- It depends on water cement ratio, rate of bleeding & ultimate strength of grout.
- Water provides enough mobility to grout, if in excess causes separation of the individual ingredients of grout.
- Lower w/c ratio should be maintained.
- In order to enchance the mobility of grout, proper admixtures should be added.
- Hence a grout with lower w/c ratio with admixtures results in good ultimate strength.

a) Cement used:

- Cement grouts are formed from OPC & water.
- W/C ration varies from 0.5:1 to 5:1 depending upon the ground conditions and required strength.
- It is suitable only in rocks, gravels & coarse sands.

* In grounds with high water flow, rapid hardening cement which has quick setting time & early strength is preferred
* High alumina cement has rapid strength gain resists sulphate and acid attack.
* In case of very fine fractured rocks, super sulphated cement is used, as it is very finer and capable of penetrating fine fractures in rocks.
* When selecting the particular type of cement it is important to know its final strength flow rate, setting time, shrinkage, permeability & durability.

b) **Admixtures:**

* It is used to impart particulate features to the grout.
* It is used in cement mixes are clay, fine sand, fly ash, retarders or expansion additives.

3. **Grouting with asphalt emulsions.**

* Besides of oil refining industry is emulsified to produce nearly circular droplets of asphalts which is later

suspended in water.

- By choosing proper emulsifying agent we can obtain -vely charged anoinic asphalt globales for maximum flow & penetration & +ve ly charged catinic asphalt globales to get attached to -vely charged clay particles in case of clay soils.

- Rock factures spheres are 1 to 2 μm dia, along with water can be used as a grout to fill voids in sand or fractures in rock.

Solution grouts / Injection method.

- It is a single phase system usually in liquid state. It is composed of chemicals and hence can also be called as chemical grouts.

- Chemical grouts
  - One shot system
  - Two shot system.

1) Aqueous solution :

a) Silicate derivates :

Sodium silicate, also called as water glass, is a commonly available and relatively inexpensive aqueous solution.

Sodium silicate is allowed to react with carbonic acid. by the two shot system, to form salt, sodium carbonate a solid compound & acid, silicic acid a liquid compound which further breaks down to water and silicon dioxide.

b) Lignosulphite derivates :

It is made from lignin, a residual product from wood industry. The raw lignin can be used directly, or as dried, catalyst mixed powder to which other additives are added before injection.

These additives are added for control of gel time & uniformity.

* The grouts are made from lingnosulphates and a hexa chromium compound.

c) Acrylamides:

× The acrylamide grouts are characterised by constant viscosity, good penetrability, effective control of gel time and adequate strength.

× Acrylamide and the cross linking agent methylene - bisacrylamide can be mixed & easily dissolved in cold water up to concentration the reactions.

d) Phenoplast resins:

The resorcinol - formaldehyde combination is a resin results from the polymerisation of resorcinol with formaldehyde in aqueous solution when the pH is changed.

2) Colloidal solution:

It comprises a mixture of sodium silicate & reagent solns which changes its viscosity thereby producing a gel.

* Sodium silicate is alkaline colloidal solution characterised by its molecular ratio (3 to 4). & specific density varies from 32° to 42°.
* Reagents may be organic (or) inorganic
* It determines setting time, viscosity strength & durability.

3) Non aqueous solutions.

Synthetic resins

Vulcanizable oils.

4) Combined systems:

Emulsions

It is a two phase system containing minute droplets of bitumen or asphalt suspended in water.

Grouting procedure:

Depending upon the material to be grouted and the purpose of grouting, a well planned procedure has to be adopted to attain the desired result.

1) Pre grouting site investigation
2) Grout holes pattern
3) Grout characteristics
4) Grout plant & equipment

Injection methods:

a) Grouting from the bottom
b) Grouting from the top
c) Circuit grouting
d) Tube - a - Manchette Grouting
e) Point grouting.
f) Pressure Injected lime

a) Grouting from the bottom.

A grout hole of 50 to 75mm dia is drilled to full planned depth.

In rigid soils or in rock expanding packer is placed directly above the lower line and grout is pumped. The casing is raised with packers.

2) Grouting from the top:

In this method, holes are drilled down to the layer closest to the surface & grouting is carried out. Holes are then cleaned by washing and drilling continued to next layer. It gives low output.

3) Circuit grouting:

- Grouting from top to bottom.
- Clogging is eliminated.

4) Tube-a-Manchette Grouting:

- In this method, a 12.5 to 15 cm dia hole is drilled in stratum and a 6 cm dia pipe called a tube-a-manchette, with a circumference row of holes, is lowered inside the drilled hole.
- The hole is covered with wide rigid tightly fitting rubber sleeves.
- Then the grout is pumped in through the inner pipe, due to the high pressure the dry cement grout fills the voids in soil.

Point grouting :

In shallow work of 10 to 12m deep the grout is injected from the points of a driven or jetted cut.

b) Pressure Injected lime :

* 0.3 to 0.4 kg lime / litre of water + a surfactant is injected under high pressure.

* Injections, spaced at 1 to 2m are made at vertical intervals of 0.3 to 0.5 to maximum depth of about 3m.

Grout plant & equipment :

It consists of a mixer, an agitator, a pump and piping connected to the grout holes. For solution grouts, separate ingredients are stored in stationary tanks or tank trucks and metered out, mixed at junction points and brought to the intended grout pipe.

Grout monitoring:

During the grouting process the basic information to be obtained is the weight for suspension grouts & volume for solution grouts and grout flow rate along with pressure for both. The measurement of weight or volume should be made accurately so as to confirm mix proportion.

The flow rate of grout injection should be continously monitored & plotted against the grout pressure to ascertain the condition below the ground.

Pressure should be monitored at the grout stations. Bourden tube type gauges are also used to measure pressure periodically.

Grout monitoring involves making a positive assessment of results of injected grout.

This can be accomplished by obtaining undisturbed soil & rock samples of the grouted material & then testing them for strength, permeability by adopting std lab methods.

Stabilisation.

Soil stabilization refers to the procedure employed for modifying the properties of soil by proportioning / addition or removal of cementing material or other chemicals :

Cement stabilisation :

* The soil stabilized with cement is known as soil cement.

* The cementing action is believed to be the results of chemical reaction of cement with the silicious soil during hydration.

* The binding action of individual particles through cement may be possible only in coarse grained soils.

* The following factors affecting soil cement are nature of soil,

Cement
Condition of mixing
Compaction
Curing
Admixtures.

1) Nature of soil :

Almost every inorganic soil capable of pulverization can be stablised with cement

the cement requirement will increase wit
increase in the specific surface of soil

2) Cement content :

The strength of soil cement increases an increase in the amount of cement ad to a soil.

Cement = 5 to 15% by wt of soil.

Comp. Strength = 25 to 30 kg/cm^2.

3) Mixing, compaction & curing :

Soil-cement is ~~more~~ stronger with soil com water is more mixed.

The amount of water depends on the compaction & cement hydration.

Curing is done at least 7 day.

Curing is rapid at higher temperature.

4) Admixtures :

- Lime
- Sodium carbonate
- Sodium sulphate
- Fly ash.

⑤

Lime stabilization:

Lime is produced from natural limestone.

- Lime + fly ash
- Lime + Portland cement
- Lime + Bitumen.

Principle:

Chemical reaction

↓ ion exchange of calcium

↓ pozzolanic action.

Effect:

when the lime is added, plasticity, density and strength of soil are changed.

* The optimum water content increased and a decrease in maximum compacted density, but the strength & durability increases

Proportions:

Coarse grained soil = 2 to 8% of lime.

Cohesive soil = 5 to 10% of lime

fly ash = 8 to 20% by weight.

Chemical Stabilization :

$CaCl_2$.

When $CaCl_2$ added to soil it causes collidal reactions and alters the characteristics of soil water. As $CaCl_2$ is deliquescend and hygroscopic it reduces the loss of moisture from the soil. It also reduces of frost heave as the freezing point of water is lowered. $CaCl_2$ is very effective as dust palliative. $CaCl_2$ causes increase in the maximum dry density.

$NaCl$

The action of $NaCl_2$ is similar to that of $CaCl_2$ in many aspects.

When $NaCl_2$ added to the soil crystallization occurs in the pores of the soil & it forms a dense hard mal with the stabilized surface. The pores in the soil gets filled up & altered further evaporation of water sodium chloride also checked.

Lignin :

It is available both in the powder form & in the form of sulphite liquid. It is water soluble: Its stabilizing effects are not permanent.

In an attempt to improve the action of lignin, the chrome lignin process was developed and studied by smith.

An in soluble gel is formed, when sodium bichromate (or) potassium bichromate is added to the type of soil treated. It acts as acid if not neutralized.

Stablization of expansive soils :

It is characterised by their ability to expand or shrink. when these soils are partially saturated, they increase in volume with addition of water they shrink greatly on drying.

This alternate expansion and shrinkage leads to failure.

This ability of expansive soil to expand and shrink is due to the presence of mineral called montmorillonite which possess high degree of plasticity.

Properties of expansive soils:

- * It is a residue formed from the parent rocks which include basalt, gneiss, calcareous shale.
- * It has high amt of silica sesquioxide ratio & also high amt of Fe, Ca & Mg
- * Clay size fraction - 40-70%.

  Sand - 15 to 30%.

  gravel - less than 5%.
- * Liquid limit = 50 to 110%.

  Shrinkage limit = 8 to 16%.