KARPAGAM ACADEMY OF HIGHER EDUCATION
(Deemed to be University Under section 3 of UGC act 1956)
COIMBATORE-641021

FACULTY OF ENGINEERING
DEPARMENT OF CIVIL ENGINEERING

B.E Civil Engineering **2018-2019**

Semester-VI

16BECE6E02 **Ground Improvement Techniques** **2H-2C**

Instruction Hours/week: L: 2 T: 0 P: 0 **Marks:** Internal**:40** External**: 60** Total**:100**

End Semester Exam: 3 Hours

Course Objective

- Analyze the expansive soil properties and apply the same for the design of structures on expansive soils.
- Apply mechanical modification, using deep compaction Techniques, Blasting, Vibro compaction, Dynamic and Compaction Piles.
- Design dewatering system, and using dewatering methods for ground improvement
- Adapt physical and chemical ground improvement techniques using thermal modification, like grouting, shotcreting and guniting technology.
- Analyze the Stability analysis and Design of Reinforced earth retaining wall.

Course Outcome

CO1: Analyze the field problems related to problematic soils and solve the problems using the ground Improvement techniques.
CO2: Summarize and practice ground improvement using Mechanical modification techniques.
CO3: Design drainage for seepage control, Assess dewatering field problems.
CO4:.Application of physical and chemical ground improvement techniques using thermal modification, like grouting, shotcreting and guniting technology.
CO5: Demonstrate the ground improvement techniques such as ground anchors, rock bolting and soil nailing, Design of reinforced earth retaining structures.

UNIT-I: Introduction on ground improvementtechniques–Basic soil properties and phase systems-Role of ground improvement in foundation engineering-Methods of ground improvement-Geotechnical problems in alluvial soil-Geotechnical problems in laterite soil-Geotechnical problems in black cotton soil-Ground improvement techniques – its application and effects-Selection of suitable ground improvement techniques on soil condition.

UNIT-II: Introduction to drainage and dewatering System-Drainage techniques-Vacuum method-Electro osmotic method-Introduction to seepage-Seepage analysis – principles-Seepage analysis for two-dimensional Flow-Fully penetrating slots in homogenous Deposits-Partially penetrating slots in homogenous deposits.

UNIT-III: In-situ densification of cohesion less and cohesive soil -Consolidation of cohesive soil-Dynamic compaction-Consolidation – Principles and basic Concepts-Vibroflotation-Sand pile compaction and stone columns-Preloading with sand and fabric drains-Lime piles – Installation techniques-Relative merits of various methods and their limitations.

UNIT-IV: Concept of reinforcement-Types of reinforcement materials-Properties of reinforcement material-Application of reinforced earth-Introduction to geotextiles-Uses of geotextiles as earth Reinforcement-Geotextiles for filtration and drainage Works-Geotextiles for separation in road works and other works-Design concept of geotextile.

UNIT-V: Introduction to grouting system -Types of grouts-Grouting equipment and machineries-Injection method-Grout monitoring-Stabilization techniques – concepts-Stabilization with cement and limeStabilization with chemicals-Stabilization of expansive soils.

SUPPORTING MATERIALS

TEXT BOOKS:

Sl.No	Title of Book	Author of Book	Publisher	Year of Publishing
1	Ground Improvement Techniques (T1)	Purushothama Raj, P	Tata Mc-Graw-Hill Publishing company, New Delhi	2012
2	Ground Improvement (T2)	Moseley, M.P	USA and Canada – CRC Press Inc. Florida	2004

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1	Design with Geosynthetics (R1)	Koemer, R.M	Prentice Hall, New Jersey	2002
2	Soil Reinforcement with Geotextiles (R2)	Khedkar, M.S and Mandal, J	CIRIA- Special Publication, London	2009

STAFF INCHARGE

(**Dr.C.Rajkumar**)

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16BECE6E02/ GROUND IMPROVEMENT TECHNIQUES
LECTURE PLAN

Number of credits : 3
Contact hours : 3 hours per week
Lecturer : Dr.C.Rajkumar
Semester : VI– (2018-2019)
Course Type : Core/ Elective

Lecture	Hours	Topics to be Covered	Text / Reference	Page No
1	1	Introduction on ground improvement techniques	**T1,T2,R1**	**24, 98, 195**
2	1	Basic soil properties and phase systems	**T1,R1**	**30, 189**
3	1	Role of ground improvement in foundation engineering	**T1,R1**	**35, 191**
4	1	Methods of ground improvement	**T1,T2,R1**	**37, 112, 202**
5	1	Geotechnical problems in alluvial soil	**T1, R1**	**45, 210**
6	1	Geotechnical problems in laterite soil	**T1,R1**	**47, 212**
7	1	Geotechnical problems in black cotton soil	**T1,R1**	**51, 230**
8	1	Ground improvement techniques – its application and effects	**T2,R1**	**124, 238**
9	1	Selection of suitable ground improvement techniques on soil condition	**T1,R1**	**61, 245**
Total	**9 Hrs**			
10	1	Introduction to drainage and dewatering system	**T1,R2**	**48, 196**
11	1	Drainage techniques	**T1,R1**	**49, 198**
12	1	Vacuum method	**T1,R1**	**51, 201**
13	1	Electro osmotic method	**T1,R1**	**64, 212**
14	1	Introduction to seepage	**T2,R2**	**135, 198**
15	1	Seepage analysis – principles	**T1,R2**	**79, 215**
16	1	Seepage analysis for two-dimensional flow	**T1,R1**	**83, 219**
17	1	Fully penetrating slots in homogenous deposits	**T1,T2,R1**	**85, 140, 222**
18	1	Partially penetrating slots in homogenous deposits	**T1.R1**	**103, 231**
Total	**9 Hrs**			
19	1	In-situ densification of cohesion less and	**T1,R1**	**88, 235**

		cohesive soil		
20	1	Consolidation of cohesive soil	**T1,R1**	**91, 240**
21	1	Dynamic compaction	**T1,R2**	**118, 218**
22	1	Consolidation – Principles and basic concepts	**T1,R1**	**113, 242**
23	1	Vibroflotation	**T1,R1**	**130, 245**
24	1	Sand pile compaction and stone columns	**T1,R2**	**138, 249**
25	1	Preloading with sand and fabric drains	**T1,T2, R1**	**145, 154, 249**
26	1	Lime piles – Installation techniques	**T1,R1**	**149, 251**
27	1	Relative merits of various methods and their limitations	**T1,R1**	**1150, 257**
Total	**9 Hrs**			
28	1	Concept of reinforcement	**T1,R1**	**198, 271**
29	1	Types of reinforcement materials	**T1,R1**	**199, 273**
30	1	Properties of reinforcement material	**T1,R1**	**201, 280**
31	1	Application of reinforced earth	**T1,R2**	**204, 287**
32	1	Introduction to geotextiles	**T1,R1**	**207, 283**
33	1	Uses of geotextiles as earth reinforcement	**T1,R1**	**212, 290**
34	1	Geotextiles for filtration and drainage works	**T2,R2**	**217, 289**
35	1	Geotextiles for separation in road works and other works	**T1,R1**	**219, 294**
36	1	Design concept of geotextile	**T1,T2,R1**	**224, 167, 298**
Total	**9 Hrs**			
37	1	Introduction to grouting system	**T1,R1**	**146, 270**
38	1	Types of grouts	**T1,R1**	**149, 271**
39	1	Grouting equipment and machineries	**T1,R1**	**152, 273**
40	1	Injection method	**T1,R1**	**165, 281**
41	1	Grout monitoring	**T1,R1**	**174, 283**
42	1	Stabilization techniques – concepts	**T1,R2**	**177, 270**
43	1	Stabilization with cement and lime	**T1,R1**	**189, 289**
44	1	Stabilization with chemicals	**T1,R2**	**191, 291**
45	1	Stabilization of expansive soils	**T1,R1**	**195, 294**
Total	**9 Hrs**			

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Unit - I

Introduction

14.b) (i) **Role of ground improvement in foundation Engineering**

* Improve bearing capacity
* Reduce foundation settlement
* Enable construction on granular soil fill
* provide temporary underpinning
* provide excavation support
* Reduction of foundation dimension
* Construction of shallow foundation
* Enable dry working condition for foundation excavation

Need for ground improvement Techniques

As more engineering structure are built it became increasingly difficult to find a site with suitable soil properties, the properties at many site must be improved by some form of soil improvement method, such as static & dynamic r/f, drainage or by the use of admixture

Thus it is important for the soil Engineering to know the diffent soil improvement method, the degree to which soil properties may be improved can give knowledge in order to design ground improvement project as well as to advise client regarding value engineering to save cost & obtain maximum benefits for specific project

eg: This is a classical example of leaning tower of pisa, we know that type of soil that exist here is a soft soil, this is so which means that, this is a classical case of bearing capacity problem in which the differential settlement has exceeded the permissible limits.

The following are some of method used as ground improvement techniques

Surface Compaction
Deep Compaction
Vertical drain
Mechanically stabilized earth
Cement stabilization
Lime stabilization
Micropile
Granular pipe
Light weight embankment material

Methods of ground improvement

* Ground reinforcement
* Ground improvement
* Ground Treatment

Ground Reinforcement method

- Soil nails
- ✓ Stone column
- Micro piles
- Jet grouting
- Ground anchor
- ✓ Geosynthetic
- Fiber
- Vibro - concrete column
- Mechanically stabilized earth
- Biotechnical
- ✓ Lime column

Ground improvement

- ✓ Surface compaction
- Drinage surcharge
- Electro osmosis
- Compaction grouting
- ✓ Blasting
- Dynamic compaction

Ground treatment

- ✓ Soil - cement
- ✓ Lime admixture
- Flyash
- Dewatering
- ✓ Heating / Freezing
- vitrification

Factors affecting the Selection of ground Improvement Techniques

* Type and degree of improvement required
  - Bearing capacity improvement
  - settlement reduction
  - permeability enhancement / decrease
  - Long term; short term
  - liquefaction resistance

* Type of soil, geological structure, seepage condition
  - Type of clay / sand
  - Type of foundation
  - Role of pore pressure & seepage
  - Difficulties in geological condition

* Cost, equipment, specification
  - Size of project
  - availability of equipment
  - Transportation cost
  - Experienced contractor
  - specification of work

* Possible damage to adjacent structure (or) pollution to ground water
  - Tolerable level of loading & deformation
  - Pore water contamination

* Durability of material involved
  - Corrosion
  - aggressive soil condition

* Toxity & corrosivity of any chemicals
  - Using vitrification of soil to limit radio active or hazerdous wastes
  - Remediation of chromium - contaminate soil through ex-situ Vitrification

* Feasibility of construction control & performance measures

  - Documents of quality control
  - Performance required in major ground improvement project.

14 b) ii) <u>Objectives of ground improvement techniques</u>

* Increase strength
* Reduce distortion under stress
* Reduce compressibility - Volume decreases due to a reduction in air voids or water content under loads

Ex additives, fibres, reinforcement

* Prevent determinal physical or chemical changes due to environmental condition such as freezing, thawing, wetting & drying
* Reduce susceptibility to liquefaction
* Reduce natural variability of borrow material & foundation soil

21. b) **Geotechnical problem in alluvial soil, laterite & black cotton soil**

* Soil is a material which exhibit a very wide range of characteristic that, it led a whole branch of study to better understand
* Not all soil are problematic from engineering point of view
* Diffrent soils exhibit diffrent level in their handling

Black cotton soil

* This is well known group of soil characterized by dark grey to black colour with high clay content
* They are naturally neutral to slightly alkaline in reaction
* Major black soil are foundation in maharastra, Madhya pradesh, Gujarat & TN

Problems with black soil

* The major problem with black cotton soil is its expansive nature due to presence or montmoronite clay material.
* Its Surface is hard in summer & slushy in rain & loses it strength
* This swell & shrink nature results in movement leading to heaving of lightly loaded structure & road pavement

Laterite soil

* The upper horizons of lateral Soils are rich in oxides of iron & alluminium
* Texture is light with free drainage structure
* clay is predominant and lime in deficient & contain more humus & well drained
* They are distributed in summit

Problems with Laterite soil

* Porous in nature
* Medium to high permeability
* stability problem
* Difficulty in assesment of lateral Stress
* Wide ranging characteristics

Alluvial deposits - Formed by accumulation of sediments transfered by river, it is most fertile soil

* The soil is sandy loam to clay loam with light grey colour to dark
* There soil are distributed in Indo-gangetic plains, Bh Brahmaputra valley & to punjab
* These are sediment upto 100 m in plains which is fertile in nature

Types of soil → Bhangar → old formed alluvial dark & clay mixed colour & Very course
→ Khadar
↓
Newly formed sandy pale brown composition found in lower area

The area of bangar basis is another impartant deposite formed in 5 million year before. It consist of boulder, pepples, gravels, sand silt.

It is found in punjab, hariyana, Andra pradesh, west bengal, orissa, assam & some parts of deltanic region in south India

problems with aluvial soil

* Low strength
* Low bearing capacity
* Liquitiable

21. a)

Methods of ground improvement - Explain

Ground reinforcement method

Stone column

This method provide the ground with ability of increased load bearing capacity

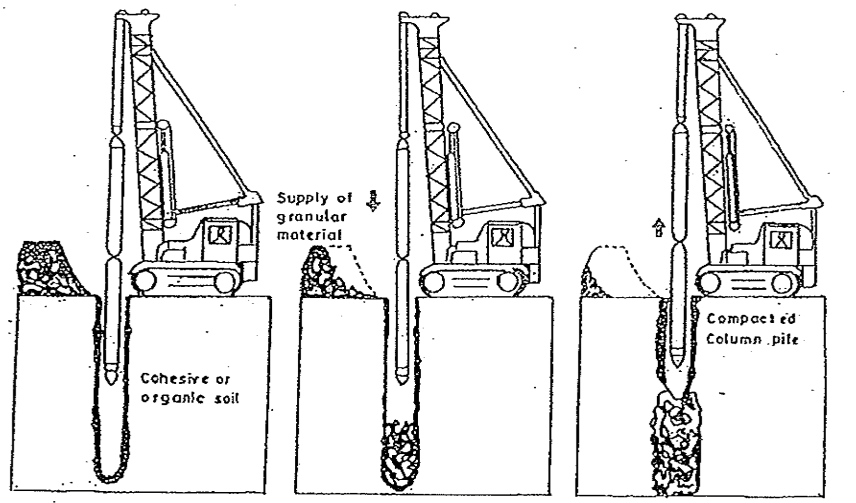
Vibro - replacement method is used in stone column formation.

Stone column column is also called as granular pile are installed mostly using vibration techniques

A cylindrical verticle hole is made and gravel backfill is placed into hole in increment & compacted by suitable device which simultaneous displace material

This results in dense. compacted stone column of certain depth & diameter

Formation of stone column using a vibroflot is quite sit suitable techniques for improvement of cohessive soil



(a) Bore hole is formed by sinking vibrator into the ground
(b) Backfill material is placed into the bore hole in stages and compacted
(c) Alternate back filling and compaction forms continuous granular pile

Jet grouting

Jet grouting which has originated and used as replacement techniques unlike other conventional injection methods

By this method soil ranging from silt to clay and week rocks can be treated

This method consist of lowering a drill pipe into a 150 mm diameter borehole

The drill pipe is specially designed which simultaneously convey pumped water, compressed air & grout fluid

At the bottom of end pipe two nozzl are provided at 500mm apart, the upper nozzle deliver water at about 400 bars, surrounded by a collar of compressed air at 7 bars to produce a cutting jet

The grout is delivered through the lower nozzle at 40 bar, the grouting action requires the stem to be slowly raised, whereby the excavated material produced from the jetting action is replaced by grout and forced to the surface. The jetting water could reach about 1.5m and rotating stem a column of replaced earth may be formed

Ground improvement method

Surface Compaction

All types of soil can not be compacted is achieved by diffent single piece of equipment.

Soil compaction oprating is achieved by diffent means such as tamping, kneading, vibrating or impact

Compactors operating on the principle of tamping, kneading & impact are mostly suitable for cohessive soil,

where as for cohession less soil, equipment operating on the principle of vibration, tamping & kneading are effective

Appropriate equipment should be used for the type of soil & the field condition

In appropriate use of equipment for a given soil type will result not only in a poor quality of construction but also leads to construction delay.

Equipments which are available based on above principle are roller, tamper & rammer

There equipment are used on surface of ground to improve material quantity property to a limited depth from ground surface are termed as Surface Compaction equipments

Compacting material to large depth by operating equipment on the ground surface is being used more recently.

This new techniques is called heavy tamping also named as dynamic compaction, dynamic consolidation or pounding

Ground treatment

Stabilization with lime

Lime has been used as a soil stabilizer for road from older days.

Hydrated lime is most commonly used for soil stabilization with combination of fly ash, cement bitumen

There are two types of chemical reaction takes place in addition to wet soil

First → It is almost colloidal-type of reaction involving any of the following

i, ion exchange of calcium for ion naturally carried by soil

ii, a depression of double layer on soil colloidal because of double layer on soil colloidal because of increase of concentration of pore water

iii, an expansion of double layer of soil colloid from high PH of lime

Second → The second reaction takes considerable time in cementing action, it is reaction between Calcium from lime with available readine alumina (or) silica from soil

* Soil plasticity, density & strength are changed by addition of lime to soil

* Lime generally increases the plasticity of low index of low plasticity soil or decrease the plasticity of high plasticity soil ie. it brings the plasticity of soil to a optimum level which is easy to handle.

* In general lime increases almost all strength of almost all type of soil

* The normal construction sequence of lime stabilization base as follows

i, scarify the bases

ii, pulvarise the soil

iii, Spread the lime

iv, Mix the lime & soil

v, Add water if necessary to bring optimum moisture content

vi, Compact the mixture

vii, Shape the stabilized base

viii, Cure for atleast 5 days

ix, Add wearing course

* Adequate care should be taken to prevent the corbonation of lime

Selection of Ground Improvement

Neccessary precaution have to be taken while designing a structure keeping in view the possible anticipated change which could occur during the design-life of structure

A few factor which contribute for ground alteration are discussed below

Effects of Seasonal Moisture variation

Soil may undergo volume changes caused by seasonal moisture content variation

When a saturated soil is allowed to dry in each voids at the soil surface and brings in tension in the water leading to a compression in soil structure which is termed as shrinkage

The effect of shrinkage depends on initial moisture content, type & amount of clay content & mode & environmental of geological deposition

Shrinkage is reduced due to the presence of sand & silt size particle soil which high plasticity shrink gravity causing settlement

Some soil not only shrinks due to drying but also shows swelling with increase of moisture content

Swelling caused mainly due to repulsive force which separates the clay particle, leading to volume increase

In region which have well defined alternately wet and dry season, susceptible soil swell & shrink in regular cycle. Due to such seasonal volume change there will be rise & fall in ground surface accompained by tension crack in soil during dry Season & closing of the crack in wet season

Effects of water Seepage & Surface Erosion

Mainly in sandy soil trouble occur due to water seepage & errosion. Internal errosion can result from carrying away of fine soil particle by ground water seeping in broken sewer or culvert and in careless techniques of deep excavation below water table.

The consequent loss of ground from foundation may occur leads to collapse of structure.

Surface erosion may occur due to loss of material in ~~strong~~ strong wind or erosion by flowing water.

Fine particle such as fine sand & silt and dry peat are very much susceptible for erosion by wind

Surface erosion by flowing water may be severe ~~if~~ if structure are constructed in the bottom of the valley particularly where monsoon rains are very heavy

Such action of seeping water & erosion may lead to change in properties of soil and in soil profile which needs careful consideration while designing a structure

Erosion can be prevented by providing adequate depth of foundation, by growing suitable vegetation or by blanketing the erodable soil by gravel, crushing rock or clay etc.

Effects of Vegetation

Swelling & shrinking problem is also aggravated due to effect of roots of vegetation

The roots of trees, plant and shrubs consume considerable amount of water from the soil leading to the soil shrinkage

Effects of Temperature variation

Volume change leading to heave and shrinking respectively

When daily mean temperature remains below 0°c for a long period the soil moisture near the near ground surface freeze

Continued sub-zero weather lead to increase in depth of freeze which result in rise of ground surface known as frost heave

The frozen water is concentrated into ice lenses or layer that lies parallel to ground surface

When soil is subjected to very high temperature severe shrinkage cracks may occur. Such condition may raise on soil beneath foundation of boilers, kiln & furnace

Effects of Construction operation

Ground subsidence during construction may also occur due to increasing load on surrounding soil & excavation apart from vibration and lowering of water table

In sandy subsoil the settlement due to load on adjoining site cannot be computed reasonably but has to be estimated based any on records precedents

Unit - 2

Drainage & Dewatering

Drainage :

Drainage is the removal of gravity from the soil mass in order to keep in as stable condition Drainage may be classified into two categories

i, surface drainage

ii, Sub- Surface drainage

Surface drainage

* Surface drainage is the method of collection of the surface runoff

Sub- Surface drainage

* Sub- Surface drainage consist of a collection of and disposal of ground water

* Sub- Surface drainage is also known as dewatering

* It is the process of removal of water from a foundation pit . when it is situated below the ground water level when it is surrounded coffer dam

* purpose of dewatering is to keep the excavation dry so that connection can be done

* Various methods of suchage drainage are as follows

- Well point system
- Vaccum system
- Electro osmosis method
- Deep well system

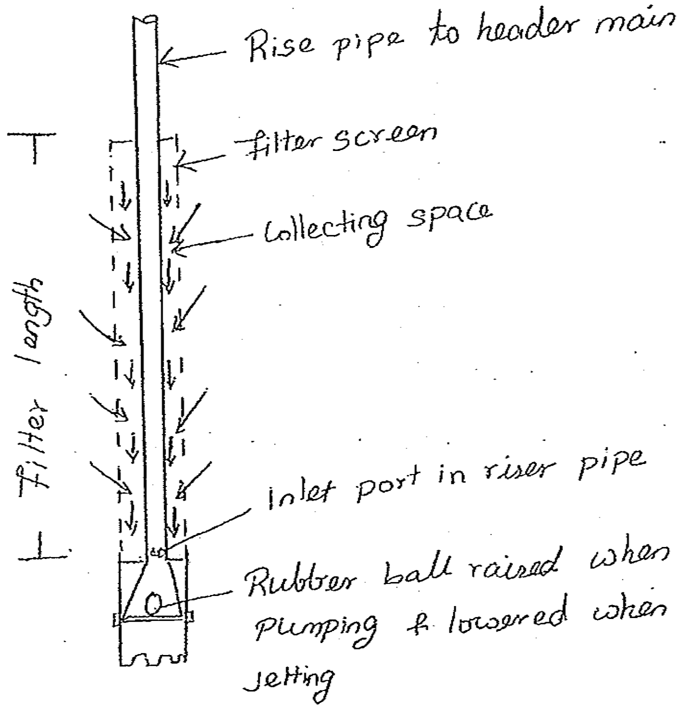
Well point System

a) Single stage well point system

* A well point is perforated pipe about 1m to 2m long & 5cm in dia. The perforations are covered with a screen to prevent clogging
* An jetting nozzle is provided at its lower end
* A conical steel drive point is fixed to the lower end of the well point installation
* A valve is also provided near the lower end which permits flow of water only in the downwards direction during installation.
* The well point is connected to the bottom of the rise pipe of some direction, rise of diffrent well point are conneded to a horizontal pipe of 15-30 cm dia known as header
* The header is connected to a specially designed pumping unit
* The spacing of well points depends upon the types of soil & depth of water generally varies between 1-3m

Well point System

* Well points are small well-screen of size 50 to 80mm in ϕ & 0.3 to 1m length
* It is either with brass or stain-less screen and are made with either closed ends or self Jetting type
* Water drawn through screen enter the space between the gauze and the outside of riser pipe to hole drilled in the bottom of this pipe and then reaches the surface
* The well point are installed by jetting them into ground



* The capacity of a single well point with a 50 mm riser is about 10 liters/m.

* Spacing of well point depends on the permeability of soil & availability of time to effect the drawdown

* In fine to coarse sand or sandy gravel, a spacing of 0.75 to 1m is satisfactory

Spacing of 1.5m for silty sand of fair low permeable. In high coarse gravel they may need to be as close as 0.3m centers, In general with a separate jetting pump. The well point pump has an air/water separator and a vacum pump as well as the normal centrifugal pump

* Well point system is mostly commonly used method for construction purpose

* A well point is suitable when the site is accessible and where water bearing stratum to be drained is not too deep

* Well point system acts more efficiently in sand & sandy gravel of moderate permeability

* Further in wellpoint system the water is drawn away from the excavation, thus stabilization the side and thereby permitting steep slope unlike in open-sump pumping

* The installation of well point system is very rapid & required reasonably simple & cheap equipment.

* In this there is an advantage that there is less drainage water filtered & carries little or no soil particles

*Because of this there is less danger of subsidence of the surrounding ground than with open-sump puming

*The serious limitation of well point system in suction lift

*A lowering of about 6m below pump level is generally possible beyond which excessive air shall be drawn into the system through joints in pipe, value etc resulting in loss of pumping efficienty

*If the ground is consisting mainly of large gravel, stiff clay or soil containing cobble or bolders it is not possible to instal wellpoint

GROUND IMPROVEMENT TECHNI

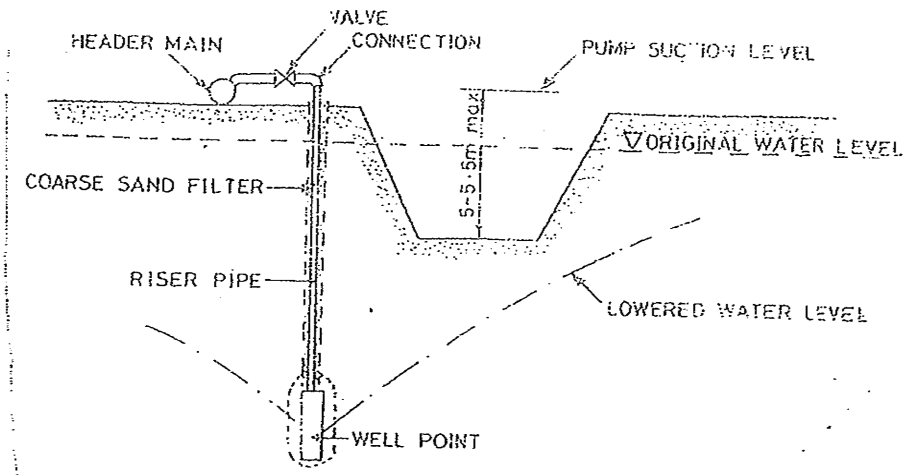


Fig. 3.5. Single-stage wellpoint installation.

Multi Stage

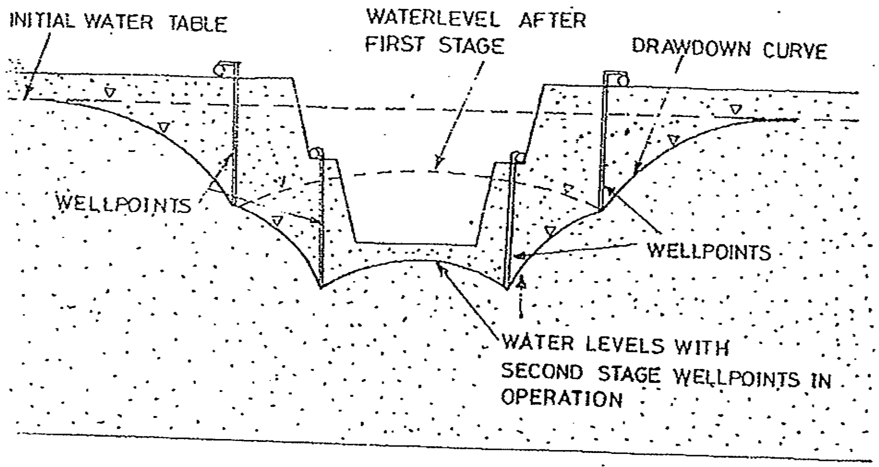


Fig. 3.6. Multistage wellpoint operation.

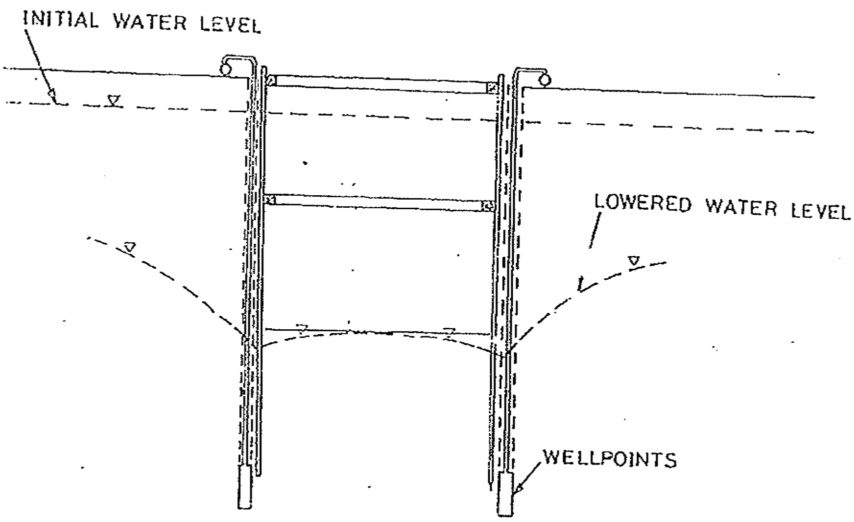


Fig. 3.7. Wellpoints in braced excavation.

* For dewatering deeper excavation the wellpoint must be installed in two or more stage shown in fig. There is no limit to the depth of drawdown in this way, but the overall width of excavation at ground level become very large. On the other hand it is possible to avoid multi-wellpoint stage by excavating down to water level before installing the pump & header

* When wellpoint are used in braced excavation they are placed close to the sheet pile rows

* Wellpoint are provided in conjunction with the sheet pile under the following condition

i, to prevent quick condition of the bottom when sheet piles are of limited penetration

ii, to eliminate hydrostatic pressure on the back of sheet piles coffer dam thus allowing higher bracking to be used

* As an alternate to the conventional wellpoint system with suface pumps, one can use a jet-eductor wellpoint system

* A jet-eductor wellpoint system consist of a well point attached to the bottom of jet-eductor pump, with one pressure pipe and slightly larger return pipe

* These two pipe along with the wellpoint & jet-eductor pipe pump are installed in a cased hole and surrounded with a filter sand, if necessary

<u>adv</u> - Not limited depth by suction lift pump at G.L

<u>Disadv</u> - loo efficiency

22.a) **Deep-Well Drainage**

* Deep-Well drainage system consist of deep well & submersible or turbine pump which can be installed outside the zone of construction apluo operation & water table lowered to desire level

* Deep well system is suitable for lowering the ground water table where the soil formation is pervious with depth, the excavation extend through or is underlin by coarse-grained soil

* This method is also suitable when great depth of water lowering is required

* Deep well may be combined with the well point system on certain field condition for lowering the groundwater table

* The installation of a deep-well is done by sinking a cased borehole having a diameter of about 200 to 300 mm larger than the well casing which depend on the size of the submersible pump

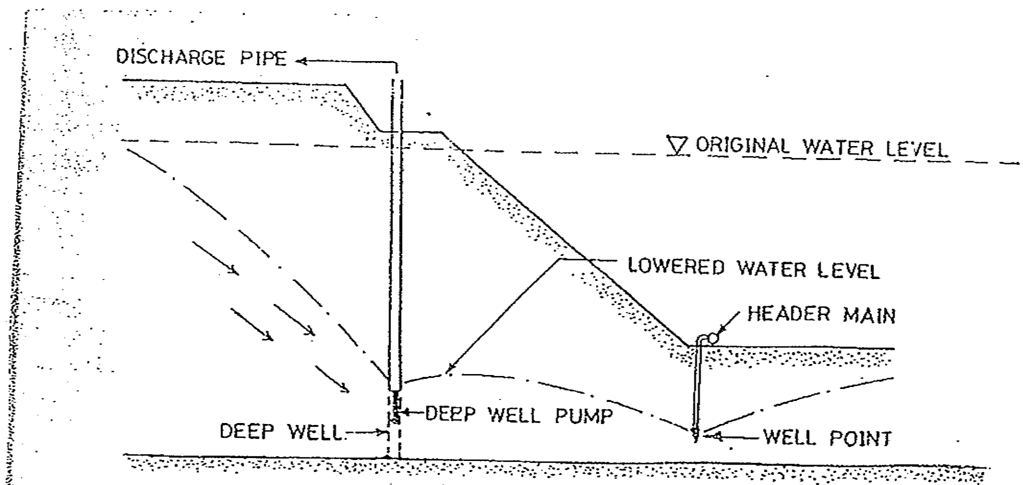


Fig. 3.10. Deep-well dewatering.

* The inner well casing is inserted after the completion of the borehole

* A perforated screen installed over the length of soil which required dewatedring and is terminated in a 3 to 5m length of unperforated pipe to act as a sump to collect any fine material which might be drawn through the filter mesh.

* Graded filter material is placed between the well casing and the outer bolehole casing over the length to be dewatered

* Then the outer casing is withdrawn in stage as the filter material is placed

* The space above ab the screen is backfilled with any available material

* The water in well is then surged by a boring tool to promote flow back and forth through the filter and at the same time any unwanted fine which fall into the sump are cleared out by bailer before the submersible pump is installed.

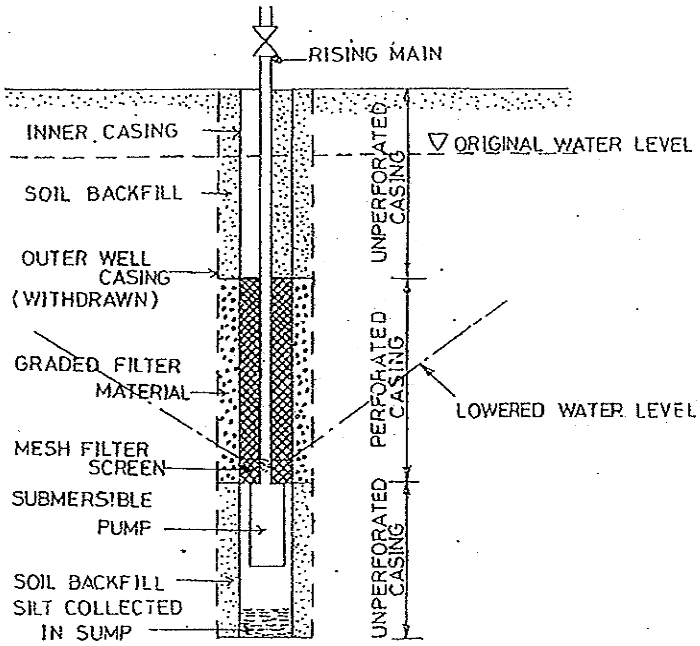


Fig. 3.11. Details of deep-well installation.

*This is the last operation before putting the well into Commission. If Centrifugal pump are used in a deepwell system, the top of Screen should below the computed water surface in the well

*If the well are pumped by deep-well pump, the bottom of well should be set to provide sufficient length of submerged screen to admit the flow without excessive head loss

*As heavy boring plant is used to sink the well in very adverse formation like boulders, rocker or under other difficult field environment, the cost of deep-well system is relatively high

*Thus it is advised to restrict this method to job which have a long construction period such as dry dock or access shaft for long sub-aqueous tunnel

22b) i) Vacuum Dewatering System

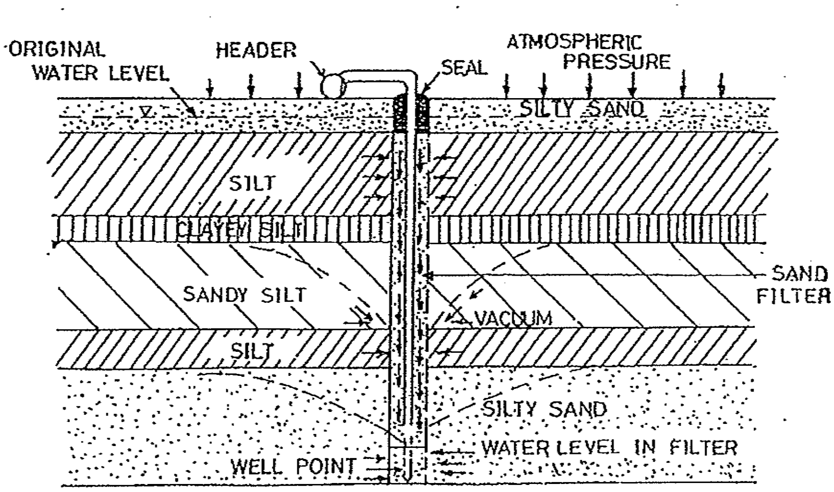


Fig. 3.12. Vacuum dewatering system.

* Gravity methods, such as well point & deep-well are not much effective in the fine-grained soil with Permeability in range of 0.1 to 10×10^{-3} mm/s

* Such soil can be dewatered satisfactory by application of vaccum to the piping system

* A vaccum dewatering system requires that the well or well point screen, and riser pipe be surrounded with filter sand extending to within a few meter of ground surface

* The top few portion of the hole is sealed or capped with an impervious soil or other suitable material

* By having the pumping main a vaccum pressure, the hydraulic gradient for flow to the well point is increased

* This method is most suitable in layered or stratified soil with coefficient of Permeability of range 0.1 to 10×15^{-4} cm/sec

* A typical vaccum dewatering system in a stratified soil is shown in fig

* In this system well point should be placed closer then the conversional system

* In common to use suction pipe pump in this system and practical maximum height of lift is about 3 to 6m

15b) Electro Osmosis Method

*Electro osmosis is a method of drainage of cohessive Soil in which direct Current is used

*when direct current is passed through a saturated soil between positive electrod and negative electrode to pour water migrate to the negative charged electrode (cathode)

*A cathode is a well point which collect the water drained from the soil. The water collected is discharge as in a conventional well point action

*The phenomena of electro osmosis is exclined with help of electrical double layer cation are formed in pore water

*This cation move towards -vely charged surface of clay minerals to satisfy the electrical charge

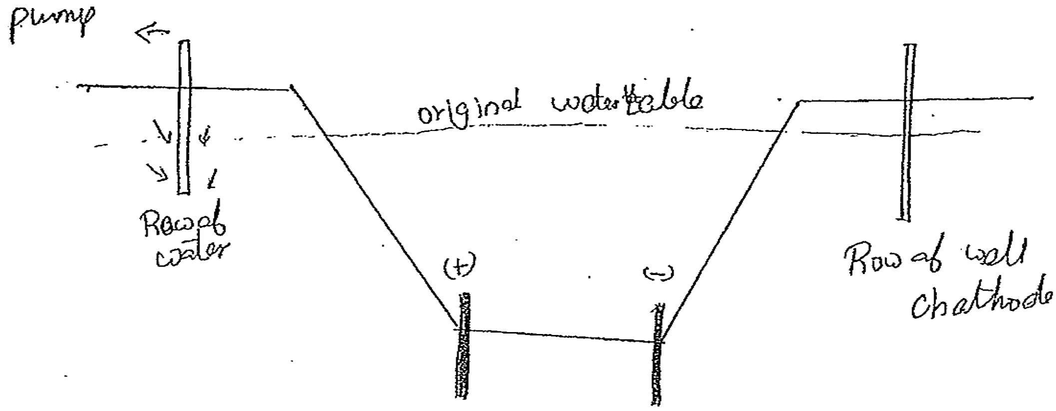
*As the water molecule act as dipole the action also attract the -ve end of dipole

*When the cation move to the cathode they take with them the attached water molecule

*In fact the center entire out part of double layer which absorbed to the soil particle gets shear ~~ega~~ along a plain

*Anode are in form of steel molelulles located near the toe of slope of excavation

Cathode are in form of perforated ties resembling well point installed in the soil mass about 4-5m



* This arrangement is required to prevent clogging of slop in many casses more reversing of direction flow help in increasing the stability of slope even if there is no significant decreale in water content of soil

* They system requires about 20-30 amp of electricity per well at a voltage of 40-180

* The consumption of energy is between 0.5 to 10 kW/m³

* Because of specialized equipment and high electricity consumption drainage by electro osmosis is exponsion compared with other method

* This method should be used only in critical cases when other method cannot be used. It is normally used to drain water in cohesive soil of low permeability 1×10^{-5} to 1×10^{-8}

* It helps in increasing the shear strength of cohessine soil.

Seepage Analysis

Seepage is defined as the flow of fluid, through soil under hydraulic gradient

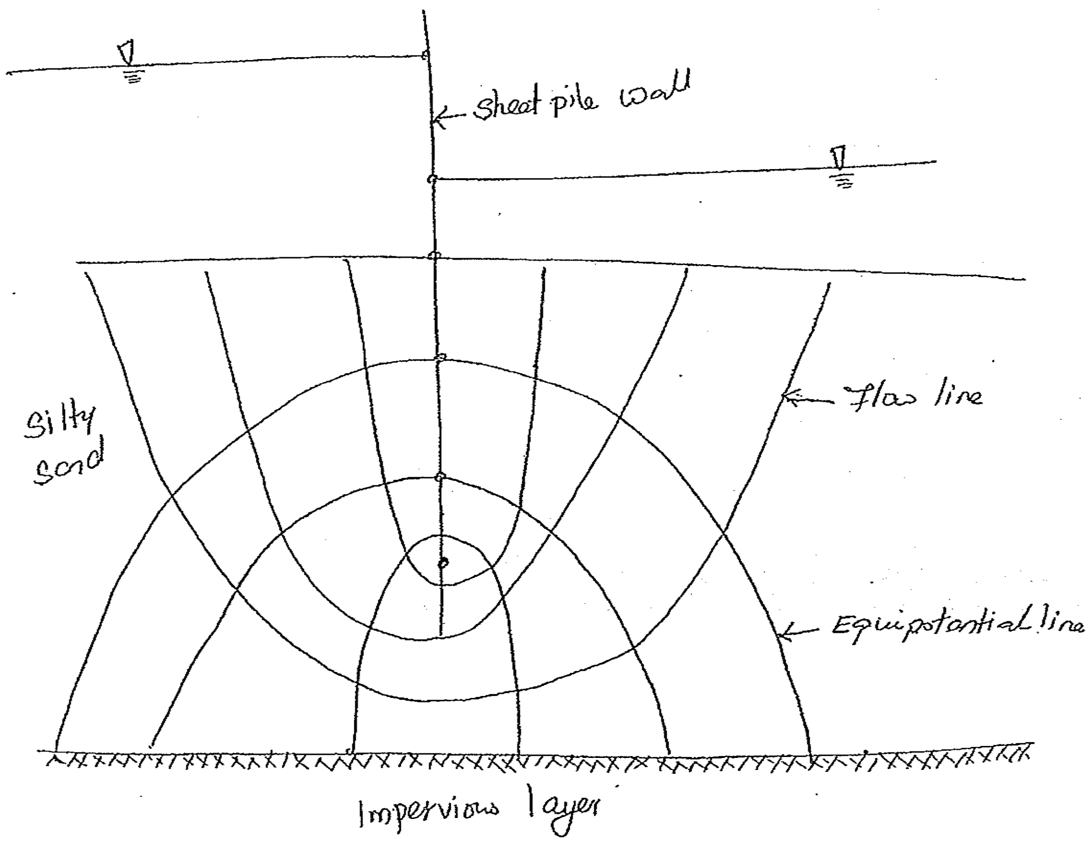
A hydraulic gradient is supposed to exist between two point if there is diffrence in 'hydraulic head' at two point

<u>Flow Net for 2D-Flow</u>

Flow net are pictorial method of studing the path of moving water

Equipotential lines must cross flow line at right angle since they represent pressure normal to direction of flow

Flow line + Equipotential line = Flow net



13.b) Fully penetrating slot

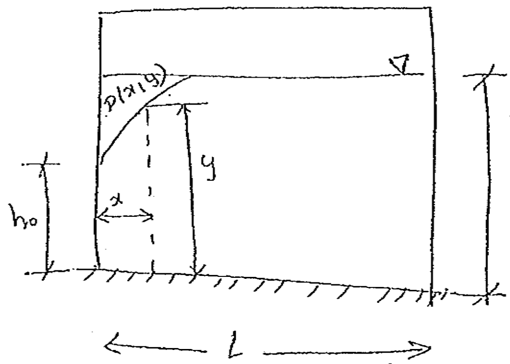
i, Unconfined Flow

It is assumed that the flow originates on one side of the slot consider a length a of slot

The discharge is given on the assumption that on any vertical line below the drawdown curve, the hydraulic gradient is constant & is equal to the slope of drawdown curve @ point where the vertical line intersect the drawdown curve

For any point P(x,y) the discharge crossing the vertical plane through P per unit length a of slot is given by $q = kiA$

$i = \frac{dy}{dx}$ $A = ya$



$q = k.\frac{dy}{dx}.ya$

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

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

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

$\frac{qL}{ka} = \left[y^2/2\right]_{h_0}^{H}$

$\frac{qL}{ka} = \frac{1}{2}\left[H^2 - h_0^2\right]$

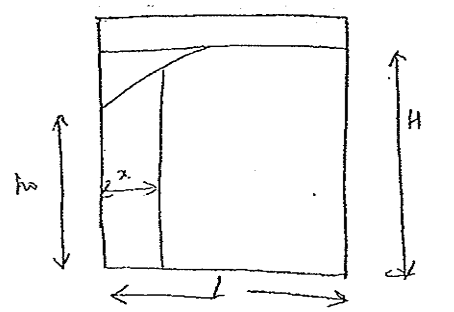
$q = \frac{ka}{2L}\left[H^2 - h_0^2\right]$

ii, Confined Flow

$q = kiA$

$i = \frac{dy}{dx}$, $A = ab$

$q = k.\frac{dy}{dx}.ab$



$$\frac{q}{Kab} = \frac{dy}{dx}$$

$$\frac{q}{Kab}\, dx = dy$$

$$\frac{q}{Kab} \int_0^L dx = \int_{h_0}^H dy$$

$$\frac{q}{Kab} [x]_0^L = [y]_{h_0}^H$$

$$\frac{qL}{Kab} = H - h_0$$

$$\boxed{q = \frac{Kab}{L}[H-h_0]}$$

iii) Combined flow (artesian & gravity flow)

In this case the rate of withdraw is such that the drawdown curve goes below the impervious layer at the slot

The analysis can be done by using the discharge equation for gravity flow for length (L_g) that is using 'L_g' in place of L and b in place of H in gravity flow discharge equation

The discharge equation for artesian flow for the length ($L-L_g$) that is length ($L-L_g$) in place of L and b in place of h_0

Discharge equation for gravity flow

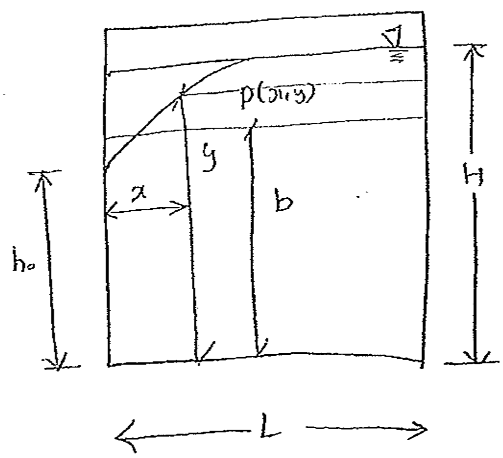
$$q_1 = \frac{Ka}{2L}(H^2 - h_0^2)$$

$\Rightarrow$ sub values $q_1 = \frac{Ka}{2L_G}(b^2 - h_0^2)$

Discharge eqn for artesian flow

$$q_2 = \frac{Kab}{L}[H - h_0]$$

$$= \frac{Kab}{L-L_g}[H-b]$$

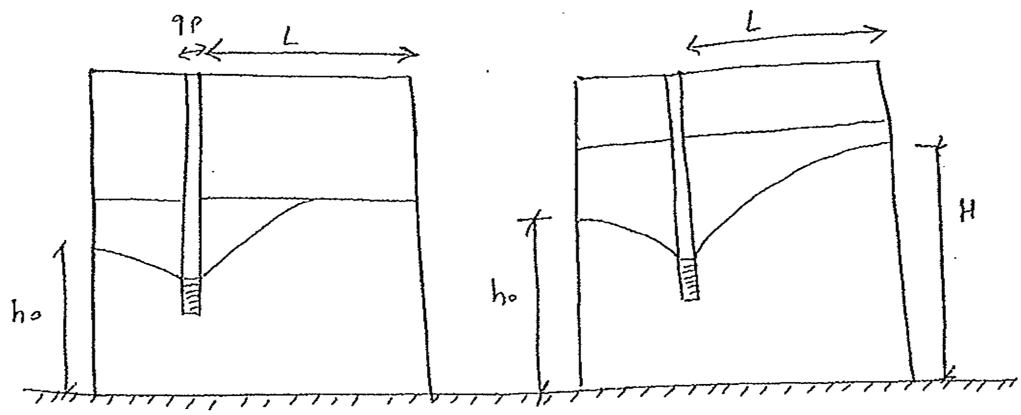


$$\frac{ka}{2LG}\left(b^2 - h_0^2\right) = \frac{kab}{L-LG}(H-b)$$

$$\frac{b^2-h_0^2}{2LG} = \frac{b}{L-LG}(H-b)$$

$$LG = \frac{L - LG\,(b^2-h_0^2)}{2b(H-b)}$$

22.b) ii) Partially penetrating slot



The discharge 'q_p' from a partially penetrating slot in an unconfined flow can be found from the following expression developed by Chapman by model studies

$$q_p = \left[0.73 + 0.27\,\frac{H-h_0}{H}\right]\frac{ka}{2L}\left(H^2-h_0^2\right)$$

The symbol are shown in fig the max residual head 'H' from the slot is given by

$$h = h_0\left[\frac{1-48}{L}(H-h_0)+1\right]$$

For the case of a slot partially penetrating on artesian flow the discharge 'q_p' per unit length is given by

$$q_p = \frac{Kba(H-h_o)}{L+E_A}$$

where

E_A = Extra length factor

3. INSITU TREATMENT

Insitu treatment of cohesionless & cohesive soils:

Soil is used as a basic construction material. It is essential that in-place soil should possess certain property to withstand the force caused by the structure. Soil should have adequate strength, resist settlement or heave, permeabile, durable and safe against deterioration.

⇒ Cohesionless soil - sandy soil, loose condition.

⇒ cohesive soil - soft clay, large void ratio & high water content

Densification of cohesionless soil:

- Densification - reduction in void volume which can be acheived by the following ways such as

→ re-orientation of particles,

→ fracture of grains or their bonds,

→ bending or distortion of particles and their absorbed layers.

- Structural fill consists of placing, spreading & compaction.
- soil is excavated from suitable borrow pits and tranported using self propelled scrapers, bulldozers, graders and trucks.
- soil compaction or densification can be achived by tamping, kneading, vibration and impact.
- primary compaction equipments are

→ Rollers - smooth wheeled rollers, pneumatic - tyred rollers, sheepfoot rollers and grid rollers

→ Rammers -

→ Vibrators - Vibrating drum, vibrating pneumatic tyre, vibrating plate & Vibroflot

Consolidation Of Cohesive Soils:

- The process of gradual compression due to expulsion of pore water under steady pressure is referred as 'consolidation.'
- In clays the consolidation proceeds long after constructi hence greater attention is required.
- It is a time dependent process.
- Cohesive soils such as soft clay have large void ratio and higher water content. Ground improvement is required to reduce void ratio and water content to increase the strength so that the bearing capacity is increased and compressiblity is decreased.
- The consolidation technique involves

→ pre compression
→ Sand drains & wick drains
→ Stone columns.

Dynamic Compaction:

- Heavy weight - 45,000 kg dropped from a height of 15 to 40m fall freely on ground surface.
- In cohesionless soil it causes liquefaction followed by settlement due to rapid drainage.

spacing - 5 to 10 m. for stabilization. No of blows - 5-10

- After required number of drops the area shall be compacted at depth.
- The heavy weight is made of concrete or steel block.
- A Crane is used to lift the weight to required height and then it is allowed to fall freely under gravity.
- A pit is formed at the point where the weight block hits the ground to a depth of 1 to 3m.
- The upper layer upto a depth of 2m is compacted using small weight and height.
- Dynamic compaction effective in loose sands, silty sands, boulders and sanitary land fills.
- Good densification depth – 5 to 10m. when depth increases densification is decreased.

For effective compaction the depth is determined by

$$D = \frac{1}{2}(MH)^{1/2}$$

where,

M = Mass of the block (kg)
H = Height of drop (m)
D = depth of densification (m).

In dynamic compaction method large shock waves are generated in ground. care should be taken to ensure that the harmful vibrations are not transfered to adjacent structures. Hence it has limitation in urban areas.

- The radius of influence (R) beyond which no harmful vibrations are transmitted is given by

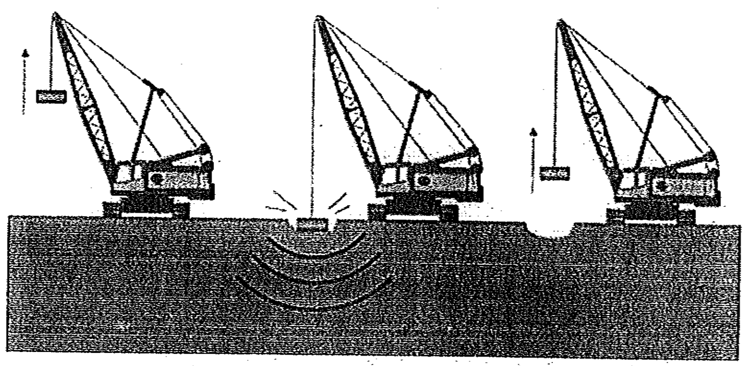
$$R = 130\sqrt{MH}$$

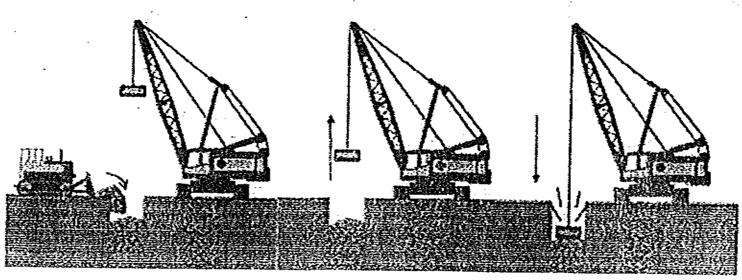
Major variables in this process:

1) Magnitude & size of weight 2) height of free fall.
3) No of drops & its distribution 4) Non-homogenity of soil.
5) strength & permeability of soil 6) Degree of saturation.

<u>Merits</u>:

→ Simplest & basic method of compacting loose soil.
→ Depth of compaction reaches upto 20m.
→ Applicable to all types of soils.
→ produces equal settlements.
→ used to treat both above & below water table.





Dynamic Consolidation :

- The application of this method is same as that needed for dynamic compaction but more time is required.
- several blows at each location followed by 1-4 weeks rest period, then the process is repeated.
- In each repetition immediate settlement occurs followed by drainage of pore water.
- Drainage is enhaced by radial fissures around impact points and by peripheral & horizontal drains.
- Dynamic consolidation effective in soft clays.

→ soft clays when not fully saturated contains gas in voids is dissolved in pore water under hammer impact reducing void volume

→ soft clays liquify under impact.

→ permeability is increased during tamping because of liquefaction, fissuring and shearing and rapid dissipation of pore pressure occurs.

Vibroflotation :

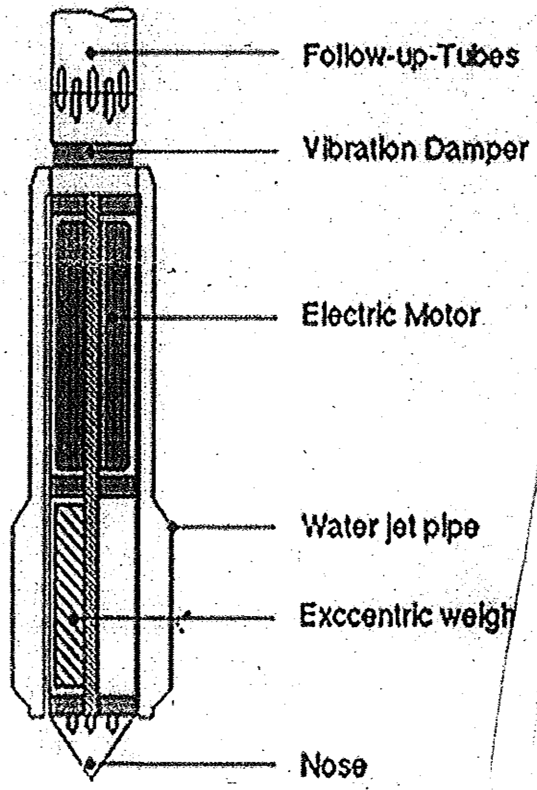
Vibroflotation is simultaneous vibration and saturation.

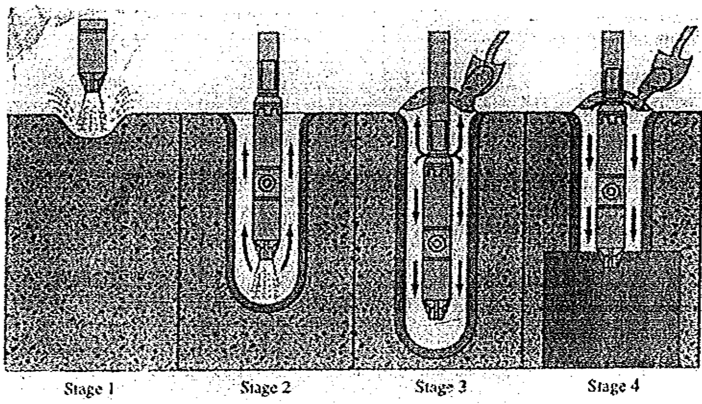
Equipment - vibrofloat probe, power supply, water pump, Crane and front end loader.

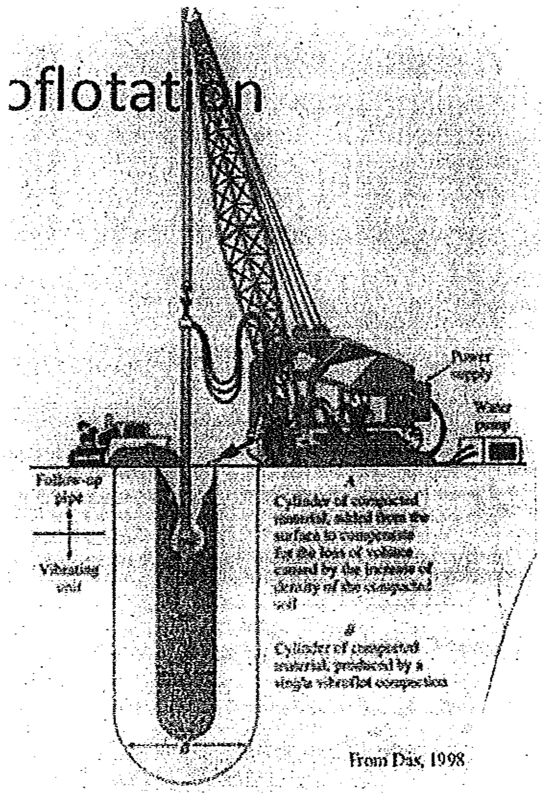
Vibrofloat probe - cylindrical penetrator 400mm ϕ & 2m length with eccentric weight inside the cylinder developing a centrifugal force of 100KN @ 1800rpm.

- Vibrofloat consists of 2parts - vibrating unit & flow up pipe. where the length can be varied depending on compaction depth.
- Water flow rate - 225 to 300liters/min at a pressure 400-600kPa
- The water jets the vibrofloat into the ground with the crane.
- Front-end loader - supply backfill as in-situ soil is densified

Compaction. Sequence:







From Das, 1998

1) vibrafloat is positioned and lower jet is fully opened.

under pressure → boiling.

2) Quicksand condition is developed (liquified soil which loses strength and stability) by the jetting action.

3) After the vibrafloat is sunk to desired depth the compaction is started to compact surrounding soil.

4) As the compaction of soil occurs, additional soil is continuously dropped into the crater.

The vibrafloat is then raised about 30cm at a time and the operation of compaction and backfilling is repeated. In this way a thick layer of compacted soil is produced.

Spacing - 3 m , Average depth 9m to the greatest of 22m

Factors involved:

1) Equipment capacity 2) probe spacing & pattern 3) type of soil 4) backfill material 5) vibrafloat withdrawl 6) workmanship.

Merits:

→ No material cost except backfill.
→ complete uniformity in density and control on settlement.
→ High bearing capacity is produced.
→ Faster than pile driving.
→ Quicker in operation.

Sand Compaction Piles:

Equipment: Hollow steel pipe with detachable bottom plate, impact hammer or vibratory driver, backfill sand.

Procedure:

A hollow steel pipe is driven into the soil to a desired depth.

The pipe is driven using an impact hammer or vibratory driver, the in-situ soil is densified simultaneously while the pipe is being driven down.

Sand is introduced into the hollow pipe through a hooper in lifts with each lift the sand is compacted concurrently while withdrawal of pipe pile.

The compacted pile prevents collapsing of the surrounding soil as the pipe is withdrawn.

Factors:

The required level of relative density can be acheived by varying the diameter of compaction pile and spacing.

The pile spacing 'S' may be obtained from

Square pattern $$S = \left\{ \frac{\pi(1+e_0)}{e_0 + e} \right\}^{1/2} \times d$$

Triangular pattern $$S = 1.08 \left\{ \frac{\pi(1+e_0)}{e_0 - e} \right\}^{1/2} \times d$$

where,

$e_0 \Rightarrow$ Initial void ratio

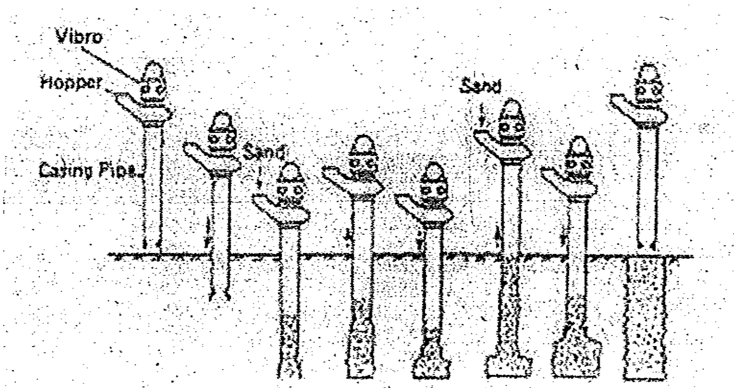
$e \Rightarrow$ Final void ratio.

Merits:

- Economical for moderate depths upto 15m
- Treated ground has uniform properties.

Demerits:

- costlier incase of deeper depths.



Preloading:

preloading of soil is simplest method which is merely applying an external loading for a long duration to cause desirable changes in the soil.

Preloading principles:

- preloading increases the pore water pressure in the soil, an increase in effective 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 stress in soil equal to that anticipated from the final structure
- preloading is sufficient only when the thickness of layer is less and more construction time is allowed.

Preloading Methods:

- Heaping of fill materials which may be reutilized for the same project.

- The required weight for preloading can also be applied to the ground by constructing peripheral dyke and filling the enclosed area with water.

- In another method of preloading, the final structure is used as a vehicle for load application.

- Another most effective method of preloading is by lowering the water table provided the soil conditions permi
The lowering of water table is done by suitable dewatering system. As the water table is lowered the effect of buoyancy is lost and the soil above water table gains unit weight by about $10 kN/m^3$.

- Another approach is inundating or preloading. Lowering of water table is applicable when the water table is high. When the water table is low a load can be applied to some soils by opposite action i.e, by inundating or preponding the surface. The effect of preponding is breaking loose bonds between particles increasing surface tension forces and the water weight. Thus the soil is densified by hydrocompaction.

- In Vaccum Preloading method. a 150mm layer of sand is placed on the surface of soft clay, the layer is covered with an impervious membrane, An application of a vaccum of 60 to 80kpa is induced in the sand which acts as an equivalent overload.
- Jacking is an method mostly applied to individual footings of either new buildings to which extra stories are to be added. Jacking is standard method of preloading footings and piles in underpinning.
- In normal practice the most frequent method of preloading is embankment loading. This process takes 3-8 months. The height of preload soil heap is 3-8m and the maximum height upto 18m.

settlement range will be 0.3 to 1m.

In general mixed methods provide increased safety for structures and low cost for utilities.

Vertical Drains:

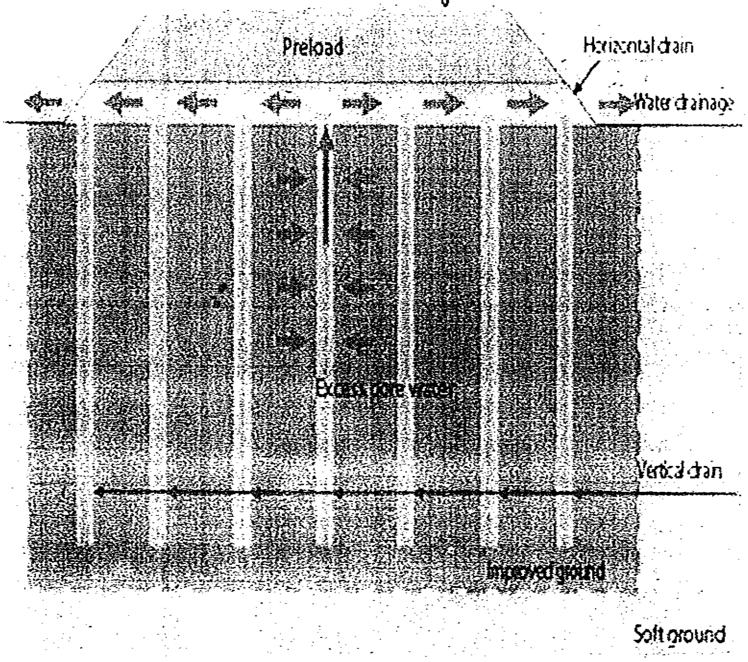
The preloading techniques is inefficient when used alone in very thick soft clays or soils with low permeability.

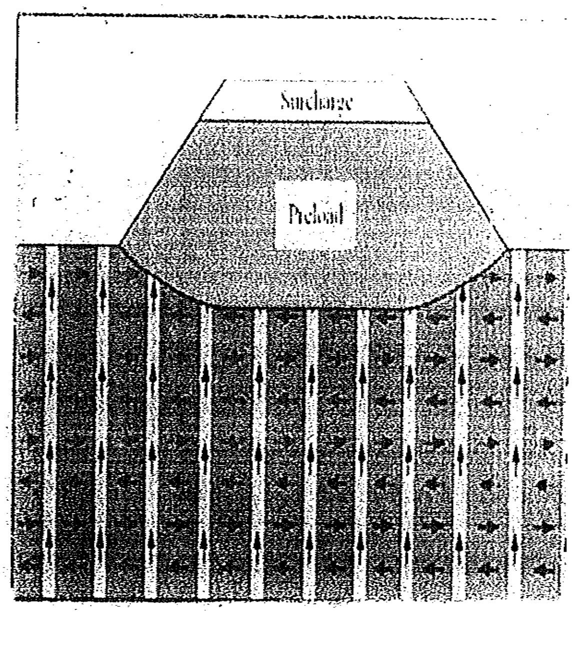
The length of drainage path controls the consolidation time this should be as short as possible.

A layer of sand or sand blanket is placed on ... of construction site. By this provision water squeezed from the underlying soil layer and flow fast, laterally to fill edge as the permeability of sand is much larger than underlying soil.

Principle:

- Vertical drains are continuous vertical columns of pervious material (sand or fibrous) installed in clayey soil.
- The drains provide pathway for pore water to escape from the soil by travelling shorter path
- They allow flow inside soil along horizontal direction and serves the purpose of collecting and discharging expelled water faster during consolidation process.





Vertical drains are mainly of two columnar types I) sand drain II) prefabricated drains.

Sand drains:

Sand drains are made by filling a cylindrical hole with sand.

The holes required for sand drain consists of three method

i) high-pressure water jetting.
ii) displacement of natural ground
iii) Wash boring

In all these methods a steel pipe is inserted in the ground and withdrawn as sand is poured from the hole top

Diameter - 180 - 450mm
spacing - 2.5 - 5m

i) **High pressure water jetting method:**

High pressure water jetting provides forcing water through the bottom of steel jetting rod at a rate of 50l/sec. The water jetting looses up the soil and the loosened soil flows upward around jetting rod. The steel pipe sinks by its own weight as the hole progress downward.

ii) **Displacement method:**

- A closed mandrel made of steel tube closed at the lower end by a loose cap is used.
- The mandrel is driven by precussion or vibration or jetting
- At desired depth sand & water is introduced and pipe is withdrawn

iii) <u>Wash Boring Method</u> :

The hole is advanced by circulating water into the hole at a rate of 1-2l/sec.

The soil slurry from the hole are allowed to settle and from which clean water is drawn back into circuit

1) <u>Sand drain</u> :

The sand used for filling the holes should not contain fines and uniformly graded.

The sand should not be coarse and particles >4mm should not be used.

The voids in sand created by filling the hole should be sufficiently pervious to allow unobstructed flow of water from soil into drain

2) <u>Fabric drain</u> :

<u>Geodrain</u> consists of 40-100mm wide and 3-5mm thick paper covered polythene strip which contains channels along both sides.

The exterior filter paper is chemically impregnated to give long life.

Large settlement takes place without break of drain continuity.

open or closed mandrel are fitted to the rigs. A downward force of 200kN is executed by the rigs and they drive up to four wicks @ a time.

Installation speed - 0.3 - 0.6 m/sec

Driving depth - 45m ; spacing = 1½ - 2 wick drains per sand drain

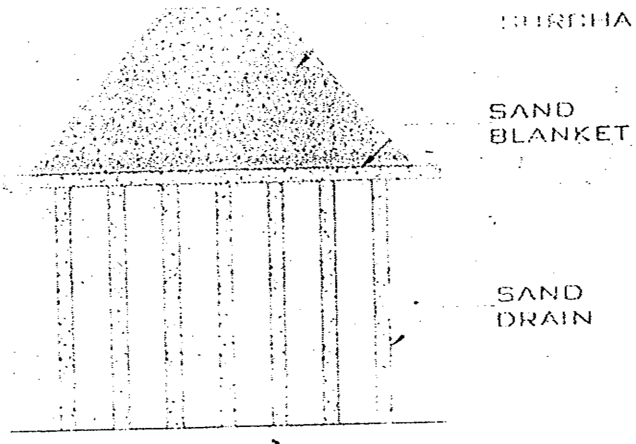
Plastic drains are wound around reels and as the mandrel is lowered into the ground the band is released by unwinding.

Advantages:

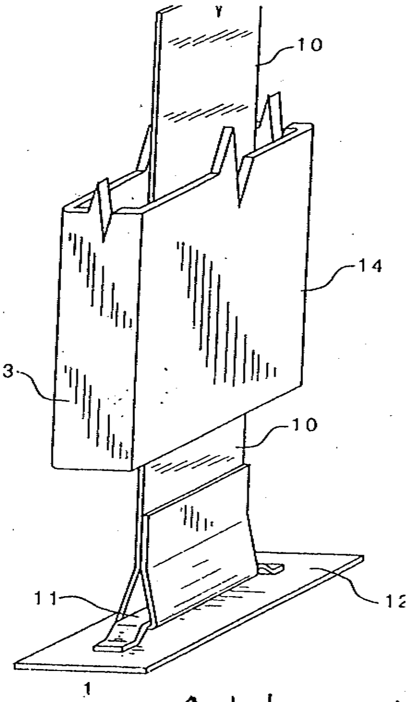
i) Low cost
ii) Fast installation
iii) Ensured drain continuity
iv) clean site
v) Light-weight installation equipment
vi) high permeability
vii) positive drainage
viii) negligible subsoil disturbance

Limitations:

- High pressure jetting method requires large water quantity and creates problem in disposing soil slurry.
- In displacement method due to the forcing of pipe severe soil disturbance takes place which causes high initial pore pressure, low permeability
- The wash boring method is slower & expensive.
- Vertical drains are less effective in organic soils, highly stratified soils

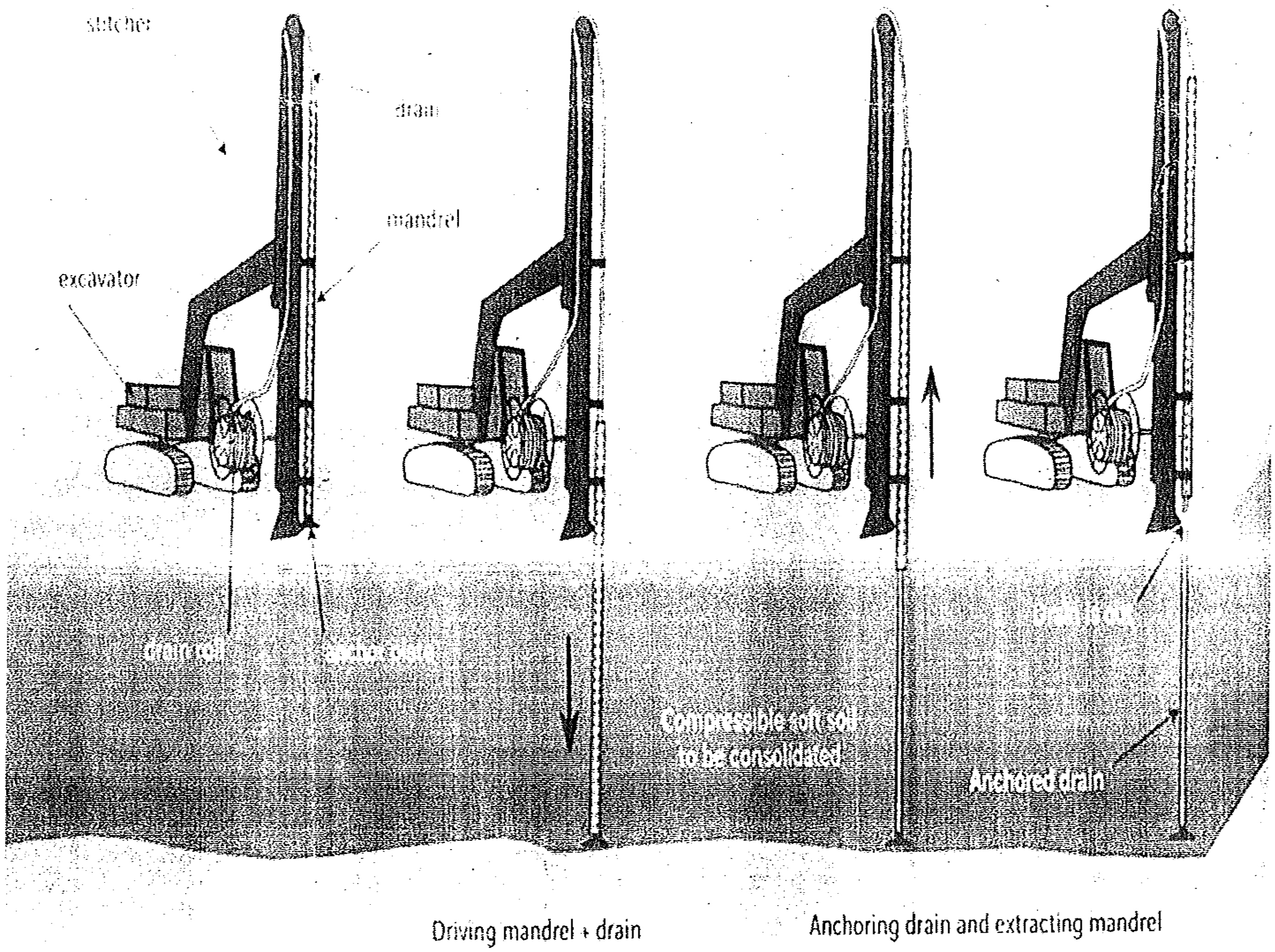


Sand Drain



Prefabricated Drain

Fabric Drain Installation



Stone Columns :-

Stone columns also called as granular piles are installed using vibration techniques ; A cylindrical vertical hole is made and gravel backfill is placed into the hole in increments and compacted by a suitable device which simultaneously displaces the material radially . This results in a densely compacted stone column of certain depth and diameter .

Stone column using vibrofloat :

- vibrofloat technique is quite suitable for cohesive soils
- vibrofloat is allowed to sink into ground due to its own weight . this is assisted by water or air as flushing medium .
- The soil surrounding the vibrofloat is disturbed or remoulded and the softened material can be removed by the jetting process and bore hole of larger diameter is formed .
- In jetting process fluid /water is used for fully saturated so compressed air is used for partially saturated soil

∴

- Bore hole is backfilled with gravel of 12 to 75mm size and it is compacted till the hole is completely filled which forms a cylindrical granular pile .

Dry . Process :

- A closed end pipe mandrel is driven to desired depth and the gravel is filled after opening a trip valve . and the pipe is withdrawn simultaneously
- A rammer is used to pack the soil

Rammed stone column:

A hammer weighing 15 – 20 kN falling from height of 1 – 1.5 m compacting stone aggregate placed in pre-bored holes.

Auger bored stone column:

In this method the bore hole is made by spiral auger and granular piles are cast using 20 to 30 mm size stone aggregate and 20 – 25% of sand.

The aggregates and sand layers are placed with varying thickness of 300 – 500 mm and 50 – 100 mm respectively.

The two layered unit is compacted with cast iron hammer of weight 1250 kN with a free fall of 750 mm. By this process compaction is achived.

Specifications:

→ vibrofloat – pile dia : 300 – 500 mm

→ Rammed process – dia : 400 – 750 mm

→ Boring – dia : 250 – 600 mm.

→ spacing – 1.2 – 3 m on centre over site.

The stone column length should be greater than

$$L_c \geq \frac{P - A_c(9C_{pt})}{\pi d c}$$

P ⇒ total load on stone column
A_c ⇒ c/s area of stone column
d ⇒ Average dia of " "
c, C_{pt} ⇒ side & point cohesion.

An approximate formula for allowable bearing capacity of stone columns is given by

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

$K = \tan^2(45 + \phi'/2)$
ϕ' = drained angle of internal friction of ston
c = drained cohesion
σ_r' = effective radial stre
SF = safety factor.

Stone columns are very much suitable for soft, inorganic cohesive soil and also used in loose sand deposits to increase the density.

It is capable of dissipating excess pore water pressure and reduces void ratio.

~~Application~~ Advantages:

- → Reduces negative skin friction on piles
- → prevent lateral dissipation of soil around pile
- → prevent creep.
- → Increases stability of clay slopes
- → Decreases lateral earth pressure.

Disadvantage:

→ stone columns cannot be used effectively in thick deposits of peat or high organic silts or clays.

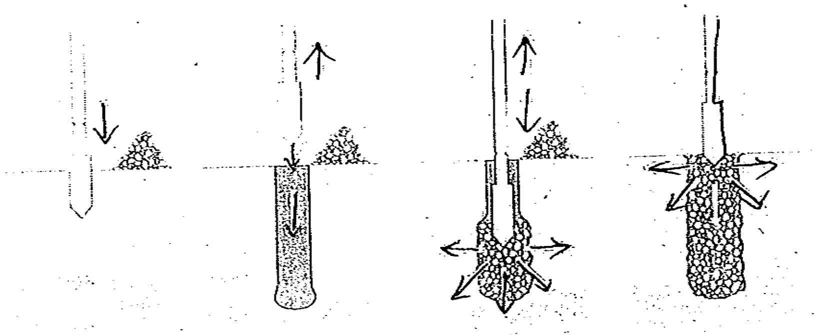


Figure 1: Dry – top - feed method process schematic(Taube, 2001).

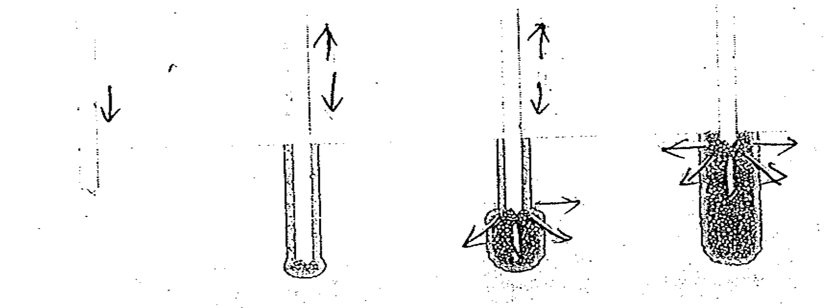


Figure 2: Dry – Bottom - feed method process schematic (Taube, 2001).

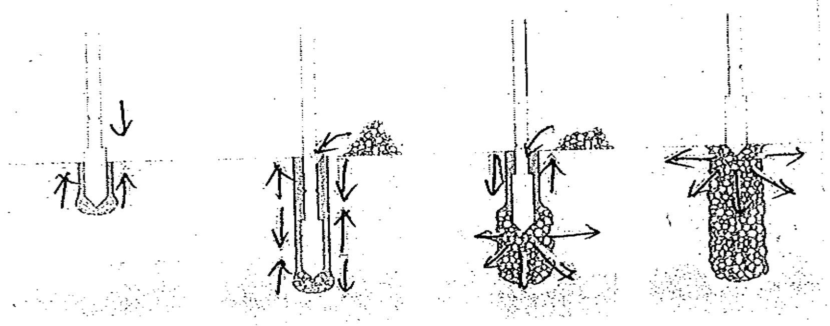


Figure 3: Wet - top - feed method process schematic (Taube, 2001).

Stone Column Installation.

18

- The radius of influence around the compaction pile in which the sand is densified depends upon the diameter of the pile. The radius of influence is about 3 to 4 times the pile diameter. For good results, the silt content should not be greater than [illegible] is present in the soil. Moreover, the clay content should not be greater than 3%.

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Ground Improvement Techniques

UNIT-IV

Earth Reinforcement.

Concept of Earth Reinforcement:-

The concept of soil reinforcement lies in the idealisation of the problem of soil reinforcement in the form of a weak soil reinforced by high strength thin horizontal membranes.

The supporting capacity of soft, compressible ground may be increased and the settlement may be reduced through use of tensile reinforcement in planes normal to the direction of applied stress of compression reinforcement in the direction parallel to the applied stress.

Materials:-

a) Soil or fill matrix

b) Reinforcement or anchor system

c) Facing if necessary.

Application of Geosynthetics:-

Seperation:- (Unpaved Roads):-

Use of Geosynthetics for unpaved roads are a well-established and a most common one.

Although the prime function of a Geosynthetics in unpaved road construction is separation,

The secondary functions of reinforcement and filteration remain essential.

Providing a geosynthetics sheet between a granular subbase and a weak subgrade help to stabilize an unpaved road in a no of ways.

i) Provides local reinforcement

ii) Restrains the aggregate from downward and lateral movement in the soil.

iii) Restrain the subgrade soil from upward and lateral movement between the soil

iv) Acts as a support membrane.

(v) provides sufficient friction to limit lateral sliding of the aggregate.

In the absence of geosynthetics, mixing up of the granular sub-base of soft mud from the underlying soil would rapidly reduce its strength to that of the soft mud alone.

Thus a geosynthetics sheet placed beneath the granular subbase can greatly reduce maintenance, enable better compaction during construction and reduce the thickness of aggregate layer.

Paved Roads :-

In this case, geosynthetics can be provided at three different locations in a permanent road, at the interface between the aggregate sub-base and the subgrade soil, within the pavement structure or with surface overlay.

In the first application the geosynthetics acts in a similar way as that in the unpaved road and can yield the following benefit.

1) prevents pavement sub-base aggregate from penetrating the subgrade soil.

2) prevents fine soil particles from the subgrade soil entering the subbase aggregate.

3) Reduces the need for excavation of soft fine subgrade soils.

4) speeds placement of the sub-base aggregate during construction.

5) Reduces of the sub-base aggregate while it is being used as a haul road.

6) Evens out settlement of the sub-base aggregate over any pockets of soft material that may have been overlooked.

In the second application, a high geosynthetics elastic stiffness is required to bring in some reinforcing effect.

For this application the most effective location for the Geosynthetics is within the base course or between the base course and the wearing course, at a depth of not less than 40mm.

The presence of the geosynthetics improves the tensile strength and gives the road a greater resistance to cracking and helps to provide a longer life.

In the third application, the geosynthetics is placed on the surface of an existing pavement prior to laying an overlay.

Presence of the geosynthetics restricts propagation of reflection cracks and thereby increasing the life of the overlay.

Railways:-

Ballast resting on a clay subgrade causes erosion pumping failures due to the dynamic load.

Another type of pumping failure may be caused by the contamination of the ballast by the dirty ballast pumping failure.

These two pumping failure could be prevented by providing a sand blanket.

A third mode of track support failure is a bearing capacity failure of the subgrade.

Generally this occurs in cohesive soils because of increase of pore water pressure.

A bearing capacity failure could be avoided by providing by a geosynthetics film sandwiched in the middle of the sand filter layer.

For such use the geosynthetics should have higher resistance and strength and also should be capable of dissipating the excess porewater pressure. Otherwise the excess development of pore water may cause liquefaction failure.

In other situation use of a geosynthetics in conjuction with fine granular materials could reduce thickness of filter layer.

Geosynthetics are also used in railway track surface water drainage system.

In this case heavier grade geosynthetics has to be used.

Geomembranes have to resist tensile forces, puncture and wear from object.

Advantages of Reinforced Earth Structures :-

1. The Reinforced earth structures are quite flexible, Hence these can withstand foundation deformations and settlements.

2. Reinforced earth structure, being flexible, can withstand earth-quake forces more efficiently than conventional rigid structures.

3. Reinforced earth structures are much more economical in comparison to the conventional structures of masonry or concrete.

4. Reinforced structural elements can be transported easily. Hence these can be constructed speedily.

5. Reinforced earth structures can also be constructed in stages.

6. The reinforcing elements used for such structures are easily available in various sizes and shapes. They can be easily stored, handled and placed during construction.

other applications of soil Reinforcement :-

- Reinforced earthwalls
- Bridge works
- Dams
- Embankments
- Foundations
- highways
- Root pile system
- Water way structure
- Under ground structure.

Geotextiles :-

Geotextiles are permeable or porous fabrics made from synthetic materials that are used with geotechnical material as an integral part of a man made product, structure or system.

Geotextiles are permeable sheets of synthetic fibres like polyester, polypropylene, polyethelene, polamide, viscose etc...

Geotextiles are available in thickness varying from 10 to 300 mils ($1/100$ inch = 1 mil) and in width upto 10m and in roll length upto 600m.

Geotextiles can be made of a variety of natural such as jute paper or wooden material etc...

Common Form of Geosynthetics :-

- Geotextiles and Geostrips
- Geogrids
- Geomembranes
- Geonets
- Geocells or Geoweb members
- Geofoam
- Geosynthetic clay liner
- Geo composites.

Geotextiles and Geostrips :-

These include woven and nonwoven geotextiles used for drainage, stabilization and reinforcement functions.

Geostrips are in the form of cut fabric or long strips of geotextiles.

Geostrips are generally produced from polypropylene and high density polyethylene.

They can be connected with anchors at the ends.

The anchors may be in the form of loops, rings or spirals which may help in confining soil elements.

Geogrids :-

These include extruded, woven, flexible and stiff types of geogrids used for stabilisation and reinforcement.

Geogrids are also produced by special process which align molecular chains of polymers, there by obtaining the material of high tensile strength as compared to the extruded polymeric mesh.

In geogrid, the reinforcing function is achieved by positive inter-locking of the fill material into the opening while in a geotextile, the reinforcing function is achieved by the surface friction between fabric and soil fill.

Geo membrane :-

These include HDPE [High Density polyEthylene], PVC [polyvinayal chloride], PP [polypropylene] liners etc.. and are basically impervious.

Geonets :-

The include LDPE [Low Density polyEthylene] and HDPE [High Density polyEthylene] nets and have functions similar to geogrids.

Geocells or Geoweb members :-

These include multicoloured HDPE Cells of varying heights, used for stabilization applications.

They are made from Prefabricated polymeric systems.

These systems are made from thick HDPE Strips 50 to 200 mm wide, stitched or welded together at 200 to 50 mm intervals.

Geofoam :-

These include polystyrene sheets of varying dimensions used for light weight fills and other applications.

Geosynthetic clay liners :-

These include geotextile / clay / geotextile Composites.

Geosynthetic clay liner a patented registered trade mark is a sandwitched composite of geotextiles and bentonite clay used to provide a positive barrier to liquids in containment applications.

Geocomposites :-

These are made by bonding together the geomembranes and geotextiles or any of their like forms for special applications in drainage, erosion control, bank protection etc...

Unit - 5

Grout Techniques

Introduction

Grouting is a process of ground improvement attained by injecting fluid like material into sub-surface soil or rock

The modern grouting was first started in mining works for arresting seepage & strengthing in civil Engineering

Grouting is particular valuable in foundation work before construction - [to control water problem, to infill voids to control settlement to increase soil bearing capacity], during construction - [to control groundwater flow, to stabilise loose sand against liquefaction, to provide adequate lateral support, etc], and after construction - [to reduce machine foundation vibration, to eliminate new seepage, to apply in underpinning work]

Grouting is usually limited to zones of relatively small volume and special problem

i, sealing pocket and leaves of permeable or unstable soil or rock prior to excavation of a tunnel heading or alternatively grouting a stratum from ground level

ii, Sealing the base of structure founded on previous ground iii, Fixing ground anchor for sheet pile wall, retaining wall, stabilishing rock cuttings, tunnels

iv, Filling voids between the lining and rock face in tunnel work

v, Producing mass concrete structure & piles

Aspects of grouting

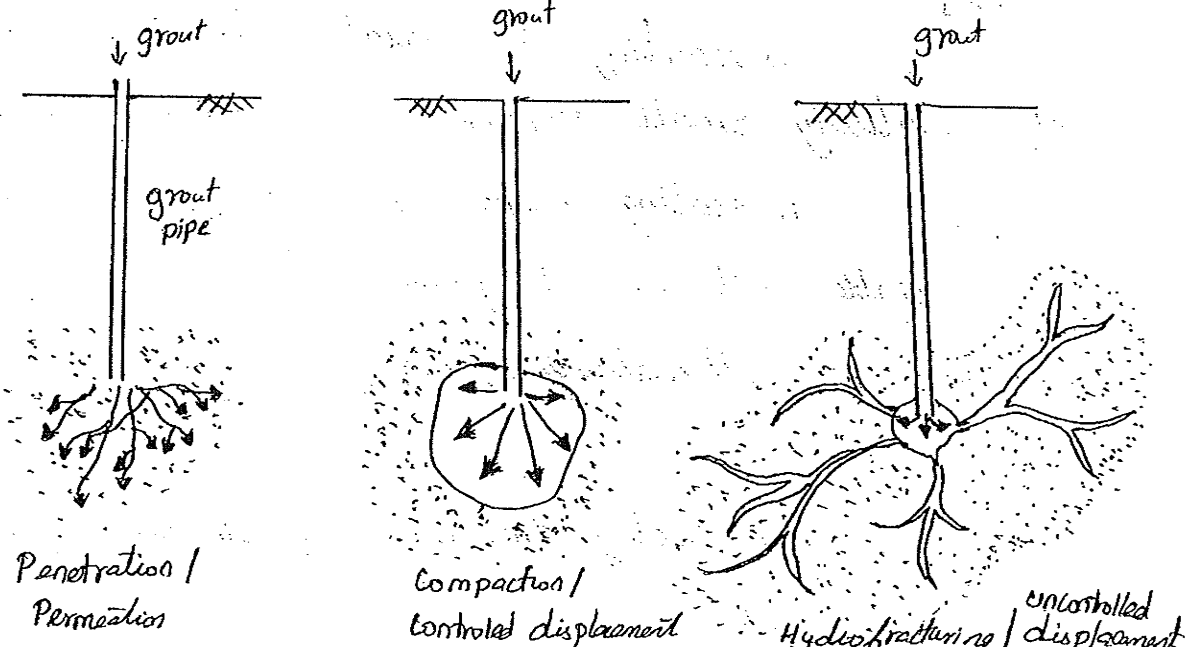
The principle of grouting is to introduce a substance into rock fissures (or) into a soil by pumping soil fluid called grout down a small diameter tube into a required depth

The three basic function involved in soil and rock grouting are

i, Penetration grouting - In this situation the grout flows freely with minerals minimal effects into soil voids or rock seams

ii, Compaction grouting - In this case the grout remain more or less instact as a mass and exert pressure on soil or rock

iii, Hydraulic fracturing - In this condition grout rapidly penetrates into a fractured zone which created when the grouting pressure is greater than the tensile strength of soil or rock being grouted



Types of grouts

i, Suspension grout
ii, Solution grout

i, Suspension grout

* When water is associated with cement, lime, soil etc., constitute suspension, Suspension grout are also referred to as particulate grout
* When these grout are injected into soil formation the relationship between the grout particle size and soil voids size should be considered

$$\text{Groutability ratio} = \frac{D_{15}}{D_{85}} > 20$$

D_{15} ⇒ Particle size at which 15% of soil finer
D_{85} ⇒ Particle size at which 85% of soil finer

→ **Grouting with Soil**

* Soil itself can be used to fill up some voids in coarse grained soil. Even sand & silt may be used for this purpose which would settle out quickly after injection
* Clay is a complex compond with particle < 0.002mm, it is suitable for injection into coarse sand and other soil with permeability
* This type of grout will exhibit low shear strength & hence used to reduce permeability
* Kaolinite & illite are preffered as filler grout, which produce low viscosity
* No flow of soil-grout occurs when water-to-soil ratio is kept very low, pressure is then exerted by grout against soil mass causing densification & movement of adjacent area. This is known as mudjacketing. quite often used for raising pavement

and to underpin shallow building foundation Nowadays it is also used to strengthen in-situ soil by forming compaction piles

→ Grouting with Cement Mixes

* The cement based grout is based on w-c ratio, rate of bleeding. The mobility of grout in excess cause high bleeding

* Low strength water cement ratio with proper admixture gives good ultimate strength

Materials used: Grout are made of usually

OPC - * water cement ratio from 0.5 to:1 to 5:1 depends on strength required & ground condition

* Suits for fissured rock, gravel, coarse sand

Rapid hardening cement * In case of high flowing water R.H.C used for its Rapid setteing, early strength

High alumina cement * For resisting attack by Sulphate and dilute acid

clay * It is consider as filler in cement grout less the 3% by weight of cement

* Used to control bleeding by holding the cement in suspension

Other materials like fine sand, fly ash, admixture, expansive additives

Water - Soil in combination with a suitable cement material would be better then soil alone

* Volume of soil between four and six times the loose volume of cement are common

* Volume of water mixing varies about 0.1/3 to 2 times of volume of clay / bag of cement

* Bentonite clay cement mixes used for Permeation grout

* Low water cement - soil cement mixture like soil alone can serve as displacement grout

Other materials - water insoluble and chemically active material, natural possolans, volcanic glass, opal, pumicite, clay material, zeolite, hydrated oxide

ii, Solution Grout

There are numerous solution grout are available

Solution grout can generally permeate finer soil than can suspension grout.

Many of them is termed as chemical grout

one shot grouting
Two shot grouting

In one short system where all the chemical are injected together after mixing setting time is controlled by varying the catalst concentration according to grout concentration, water composition and temparature.

In two-shot system one chemical is injected followed by injection of second chemical which reacts with the fist to produce a gel which subsequently hardem, it is slower and require higher injection preasure and more closely spaced grout holes with following advantages

i, absence of porticulate
ii, low viscosity
iii, control over setting time

Classification

1, Aqueous solution - silicate derivatives, Lignosulphite, Arcylamides, phenoplast resin
2, Colloidal solution - Organic solution, mineral solution
3, Non aqueous solution - Synthetic resin, vulcanizable oil, Bitumen material, Solvent system
4, Emulsion - Bituminous
5, production reacts with ground - Reaction with ground or ground water salts
6, Combined system

Grouting equipment & machinery

Both suspension and solution grout use the same mixing & delivery system and they are mainly differ in storage & mixing configuration

A grouting plants include a mixer, an agitator, a pump and piping connected to grout holes

There are two system

i, Single line type

ii, Circulating type

In circulating type, the unused grout is returned to the agitator

In single-line type the grout refussed is wasted

It is nesessary that a thorougly-mixed mixture is done in three stages

i, Formation of a vortex which acts as a centrifugal separator - thicker grout and unmixed cement are pushed to the pheriphery of vortex and passed to the mixing rotor

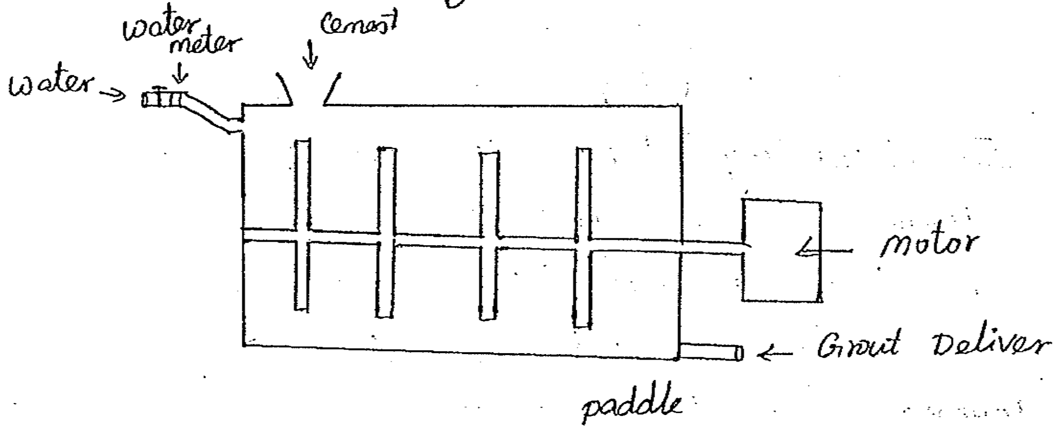
ii, Treatment of thicker fraction and unmixed cement from the vortex - there are subjected to a violent shearing action in a mixer rotor, which breaker up thicker fraction and lumps of cement and wet and produce a grout resembling like a colloidal solution rather than a mechanical suspension

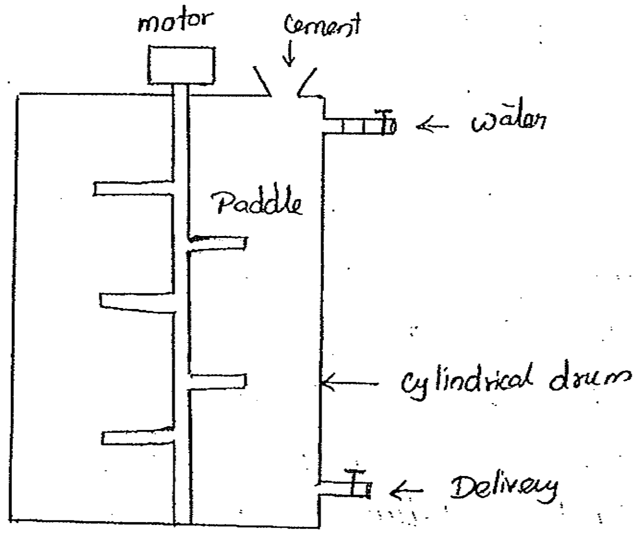
iii, circulation of treated fraction back into the entire vortex - vortex continues to spin till all the thicker fraction of cement lumps are broken the entire grout reaches an uniform consistency

A barrel type grout mixer consist of cylindrical drum placed either horizontal or Vertical with an axial shaft fitted with paddle or blade

The axial shaft is rotated normally or by power. Cement & water are thoroughly mixed with the help of paddle

Vertical type of mixer is used to handle small quantity of grout





Vertical & horizontal barrel type mixer

A grout mix should be continuosly agitated to prevent setting. This is achieved by an agitator sump between the mixer and grout pump

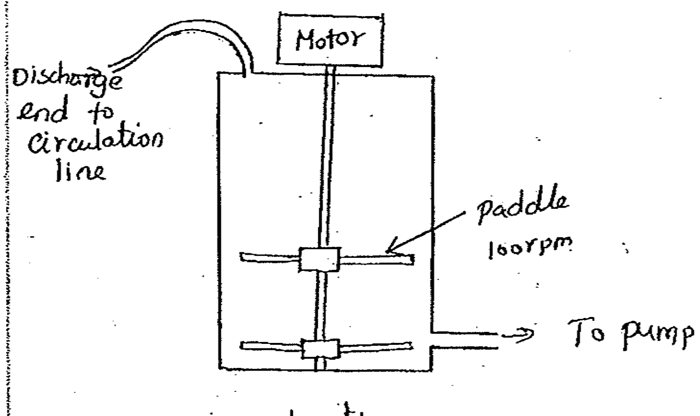
An agitator sump is a tank which has an agitating mechanism consisting of a vertical shaft to which horizontal blades are connected which is revolved at 30 to 100 rpm

The grout mix from the mixer is passed through a wire screen to remove piece of sack, string and other foreign matters

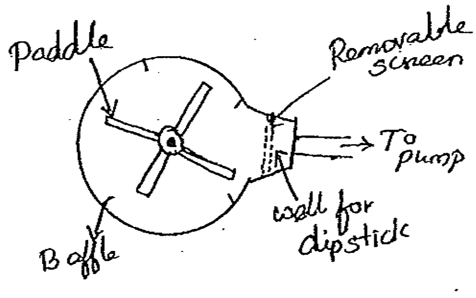
Also another screen is fixed to agitator near the delivery pipe, to prevent entering of lump to the pump

A graduated dipstick is used to measure the quantity of grout in the agitator

pump should be able to provide pressure of 2800 kN/m^2 or under and rate of displacement around 0.007 m^3. pump may be of piston or diaphragm type. The best all-purpose pump should be able to displace the wide variety of grout consistencies actually employed in practice including very low slump mixture



Elevation



Plan

Injection Methods

- Circuit Grouting
- Tube-a-Manchette grouting
- Point Grouting
- Jet Grouting
- Preassure Grouting
- Electrokinetic Injection

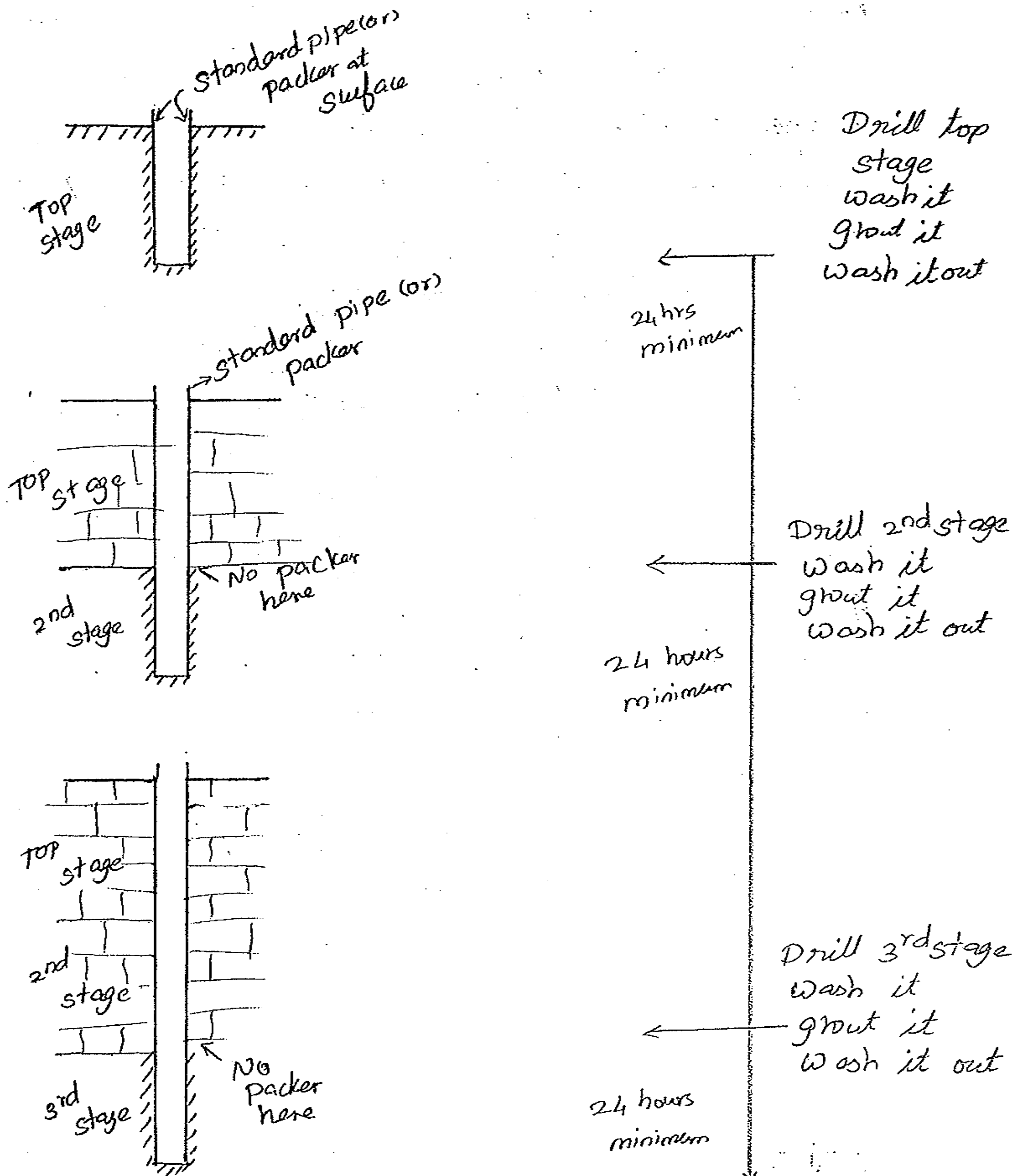
Circuit Grouting

This method is based on the principle of grouting from the top downward. A drill hole is bored to depth of bottom zone and grout is pumped down the grout pipe and returned up the drill hole. By this process clogging is almost eliminated. The grout hole is then deepened and the procedure repeated

Grouting from top :-

Holes are drilled down to the seemed closed to the surface and grouting is carried out. Holes are cleaned by washing and drilled continue to the next seam. Subsequent washing following by further drilling and repeated grouting are done until the entire operation is completed

This method gives low output. This method is quite useful for heterogeneous strata and provide improvement of upper zone and should any weakness exist, deals with at automatically. During grouting if any sensitive surface are encounted, they should be throughly tightened before grouting of lower stages



(a) Grouting from top drilling hole without packer

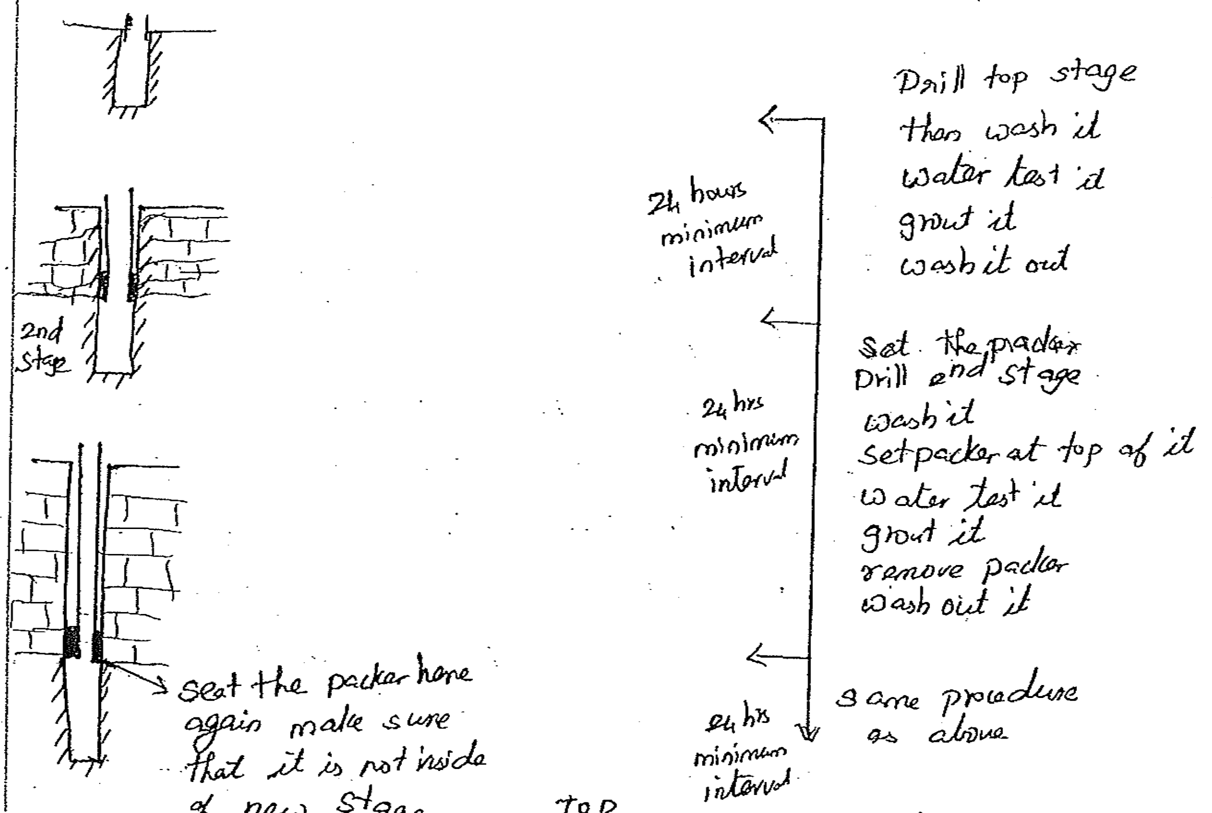
<u>Tube-a-manchette grouting</u>

The double packer method adopted for fissured rocks was found unsuitable in alluvial soil as difficulties faced to effect a seal on lower packer

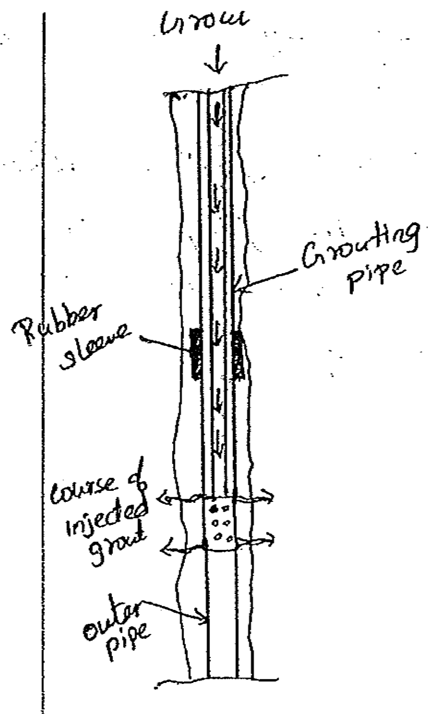
In this method a 12.5 to 15cm diameter hole is drilled in stratum and 6 cm ϕ pipe is called tube a manchette, with a row of hole is lowered inside the drill hole

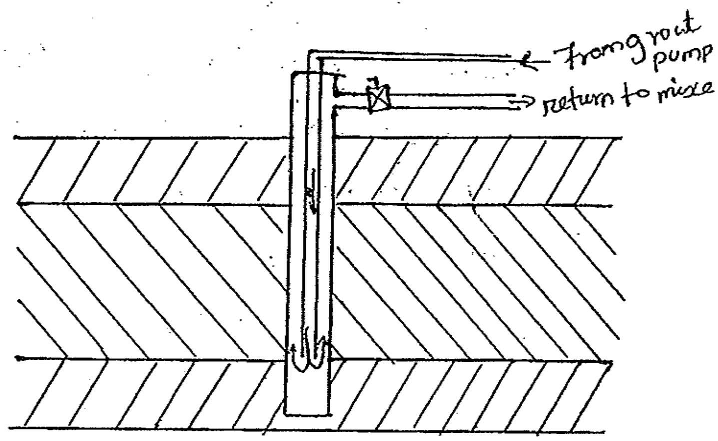
This drill hole is covered with wide tightly fitting rubber sleeves. The 6 cm ϕ pipe is sealed into the outer hole by a clay-cement grout. Grouting is effected from bottom upwards through a small interior grout pipe lowered into 6 cm diameter pipe, the inner grout pipe is tightly fitted to 6 cm ϕ pipe with the help of rubber packer

Then the grout is pumped in through the inner pipe due to high pressure clay-cement grout cracks and allow grout to fill the voids in surrounding soil. This solve both the problem of supporting the holes and allowing the holes and allowing grout to flow into the soil. This enable grouting in any desire sequence. It is difficult to assess the pressure-intake and costlier than other method



(b) TOP Circular Grouting with Packer





Circular grouting

Point Grouting

In shallow work of 10 to 12m deep the grout is injected from the point of a driven or jetted lance. Injection are delivered at pre-determined position along the line of drive and also on the return in system where a second reacting grout ingredient is to be placed independently of the initial injection. This is widdly used and has the limitation as regard to depth and penetrability of fine strata

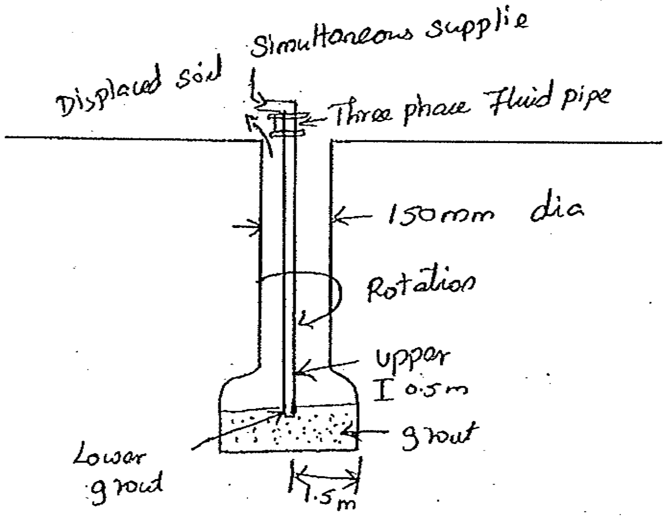
Jet Grouting

By this method, soil regar ranging from silt or clay and weak rocks can be treated

This method consist of lowering drill pipe into 150mm ϕ borehole at the bottom and pipe two nozzle are provided at 500 mm apart

The upper nozzle deliver water compressed air to produce jetting

The grout is delevared by lower nozzle. Growting action require stem to be slowly raied, where excavated material produce jetting action is replaced by forcing grout. The jet water could reach about 1.5m and by rotating the stem a colum of replaced earth may be formed !



Grout monitoring

Grout monitoring is measurement of flow rate, pressure, etc., for which diffent types of flow meters are available. Flow rate of grout during injection should be continuosly monitored. This is accomplished by the conventional method by obtaining sample undisturbed soil & rock sample of grouted material and then testing them for strength, permeability ; compressibility by adopting standard laboratory method.

The constrains about this approach is selection of test is
* boring location
* Depth of sampling
* Finance

Better method adoptable is
→ Indirect test - (Geophysical method)
(or)
→ Non destructive test

Monitoring during various time of grouting

Activity	Minor monitoring	monitoring in addition
Prior to grouting	- Inspect equipment - Set elevation survey points - Establish monitoring plan & procedure	-
During drilling	-	- Conduct pregrout radar & cross hole acoustic survey
Grouting materials	- Certificate of compilance - Trial grout mix	- Independent lab test

During grout	- Monitor injection pressure & flow rate - Grout sample for get time - plot grout-take log - Heave pressure measure on survey points	- pore pressure data - Insitu resistivity - Acoustic emission monitoring for hydrofracture
After grouting	- Final heave survey - Final review and signoff	- postgrout radar & acoustic survey

Stabilisation with Cement

Binding of soil particle together by cement is known as soil-cement stabilization.

It is generally generally accepted that cement react with siliceous soil to cement the partical together.

The pysical properties of soil-cement depend on the nature of soil treated, type + amount of cement utilised, placement + curing condition adopted. It is specially utilized in road + airfields.

Nature of soil

Soil should contain low organic matter for succesful stabilization. About 2% of organic matter is consider to be safe and inorganic soil can be pulvarised by cement.

Presence of clay in soil cause problem in pulvarising (Reduce to finer particle), mixing and compacting mixture.

If salt are presented lime (or) calcium chloride are sometimes added to cement.

In general the best result are obtained with well-graded soil having less than 50% of its particle finer than 0.074 mm and having plasticity index less than 20%.

Amount of cement

Stabilization made with cement % of 5 to 10% for satisfactory stabilization for gravel, a cement level of 5 to 10% by weight

For Sand, a cement level 7 to 12% of weight
For Silt, a Cement level 12 to 15% of weight
For clay, a Cement level of 12 to 20% of weight

When the cement is hydrating satisfactorily in a mixture, an increase in strength is obtained with increasing cement content

Mixing

More uniform soil-cement water mixture, provide strong and durable soil-cement. The initimacy of mixture is not directly proportionally to the mixing energy. As a mater of fact, increasing in continued mixing causes a decrease in degree of mixing and may lead to segregation of component. Thus continued mixing is upto optimal level. Soil-cement made by mix-in-place method and rotary tiller have shown about 50% to 70% of strength of a laboratory mixture

Moisture Content

The moisture content play two role in soil-cement

i, It influence the compaction characteristic, as with nature of soil

ii, It furnish water for cement hydration

The affect of moisture content on quality of soil-cement largely arises from its influence of compaction

Compaction Condition

In order to obtain satisfactory soil-cement, adequate compaction is essential compaction. As in natural soil it has been obsewed that for specimen having the same cement content and given the same amount of compaction, but having diffent moisture content, the greatest strength is obtained for optimum moisture content

Age and curing

* As with concrete, the compressive strength of soil-cement increase with age
* In practice, soil-cement is cured after compaction that prevent drying of surface
* The condition under which soil-cement is cured influence the resulting product
* Soil-cement cures rapidly with increase in temparature although it will harden at all temparature

Construction of soil-cement

i, Shaping the soil to be treated
ii, pulverizing the soil
iii, Adding water & cement
iv, Mixing
v, Compacting
vi, Finishing
vii, Curing

* The optimum sequence for adding water and cement and mixing depends on the Soil & site Condition

* Granular Soil are easy to handle compared to plastic soil

* Handling of plastic soils can be reduced by adding lime (1 to 3%)

* Construction of soil-cement in frost area should be done with utmost care

* Cement is most successful soil stabilizer and excellent result are guaranted if used properly

Admixture for Soil-Cement

In order to accelerate the set and to Improve properties of soil-cement, lime (or) calcium chloride is added

A reduction in amount of cement required to treat a soil responsive to cement

Stabilization of some of soil which are not responsive to cement

Use of some chemical along with cement have Important advantages such as reduce additive needed to perform, simplifying the handling & mixing, Reduce the total stabilizer cost.

Stabilization with lime

* Lime has been used as a soil stabilizer for road from older days

* Hydrated lime is most commonly used for soil stabilization with combination of fly ash, cement, bitumen

* There are two type of chemical reaction takes place in addition to wet soil

First → It is almost a colloidal type of reaction involving any of the following

i, ion exchange of calcium for ion naturally carried by soil

ii, a depression of double layer on the soil colloid because of double layer on soil colloid because of increase in concentration of pore water

iii, an expansion of double layer of soil colloid from high PH of lime

Second → The second reaction takes considerable time in cementing action, it is reaction between calcium from lime with available reactive alumina (or) silica from the soil

* Soil plasticity, density & strength are changed by addition of lime to soil

* Lime generally increases the plasticity index of low plasticity soil (or) decrease the plasticity of high plasticity soil ie IT BRINGS THE SOIL'S PLASTCITY INDEX TO OPTIMUM ~~LEVEL~~ LEVEL WHICH IS EASY TO HANDLE

In general, lime increase the strength of almost all type of soil

* The normal construction sequence of lime stabilization bases as follows

i, Scarify the bases
ii, Pulverise the soil
iii, Spread the lime
iv, Mix the stone & soil
v, Add water if necessary to bring optimum moisture content
vi, Compact the mixture
vii, Shape the stabilized base
viii, Cure for atleast 5 days
ix, Add wearing course

* Adequate care should be taken to prevent carbonation of lime

Stabilization with chemicals

There are many chemicals used for stabilization. Commonly used chemicals are discussed below:-

Calcium chloride

Calcium chloride is used as a water retentive (able to absorb moist & hold) in mechanical stabilised base and surfacing, salt absorb moisture from the atmosphere and retain it.

It makes alteration in pure water where water vapour reduces and rate of evaporation reduces

Freezing point gets lowered and results in reduction of frost heave

Calcium chloride act as a soil flocculant. (to form small mass)
It facilitate compaction and usually causes a slight increase in compaction density

The salt may be spread on the surface or incorporated into soil by mix-in-place and plant mix method

The frequent application depending upon the climatic condition therefore increase the cost

The relative humidity of atmosphere should be above 30% for salt

Sodium Chloride

The stabilization action similar to calcium chloride, but not widely used

It attracts and retain moisture and reduce rate of evaporation

Another phenomenon is crystallisation of salt in soil pores near the surface which retard evaporation and reduce formation of cracks ie shrinkage cracks

Where the salt is not applied on soil, but it is mixed into the soil by mix-in-place or plant mix method