Student ID: 15513, Discipline: MS Civil Engineering, Course Title: Ground Improvement Techniques, Instructor: Engr. Liaqat Ali, Date: 28th September 2020.

Q.NO(01)

A. How do we improve soil through excavation and replacement? How & which properties of soil are modified through additives, name a few additives with their functions?

ANS (A)

Improvement of Soil through Excavation & Replacement:

Soil replacement is one of the oldest and simplest methods which improve the bearing soil conditions. The foundation condition can be improved by replacing poor soil (e.g. organic soils and medium or soft clay) with more competent materials such as sand, gravel or crushed stone as well, nearly any soil can be used in fills. However, some soils are more difficult to compact than others when used as a replacement layer.

The use of replacement soil under shallow foundation can reduce consolidation settlement and increase soil bearing capacity. It has some advantages over other techniques and deep foundation as it is more economical and requires less delay to construction. Despite of soil replacement's advantages, the determination of the replacement soil thickness is based on experience. The region of high stress in a shallow foundation is only 1 to 1.5 its breadth and this part can be replaced by selected good soil. It has also been investigated and confirmed that with increasing replacement layer thickness the vertical settlement decreases.

How & which properties of soil are modified through additives:

The following properties of the soil are modified through additives:

- It improves the strength of the soil thereby increasing the bearing capacity of the soil.
- It is more economical, both in terms of cost and energy to increase the bearing capacity of the soil rather than going for deep or raft foundation.
- It is also used to provide more stability to the soils in slopes or other such places.
- It also prevents soil erosion or formation of dust, which is very useful especially in dry and arid weather.
- It also improves the soil water proofing and helps the soil from losing its strength.
- It also help in reducing the soil volume change, due to the change in temperature or moisture content.
- It improves the workability and durability of the soil.

Few additives and their functions are described below:

1. Sodium Silicate (Sodium silicate can be used in soil stabilization mainly because it reacts with soluble calcium salts in water solutions to form insoluble gelatinous calcium silicates)
2. Calcium Chloride (It stabilizes the moisture content of the soil and can be readily used in road construction)
3. Bituminous Material (Bituminous soil stabilization refers to a process by which a controlled amount of bituminous material is thoroughly mixed with an existing soil or aggregate material to form a stable base or wearing surface).
4. Resinous Material (For the purpose of soil stabilization, resinous waterproofing materials are considered to be those natural or synthetic resins whose chief function is to maintain the moisture content of a soil at or below optimum moisture by preventing entry of water into the treated and compacted mixture. Little or no cementing action is obtained from these materials. Unlike bonding agents, whose effectiveness generally increases with the quantity used, waterproofing agents usually attain maximum effectiveness when applied in small quantities—2 percent or less by weight of the treated soil).

Q.1B What are the various dewatering techniques which are generally used for ground improvement discuss brief?

ANS.B.

Various Dewatering Techniques for Ground Improvement:

Dewatering is a process in which groundwater contained within the site's soil is extracted, ensuring a stable foundation.
Dewatering is the term for the control of groundwater by pumping. On construction sites it may be known as 'construction dewatering'. The method is also used on mine sites –'mine dewatering'. The process of dewatering can be defined as –pumping from wells or sumps to temporarily lower groundwater levels, to allow excavations to be made in dry and stable conditions below natural groundwater level.
As an alternative to groundwater control by pumping, physical cut-off walls can be installed around a site to exclude groundwater from the site.
Water is discharged through

1. Storm drains
2. Municipal sewer System
3. Irrigation Purposes

Different methods of Dewatering are:

1. Open dewatering
2. Well point dewatering

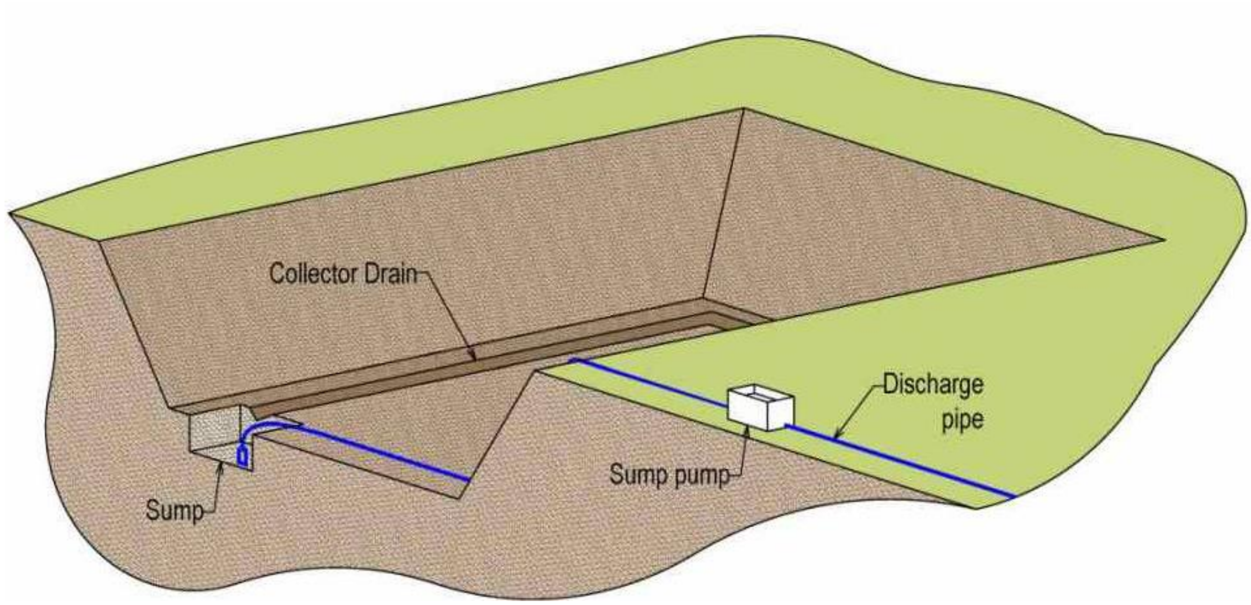
3. Deep well dewatering
4. General Sump pumping

Open Dewatering:

It enables one to lower the groundwater table adequately in cohesive and low permeable soils. Water is pumped off directly from sumps (ditches) along the toes of the slopes of the excavation works.

The suction hose with strainer is merely placed in the sump and the collected water is primed and discharged. This makes the open dewatering system easy to install and simple to operate. **Open dewatering system utilizes**

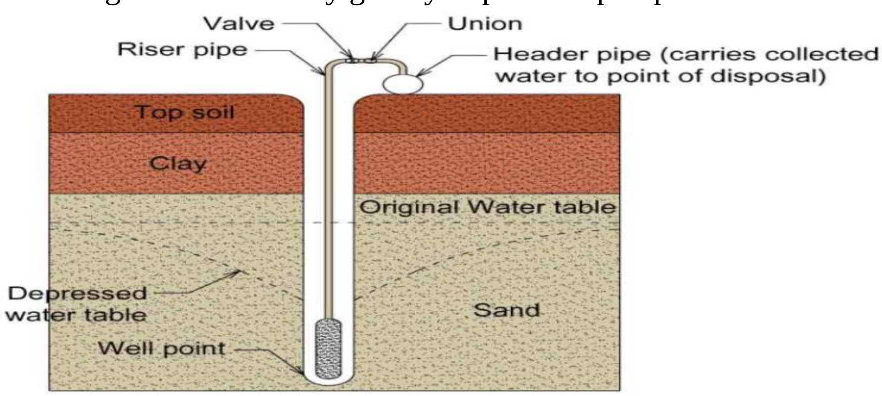
1. Self-priming
2. Vacuum assisted centrifugal pumps



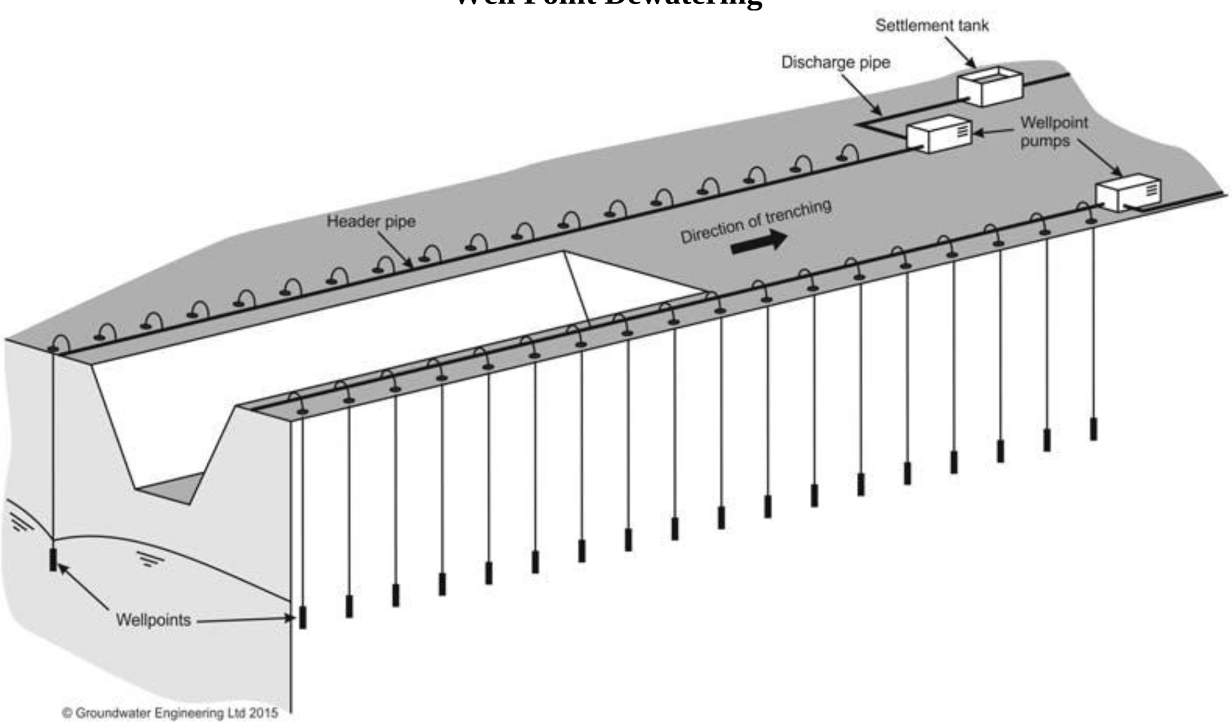
Open Dewatering System

Well Point Dewatering System:

1. Well point dewatering system is used to lower the ground water table adequately for deep and large construction sites.
2. It has proven to be a very flexible system. The water from high permeable soils is pumped from well points, installed along the trench of the site.
3. The well points are jetted and spaced to obtain an efficient drawdown against lowest capacity.
4. The well points with integral strainers are joined to transparent flexible hoses, which are connected by quick release couplers to the ring main header pipeline.
5. Well dewatering is done either by gravity or pressure pumps.



Well Point Dewatering



Well Point Dewatering

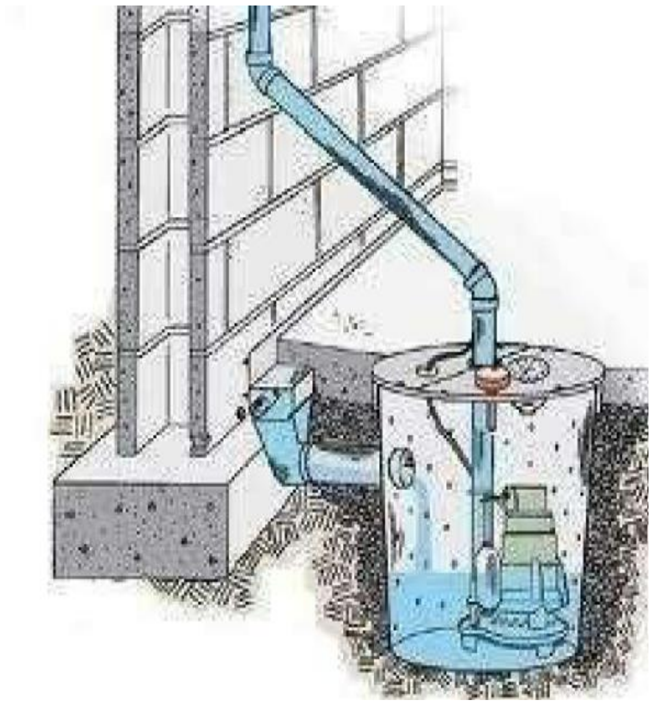
Deep Well Dewatering System:

Deep well dewatering systems enable one to lower the groundwater table to a considerable depth. A submersible pump is installed at the bottom of the well, of which the casing generally has a minimum diameter of 150 mm. The discharge pipes from the submersible pumps of a number of adjacent wells are connected to a common delivery main. The water is raised from the well by a multi-staged pump

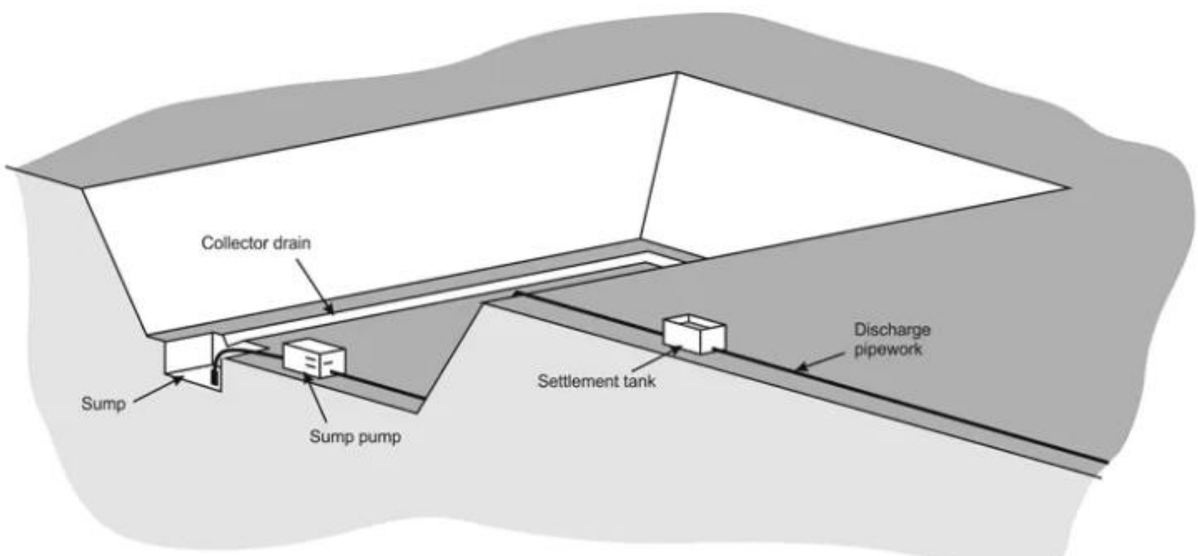
Deep Well Dewatering

General Sump Pumping:

Sump Pumps are used in applications where excess water must be pumped away from a particular area. They generally sit in a basin or sump that collects this excess water. This classification includes bilge and ballast pumps, centrifugal pumps, cantilever pumps, sewage sump pumps, submersible sump pumps and utility pumps, among others.



General Sump Dewatering



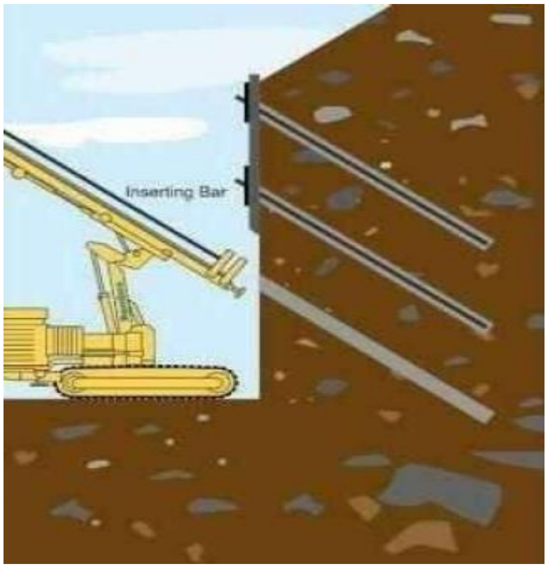
Open Sump Dewatering

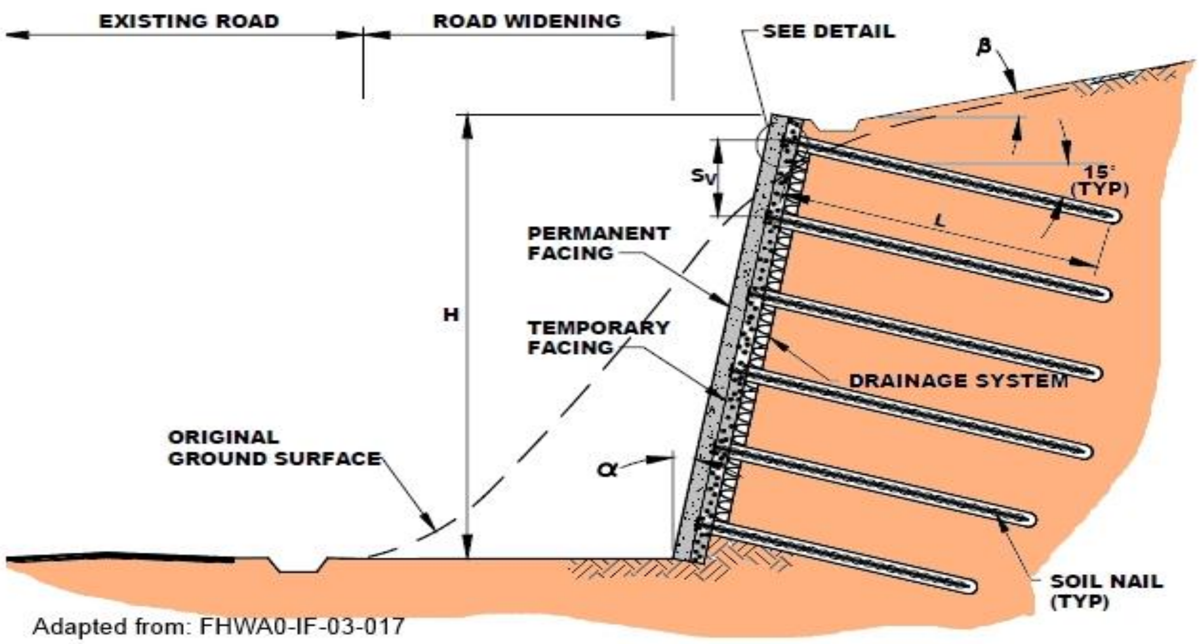
Q.NO (02)

A	What do you understand about soil nailing? Under what condition the soil nailing is preferable?	10
B	Discuss the characteristics of a grout where and why grouting is required? What is compaction grouting, discuss the advantages and disadvantages of grouting?	10

ANS 2A- Soil Nailing can be defined as follows:

- Soil Nailing is a technique to reinforce and strengthen ground adjacent to an excavation by installing closely spaced steel bars called "nails", as construction proceeds from top down.
- Soil nailing is a ground stabilization technique that can be used on either natural or excavated slopes. It involves drilling holes for steel bars to be inserted into a slope face which are then grouted in place. Mesh is attached to the bar ends to hold the slope face in position.
- It is an effective and economical method of constructing retaining wall for excavation support, support of hill cuts, bridge abutments and high way. Other applications for soil nailing include:
    - Stabilization of railroad and highway cut slopes.
    - Excavation retaining structures in urban areas for high-rise building and underground facilities.
    - Existing concrete or masonry structures such as failing retaining walls and bridge abutments.
    - Tunnel portals in steep and unstable stratified slopes.
    - Construction and retrofitting of bridge abutments.
    - Stabilizing steep cuttings to maximize development space.
    - Hybrid soil nail systems.
    - Shored Mechanically Stabilized Earth (SMSE) walls.
- The nails are subjected to tension, compression, shear and bending moments.





Typical Soil Nail Wall Arrangement

<u>Favourable Conditions for Soil Nailing:</u>

The main considerations for deciding whether **soil nailing** will be appropriate include

- the ground conditions
- the suitability of other systems, such as ground anchors, geosynthetic materials
- cost of ground improvement techniques.

Although soil nails are versatile and can be used for a variety of soil types and conditions

- It is preferable that the soil should be capable of standing – without supports – to a height of 1-2 m for no less than 2 days when cut vertical or near-vertical.

- All soil nails within a cross section are located above groundwater table.

Favourable Soils:

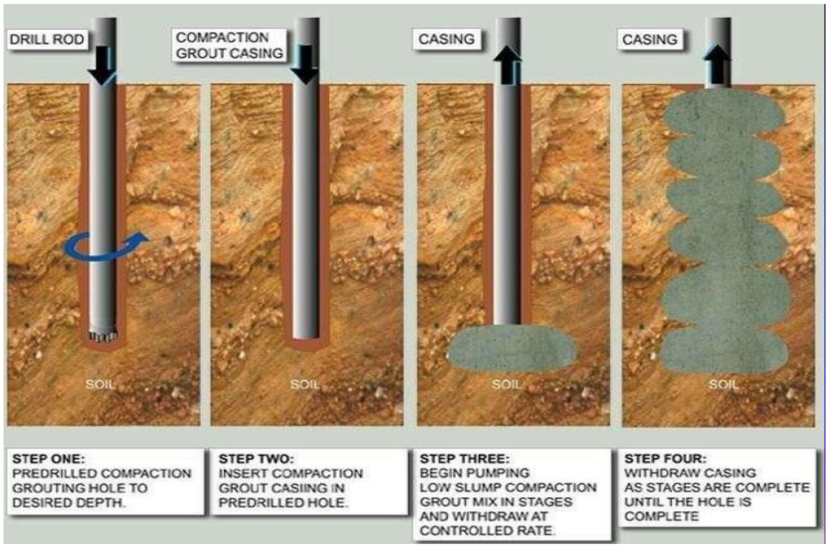
Stiff to hard fine grained soils, dense to very dense granular soils with some apparent cohesion, weathered rock with no weakness planes and glacial soils etc.

ANS 02B

- Grouting is defined as the process of injecting suitable fluid under pressure into the subsurface soil or rock to fill voids, cracks and fissures for the purpose of improving the soil.
- The process of grouting consists of filling pores or cavities in soil or rock with a liquid form material to decrease the permeability and improve the shear strength by increasing the cohesion when it is set. Cement base grout mixes are commonly used for gravely layers or fissure rock treatment.
- Grout can be defined as a solution, an emulsion or suspension in water, which will harden after a certain time interval. It can be divided into two main groups:

a. **Suspension grout** is a mixture of one or several inert materials like cement, clays etc. suspended in a fluid -- water. According to its dry matter content it is either of the stable or unstable type. Suspension grout is a mixture of pure cement with water.

b. **Liquid grout or solution grout** consists of chemical products in a solution or an emulsion form and their reagents. The most frequently used products are sodium silicate and certain resins.



TYPES OF GROUTS:

Cement Based Grout:

Cement-based grouts are the most frequently used in both water stopping and strengthening treatment. They are characterized by their water cement ratio and their Total Dry Matter / Water weight ratio. The properties and characteristics of these grouts vary according to the mix proportions used.

However, they have the following **properties and characteristics** in common.

- Stability and fluidity according to the dosage of the various components and their quality
- Unconfined compressive strength linked to water cement ratio
- Durability depending on the quantity and quality of the components
- Easy preparation and availability
- Ease of use
- Relatively low cost mixes

Pure Cement Grout:

- It is an unstable grout. However, bleeding can be avoided with water cement ratio less than 0.67.
- Usual mix proportions are from water cement ratio 0.4 to 1 for grouting. Very high mechanical strength can be attained with this type of grout.
- During grouting, cement grains deposit in intergranular voids or fissures is analogous to a kind of hydraulic filling.
- The grout usually undergoes a significant filtration effect. The grain fineness is an important factor for fine fissures.

Bentonite Cement Grout:

It is a stable grout. When bentonite is added to a cement suspension, the effects are: -

- Obtain a homogeneous colloidal mix with a wide range of viscosity.
- Avoid cement sedimentation during grouting.
- Decrease the setting time index and separation filtering processes.
- Increase the cement binding time.
- Improve the penetration in compact type soils
- Obtain a wide range of mechanical strength values.
- In water stopping, grout will include a lot of bentonite and little cement. In consolidation works, grout will contain a lot of cement and little bentonite. Ideal mixes should be both stable and easy to pump.

Grout with Fillers:

- Fillers are added in order to modify the viscosity of a given grout so as to obtain a low cost product to substitute the cement. The most commonly used fillers are the natural sands and fly ash from thermal power stations.
- The term "mortar" is commonly used to specify grouts with fillers that have a high sand content. Adding fillers reduces the grout penetrability, as the fillers are of larger grain sizes.
- Grouts with fillers are used when water absorption and/or the size of voids are such that filling becomes essential and when the leaking of grout into adjoining areas should be limited.
- In addition, fillers in grout will produce low slump grout with high viscosity for certain grouting purposes.

Silicate Based Grouts:

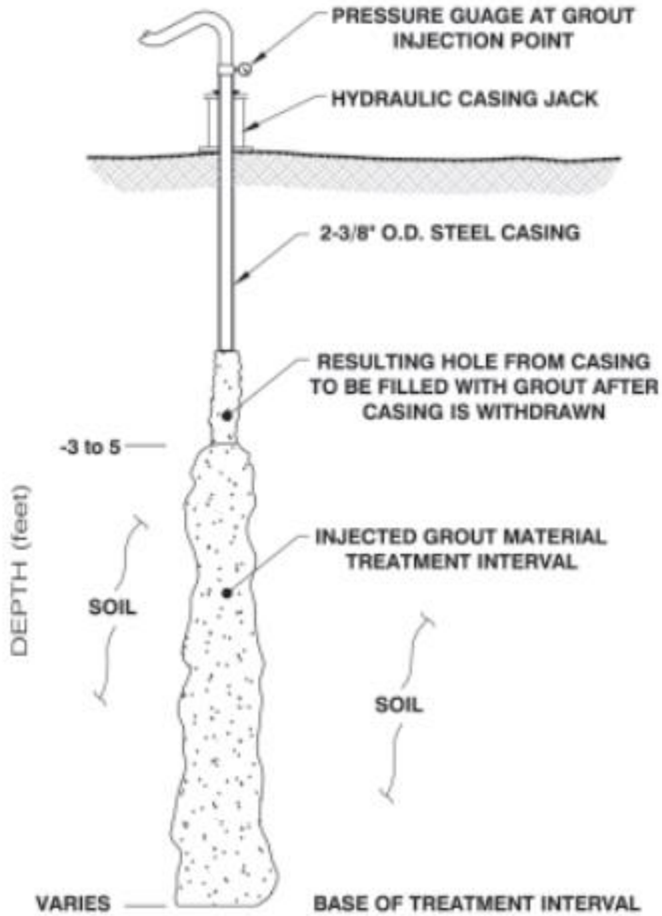
- Silicates based grouts are sodium silicate in liquid form diluted and containing a reagent.
- Their viscosity changes with time to reach a solid state that is called the "gel".
- They are used in soils with low permeability values such that all suspension grouts cannot penetrate. According to the type of grout used, the gel obtained will be water-
- Tightness and/or with strength that are temporary or permanent.
- When the temperature of a silicate decreases, its viscosity increases very rapidly. This temperature should not fall below 0 degree C in order to eliminate any risks of modification of its properties.

Soft Gel:

- It is mainly for water stopping purpose. They are gels with a very low dosage in silicate in which the gelling process is most generally obtained by adding a mineral reagent
- Their very low degree of viscosity (close to water) ensures the injection of very fine sand to achieve the water stopping purpose.
- Reduction in permeability can be up to 1 x 10-6 m/s and, in some case even up to 1 x 10-7 m/s when more lines of grout holes are added. There is also a slight improvement in strength, about 0.2 MPa.

Compact Grouting:

Compaction grouting is a ground treatment technique that involves injection of a thick-consistency soil- cement grout under pressure into the soil mass, consolidating, and thereby densifying surrounding soils in- place. The injected grout mass occupies void space created by pressure-densification.



Generalized Compaction Grouting Injection Profile

Advantages

In compaction grouting, a grout mixture is injected into the ground at the elevation of the substandard soil, where it then densifies and sturdies the soil. Here are some of the key advantages of this ground-shoring method:

- Compaction grouting causes minimal disruption to the landscape, surrounding soils, and nearby structures.
- This technique can be utilized for projects that have limited access and require more delicate installations.
- It is cost-effective and easy to install compared to some other soil stabilization and ground-shoring methods.
- Engineered Solutions has used this versatile technique on a variety of projects, and it has successfully strengthened ground soils in each instance.

Disadvantages

Truth be told, there are few disadvantages associated with compaction grouting. It is a very effective, affordable, and practical soil stabilization technique, and many satisfied clients throughout the region have been pleased with the success of this method when installed by Engineered Solutions. The one main disadvantage of this technique is that it is a bit messy and may require cleanup. However, when you work with Engineered Solutions, this is never an issue, as our team strives to leave your property looking as it did when we arrived, only with sturdier ground soils underneath.

Q.NO (03)

A	What are the causes for which ground improvement techniquies are under taken?	10
B	Identify various geotechnical problem of expansive soil?	10

ANS 3A: Due to present scenario best buildable lands not available for construction. Under the following scenario for which ground improvement techniques are under taken:

- Available sites are having low strength because :
- Filled up sites,
- Low lying water logged,
- Waste lands,
- Creek lands with deep deposits of soft saturated marine clays.
- Another problem: Design loads are high and the site is situated in seismic zones.

Traditional foundation techniques sometimes costlier than the super structure and in many situations can't be built.

When a poor ground exists at the project site, designer faces following questions:

- Should the poor ground be removed and replaced with a more suitable material.
- Should the weak ground be bypassed laterally by changing the project's location or vertically by the use of deep foundations OR
- Should the design of the facility (height, configuration, etc) be changed to reflect the ground's limitations?

Development of ground improvement, gives the designer/builder has a fourth option

To "fix" the poor ground and make it suitable for the project's needs

- Now the designer/builder faces new questions:
  - Should the problematic ground at the project site be fixed instead of bypassed?
  - What are the critical issues that influence the successful application of a specific fixing tool? And
  - Which fixing tool to be used from comprehensive and diversified set currently available in the tool box.

Major functions of Ground improvement in soil are listed below:

- ✓ To increase the bearing capacity
- ✓ To control deformations and accelerate consolidation
- ✓ To provide lateral stability
- ✓ To form seepage cut-off and environmental control
- ✓ To increase resistance to liquefaction
- Above functions can be accomplished :
  - By modifying the ground’s character - with or without the addition of foreign material.

ANS 3B:

Expansive Soils are soils that have the ability to shrink and/or swell, and thus change in volume, in relation to changes in their moisture content. They usually contain some form of expansive clay mineral, such as smectite or vermiculite, that are able to absorb water and swell, increasing in volume, when they get wet and shrink when they dry. The more water they absorb, the more their volume increases.

When the volume of earth increases because of losing, this increase is defined as swell. It is expressed as a percent of the original undisturbed volume. If the earth removed from a hole having a volume of 1 Cu Yd. is found to have a loose volume of 1.25 Cu Yd. The gain in volume is 0.25 Cu Yd., or 25 percent when earth is placed in a fill and compacted under modern construction methods, it will usually have a smaller volume than in its original condition. This reduction in volume is the result of an increase in the density. This reduction in volume is defined as shrinkage.

These expansive soils can prove to be a substantial hazard to engineering construction due to their ability to shrink or swell with seasonal changes in moisture content, local site changes such as leakage from water supply pipes or drains, changes to surface drainage and landscaping or following the planting, removal, or severe pruning of trees or hedges. Houses and other low rise buildings, pavements, pylons, pipelines, and other shallow services are especially vulnerable to damage because they are less able to suppress differential movements than heavier multi-story structures. Pavements are also highly susceptible to damage because of their relative light-weight nature extended over a relatively large area.

The amount by which the ground can shrink or swell is determined by the water content in the near-surface (active) Zone; significant activity usually occurs to about 3 m depth, unless this zone is extended by the presence of tree roots. During rainfall these soils can absorb large quantities of water becoming sticky and heavy and causing heave, or lifting, of structures, and during prolonged periods of drought they can become very hard, causing shrinkage of the ground and differential settlement. This hardening and softening is known as "shrink–swell" behavior and presents a significant geotechnical and structural challenge to anyone wishing to build on, or in, them. The main factors controlling this behavior are the clay content and mineralogy, the in-situ effective stresses, and the stiffness of the material. Processes such as original geological environment, climate, topography, land-use, and weathering affect these factors, and hence shrink–swell susceptibility.

Expansive soils can cause heaving of structures when they swell and differential settlement when they shrink. Damage to a structure is possible when as little as 3% volume expansion takes place, especially where these changes are distributed unevenly beneath the foundations. If the water content of a clay soil around the edge of a building changes, the swelling pressure will also change, while the water content of the soil beneath the centre of the building remains constant, causing a failure known as end lift. Where the swelling is concentrated beneath the centre of the structure (or where shrinkage takes place under the edges) a failure known as centre lift takes place. Another major contributing factor to ground shrinkage is tree growth, more specifically tree roots. Roots will grow in the direction of least resistance and where they have the best access to water, air, and nutrients. The actual pattern of root growth depends upon the type of tree, depth to water table, and local ground conditions. Damage to foundations resulting from tree growth occurs in two principal ways:

- Physical disturbance of the ground – caused by root growth and often seen as damage to pavements and walls

• Shrinkage of the ground – caused by water removal and often leading to differential settlement of building foundations.

Vegetation-induced changes to water profiles can also have a significant impact on other underground features, including utilities. Tree-induced movement has the potential to be a significant contributor to failure of old pipes located in clay soils near deciduous trees. Building, or paving, on previously open areas of land, such as the building of patios and driveways, can cause major disruption to the soil-water system. Sealing the ground in this way cuts off the infiltration of rain water and the trees that are dependent upon this water will have to send their roots deeper, or further afield, in order to find water. The movement of these root systems will cause a major ground disturbance and will lead to the removal of water from a larger area around the tree . Problems occur when structures are situated within the zone of influence of a tree. Pavements are also highly susceptible to damage because of their relative light-weight nature extended over a relatively large area.

The shrink–swell potential of expansive soils is determined by its initial water content; void ratio; internal structure and vertical stresses; as well as the type and amount of clay minerals in the soil. These minerals determine the natural expansiveness of the soil, and include smectite, montmorillonite, nontronite, vermiculite, illite, and chlorite. Generally, the larger the amounts of these minerals present in the soil, the greater the expansive potential. Clay particles are very small and their shape is determined by the arrangement of the thin crystal lattice layers that they form. In expansive clays, the molecular structure and arrangement of these crystal layers has an affinity to attract and hold water molecules between them (and on their surfaces) in a strongly bonded "sandwich," giving them a large shrink–swell potential. Soils with high shrink–swell potential will not usually cause problems as long as their water content remains relatively constant. This is controlled by the soil properties (mineralogy); suction and water conditions; water content variations; and geometry and stiffness of a structure founded on it. In a partially saturated soil, suction or water content changes increase the likelihood of damage occurring. In a fully saturated soil, the shrink–swell behavior is controlled by the clay mineralogy.

Expansive soils are found throughout many regions of the world and the subsidence and heave problems associated with them causes billions of pounds of damage annually, making them one of the most costly and widespread geological hazards to domestic properties and other low-rise structures. In arid/semiarid regions, their ability to take up large quantities of water can cause major damage to structures, whereas in more humid regions, problems mainly occur in the more highly plastic soils, especially after prolonged periods of drought. Either way, expansive soils have the potential to demonstrate significant volume change in direct response to changes in water content, induced through water ingress, modification to local water conditions, or via the action of external influence such as trees and shrubs. The shrink–swell hazard is controlled by a number of factors, primarily, the geology and mineralogy and the climate. Shrinkage and swelling usually occurs in the near surface to depths of about 3 m; water content in this upper layer is significantly influenced by climatic and environmental factors and is generally termed the active zone. The shrink–swell potential of expansive soils is determined by its initial water content; void ratio; internal structure and vertical stresses; as well as the type and amount of clay minerals in the soil. To understand and hence engineer expansive soils in an effective way, it is necessary to understand soil properties, suction/water conditions, temporal and spatial water content variations, and the geometry/stiffness of foundations and associated structures.

Q.NO (04)

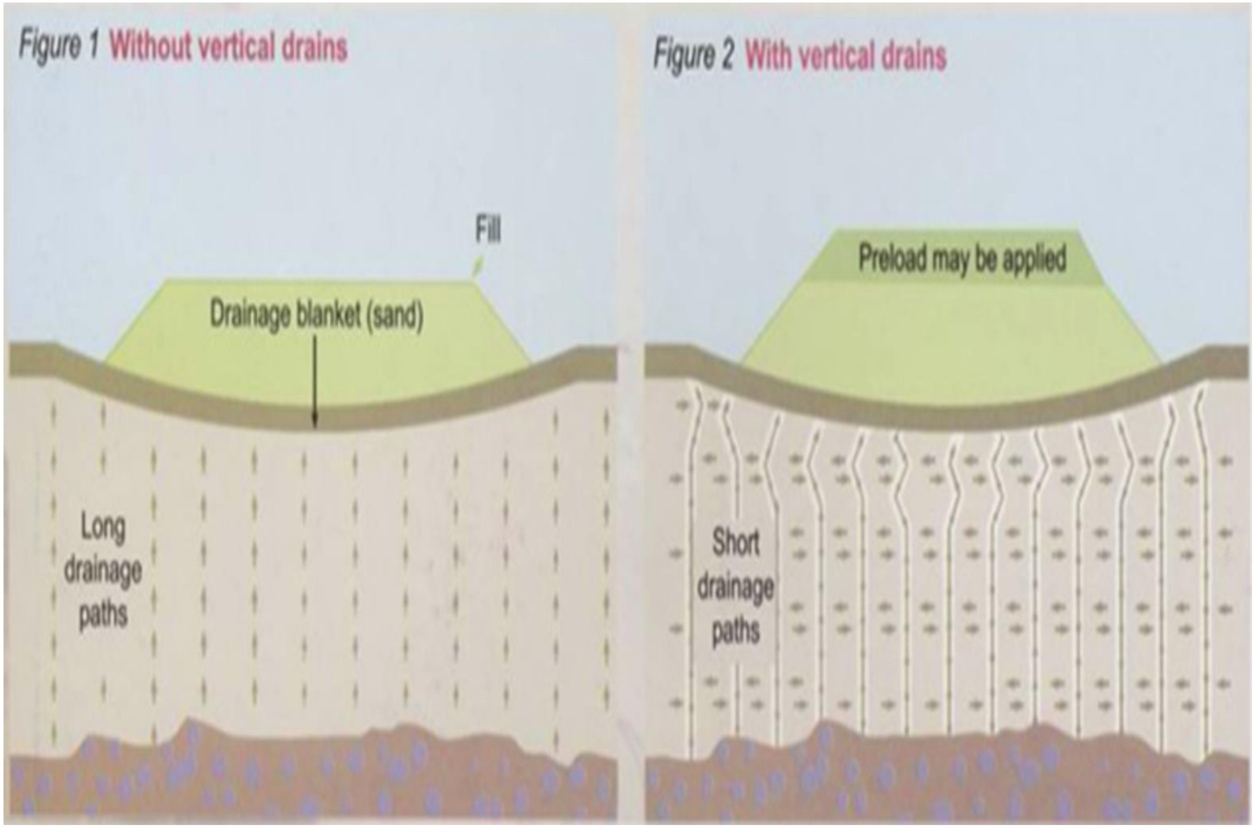
A	How stone columns and blasting help soil to stabilize and gain bearing capacity?	10
B	Which types of ground improvement would be used in black cotton soil and why?	10

ANS 4A:

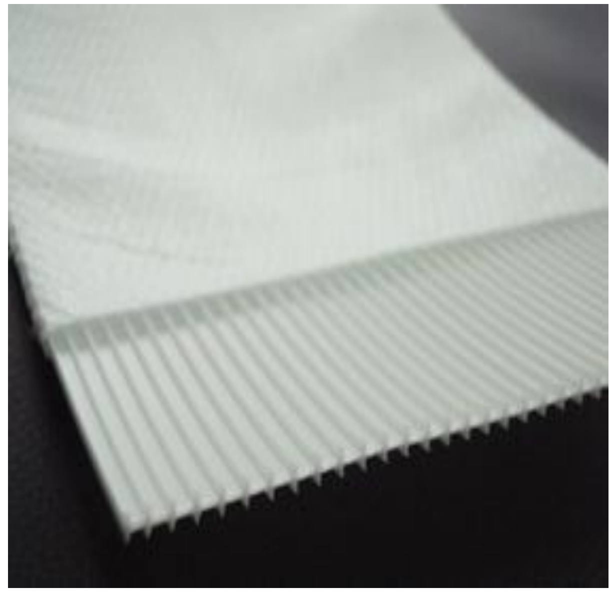
Stone column ground improvement involves adding vertical columns of stone into the ground to a depth of at least 4m below the ground surface. A layer of compacted gravel can then be put over the top of the columns, ready for the construction of new house foundations. The stone column method is quick to construct and can be done at any time of the year. Stone columns are extensively used to improve the bearing capacity of poor ground and reduce the settlement of structures built on them. A stone column is one of the soil stabilization methods that is used to increase strength, decrease the compressibility of soft and loose fine graded soils, accelerate a consolidation effect and reduce the liquefaction potential of soils. The columns consist of compacted gravel or crushed stone arranged by a vibrator. Geogrid is used for encasement to control bulging effect. A set of tests were conducted on the Load versus settlement behavior of the stone columns at laboratory by installing the stone columns of size fixed based on the length to diameter ratio. Clay soil has been taken as sample and waste marbles, pebbles were taken and different parameters. Another set of laboratory tests were conducted on the stone columns with geogrid encasement to control the bulging. From the results it was observed that encasement with geogrid controls the bulging effect and the locally available materials could be used as filler material of stone columns which can be used for improving the strength of loose soils.

Prefabricated Vertical Drains (PVDs) or ‘Wick Drains:

Composed of a plastic core encased by a geotextile for the purpose of expediting consolidation of slow draining soils. They are typically coupled with surcharging to expedite preconstruction soil consolidation. Surcharging means to pre-load soft soils by applying a temporary load to the ground that exerts stress of usually equivalent or greater magnitude than the anticipated design stresses. The surcharge will increase pore water pressures initially, but with time the water will drain away and the soil voids will compress. These prefabricated wick drains are used to shorten pore water travel distance, reducing the preloading time. The intent is to accelerate primary settlement. Pour water will flow laterally to the nearest drain, as opposed to vertical flow to an underlying or overlying drainage layer. The drain flow is a result from the pressures generated in the pour water.

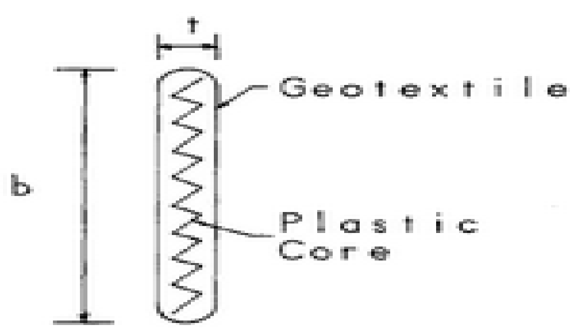


PVDs have a channeled or studded plastic core wrapped with a geotextile. The plastic core functions as support for the filter fabric, and provides longitudinal flow paths along the drain length. It also provides resistance to longitudinal stretching as well as buckling of the drain. The drain jacket acts as a filter to limit the passage of fine-grained soil into the core area. It also functions to prevent closure of the internal water flow paths under lateral soil pressure.



Equivalent Diameter:

Wick drains have an oblong shape, but the available theories of radial consolidation have been derived for drains having a circular shape, often taken as equal to the nominal diameter of the sand drain. Fellenius (1977) suggested that the equivalent cylindrical diameter of a sand drain is the nominal diameter of the sand drain multiplied by the porosity of the sand in the drain. The porosity of loose, free-draining sand can range from 0.4 to 0.5. This would result an equivalent cylindrical diameter of a sand drain of approximately half of the nominal diameter. In order to apply these theories to the design of fiel installations of wick drains, the equivalent diameter of an oblong shape is needed. Many equations have been suggested for computing the equivalent diameter, but each computation yields different results because they were derived under different assumptions.



Hansbo (1979) used a finite-element analysis and reported that the equivalent diameter of a drain is given as:

$d_w = 2 * ((b + t) / \pi)$ (1)

Where:

d_w = equivalent diameter of the drain

b = width of the prefabricated drain

t = drain thickness

Quality control of PVDs have improved in recent years with the incorporation of electronics to the installation equipment. Depth, installation force, GPS coordinates, and date/time information has been adopted in certain cases – such as the Craney Island project as documented by Goldberg (2013). Goldberg notes that this level of quality control is often not needed, as projects have consistently been successful without such measures.

Pre-Loading:

In this method preloading of 1.2 to 1.3 times of designed load is applied in advance to allow desired settlement and accelerate consolidation.

Specifically for alluvial soils having high moisture content, high compressibility and low shearing strength by lowering water table by any means.

Process can be accelerated by introducing sand piles in the periphery.

Best suited for air fields, storage tanks, flood control structures etc.

Undesired initial investment, disposal of use of preloaded soil, unexpected time delay may be considered.

Blasting Method:

Blasting is the use of buried explosives to cause the densification of loose cohesion less ground. The principal is that the blasting of explosives in a predetermined pattern causes liquefaction, followed by the expulsion of pore water and subsequent densification of the ground. Blast densification is being utilized for more than 80 years to densify loose, saturated sand deposits.

The aim of this ground-improvement technique is to densify and improve the engineering characteristics of loose sand deposits and thus prevent or minimize the effects of liquefaction during an earthquake. The liquefaction of loose, saturated sands due to seismically induced ground motions continues to be the major source of damage to facilities and loss of human lives after severe earthquake events.

Procedure of the blasting for ground improvement

- Series of boreholes are drilled and Pipe of 7.5 to 10 cm is driven to the required depth
- The detonator and the dynamic sticks are both enclosed in a water proof bundle and is lowered through casings
- Casing is withdrawn and a wad of paper or wood is placed against the charge of Explosive (To protect it from misfire)
- Boreholes are backfilled with sand to obtain full force of blast

- The charge is fired in definite pattern

Blasting is more effective in loose sands that contain less than 20% silt and less than 5% clay. In case of partial saturated soil, the capillary action obstructs the densification tendency by preventing soil particles to come close. So this method is not useful for partial saturated soils. When deeper deposits are in question, the blasting is done in stages. Repeated shots are more effective than a single larger one.

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With the increasing of population and the reduction of available land, more and more construction of buildings and other civil engineering structures have to be carried out on weak or soft soil. Owing to such soil of poor shear strength and high swelling & shrinkage, a great diversity of ground improvement techniques such as soil stabilization and reinforcement are employed to improve mechanical behavior of soil, thereby enhancing the reliability of construction. Black cotton soil is one of the major soil deposits of Indo-Pak Subcontinent. They exhibit high swelling and shrinking when exposed to changes in moisture content and hence have been found to be most troublesome from engineering considerations. Stabilization occurs when lime is added to black cotton soil and a pozzolanic reaction takes place. The hydrated lime reacts with the clay particles and permanently transforms them into a strong cementations matrix.

The basic objectives are to improve the characteristics of black cotton soil as follows.

- Improvement of bearing capacity of Black Cotton Soil by adding of lime.
- Variation of Strength of soil at different water content.
- Effect of lime on CBR value of the soil.
- Effect of lime on Compressive strength of soil.

In order to achieve the above objective, the black cotton soil has been arbitrarily reinforced with lime. So the suitability of lime is considered to enhance the properties of black cotton soil.

Soil Lime Stabilization:

1. Basic Properties of Soil Lime Mix:
    - Soil – lime has been widely used as a modifier or as a binder.
    - Soil – lime is used as modifier in high plasticity soils.
    - Soil – lime also imparts some binding action even in granular soils.
    - It is effectively used in expansive soils with high plasticity index.

2. Factors Affecting the Properties of Soil with lime:

- Lime Content: Generally increase in lime content causes slight change in liquid limit and considerable increase in plasticity index. The rate of increase is first rapid and then decreases beyond a certain limit upto lime fixation point.
- Types of Lime: After long curing periods all types of limes produce some effects. However the quick lime has been found more effective than hydrated lime. Calcium carbonate must be treated at higher temperature to form quick lime calcium oxide. Calcium oxide must be slaked to form hydrated lime.
- Curing: The strength of soil – lime increases with curing period upto several years. The rate of increase is rapid during initial period. The humidity of the surroundings also affects the strength.
- Additives: Sodium metasilicate, sodium hydroxide and sodium sulphate are found to be very much useful.

Lime Meets the Construction Challenge: Using lime can substantially increase the stability, impermeability and load bearing capacity of the subsurface. In general, all lime treated fine-grained soils exhibit decreased plasticity, improved workability and reduced volume change characteristics. Black cotton soil exhibits improved strength characteristics using appropriate type, percentage and curing of lime. Lime-stabilization of geo-materials by producing cohesive materials in the soil increases the strength and decreases materials plastic properties. That is why lime-stabilization is the most appropriate chemical modification ground improvement technique for Black Cotton soil.