ANSWER BOOK

OF

GROUND IMPROVEMENT TECHNIQIUES

Submitted To	**Engr Liaqat Ali**
Submitted By	**Mubasher Daraz**
Student ID	**15266**
Program	**MS (CEM)**
Date Of Submission	**28 sep 2020**

IQRA NATIONAL UNIVERSITY

PESHAWAR

Q No 1

Part A:

Soil Improvement through Soil removal and 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 which in many cases is questionable

Properties of soil are modify through additive

Improvement of soil properties or soil stabilization is a technique introduced for the purpose of improving poor soil properties to make it acceptable for construction in the engineering projects. The effect of additives on the engineering properties of soil has been studied by many researchers. The wide use of traditional additives such as cement, lime, fly ash, and asphalt emulsion etc. for improvement of soil led to an attempt to select other non-traditional additives, especially, a few studies have been conducted in the field of soil improvement using non-traditional additives. The variety of non-traditional stabilization additives dictated some attempts to classify these different additives according to their active composition

Few additives with their function

Gypsum

Gypsum is a fantastic clay breaker. Gypsum is calcium sulfate, a naturally occurring mineral. It has been touted as beneficial for breaking up compact soil, especially clay soil. It is useful in changing the soil structure of excessively heavy soils which have been impacted by heavy traffic, flooding, over cropping, or simply overly weatherized

Lime

Lime used to increase soil Ph value. Lime is a soil amendment made from ground limestone rock, which naturally contains calcium carbonate and magnesium carbonate. When lime is added to soil, these compounds work to increase the soil's pH, making soil less acidic and more alkaline.

Fly ash

Fly ashes are used as fill material, alkaline amendments, cement, and grout material. Because of high-soluble salt content and leachable macro and micronutrients, they can be used as a soil amendment to replace fertilizer and lime.

Part B:

Dewatering Methods

The different methods available for dewatering are not interchangeable, since each method has a specific application. For this reason, selecting the proper method for a particular ground condition is critical. There are four main dewatering methods used in construction:

- WellPoint
- Eductor Wells
- Sump Pumping
- Deep Wellpoint.

Wellpoint Method

In the wellpoint method, a series of wells is aligned along the excavated area. The wellpoints are connected to riser pipes, and these are connected to a common header pipe and vacuum pump. Water is discharged away from site, with the adequate treatment to remove contaminants and unwanted materials.

Since the wellpoint method uses suction, it is suitable for depths up to 5 or 6 meters. A deeper drawdown requires multiple stages of wellpoints.

Eductor Wells

The eductor well method is similar to the wellpoint method. The main difference is that Eductor wells use high-pressure water instead of a vacuum to draw water from the wellpoints. This method uses the venturi principle:

- High-pressure water is circulated through eductors in the base of each well, creating a reduction in pressure.

- The pressure drop draws water through the riser pipe.

With this method, the water table can be lowered to a depth of 10m to 45m, and multiple pumps can operate in a single station. The Eductor well method is suitable when the ground has low permeability materials, such as clays and silts.

Sump Pumps

Sump pumping is the most common method for dewatering, since it basically works by gravity. This method is also the most economical.

Groundwater is allowed to seep into the excavation area, where it is collected in sumps to be pumped out. This method is used in shallow excavation areas, where the soil has a high content of sand or gravel. If the excavation area is large, this method can use a ditch - a long and narrow sump along the excavation.

Deep Wellpoint

The deep wellpoint methods use boreholes with submersible pumps, lowering the groundwater level below the excavation level. Wells with diameters between 15 to 20 cm are drilled around the excavated area, where groundwater falls due to gravity .This reduces the water table, depleting the groundwater in the excavated area.

Casings are used to retain wells, along with screens and filters to keep sediment out. This method is suitable for projects where a large amount of water must be removed from the well.

Q No 2

Part A: Soil nailing is a construction remedial measure to treat unstable natural soil slopes or as a construction technique that allows the safe over-steepening of new or existing soil slopes. The technique involves the insertion of relatively slender reinforcing elements into the slope – often general purpose reinforcing bars (rebar) although proprietary solid or hollow-system bars are also available. Solid bars are usually installed into pre-drilled holes and then grouted into place using a separate grout line, whereas hollow bars may be drilled and grouted simultaneously by the use of a sacrificial drill bit and by pumping grout down the hollow bar as drilling progresses. Kinetic methods of firing relatively short bars into soil slopes have also been developed. Bars installed using drilling techniques are usually fully grouted and installed at a slight downward inclination with bars installed at regularly spaced points across the slope face.

Conditions for which soil nailing preferable:

- **Dry, poorly graded cohesion less soils.** When poorly graded cohesion less soils are completely dry, contain no fines, or do not exhibit any natural cementation, apparent cohesion is not available. Therefore, the required vertical or nearly vertical cuts are difficult to achieve.
- **Soils with high groundwater.** Perched groundwater occurring behind the proposed soil nail wall will require significant drainage, which is necessary to stabilize the mass of soil in this location. Additionally, large amounts of groundwater can cause drill holes (particularly in loose granular soils) to collapse easily, thus requiring a costly soil nail installation. Excessive groundwater seeping out to the excavation face may cause significant difficulties for shotcrete application.
- **Soils with cobbles and boulders.** A large proportion of cobbles and boulders present in the soil may cause excessive difficulties for drilling and may lead to significant construction costs and delays. When only a few boulder sand cobbles are present, modifying the drilling orientation from place to place may minimize or eliminate most of the difficult drilling. However, this approach has practical limitations when too many boulders are present.
- **Soft to very soft fine-grained soils.** These soils typically have SPT N-values less than 4 and are unfavorable for soil nailing because they develop relatively low bond strengths at the nail-grout-soil interface, thereby requiring unreasonably long nail lengths to develop the required resistance. Long-term deformations (creep) of the soils may be a concern for highly plastic clays. Concerns for creep deformations are generally less critical for temporary applications. As with any retaining system constructed in a top-down manner, the potential for instability at the bottom of the excavation is high in soft fine-grained soils. Additionally, high-plasticity soils may be expansive and may induce additional localized pressure on the facing due to swelling.
- **Organic soils.** Some organic soils such as organic silts, organic clays and peat typically exhibit very low shear strengths and thereby low bond strengths, which causes uneconomical nail lengths. While some organic soils can exhibit acceptable shear strengths, other organic soils like fibrous peat may be highly heterogeneous and highly anisotropic. In this case, while the soil shear strength can be reasonable along some orientations, it may be significantly low along other orientations. These unfavorable orientations may have a detrimental impact on the wall stability and very long soil nails will be required. In addition, organic soils tend to be more corrosive than inorganic soils.
- **Highly corrosive soil (cinder, slag) or groundwater.** These conditions may lead to the need of providing expensive corrosion protection. These conditions are obviously more disadvantageous for permanent applications of soil nail walls.
- **Weathered rock with unfavorable weakness planes and karst.** Weathered rock with prevalent unfavorable weakness planes such as joints, fractures, shears, faults, bedding, schistosity, or cleavage may affect the drill hole stability and make grouting

difficult. In addition, the presence of these discontinuities may cause the formation of potentially unstable blocks in the retained mass behind the wall during excavation. The marginal stability of blocks may rapidly deteriorate due to various factors, such as gouge in the joints, uplift and lateral hydrostatic pressures, and seepage forces. The stabilization of individual blocks may be necessary and can make this solution uneconomical when compared to conventional soil nails. In addition, grouting in rock with very large open joints or voids will be very difficult and/or expensive due to excessive grout loss. Grouting in karstic formations is not appropriate.

- **Loess.** When it is dry, loess may exhibit acceptable strengths that would allow economical installation of soil nails. However, when sizable amounts of water ingress behind the proposed soil nail wall, the structure of the loess may collapse and a significant loss of soil strength may take place. Therefore, the collapse potential upon wetting of these soils must be evaluated. Appropriate measures to avoid excess water migration to the soil nail area must be provided in loess exhibiting significant collapse potential. Additionally, considerably low soil shear strengths may arise for the wetted condition. In these cases, unusually long soil nail lengths may result in using conventional methods of nail installation. Regrouting (an atypical and more costly step) has been used to increase bond strengths in loess.

Part B:

A grout is a neat, meaning that this operation must be performed by gravitational injection, cement or a mortar of fluid consistency with fine granulates.

It is used:

- in the renovation of old masonry elements exhibiting structural damage (disintegration of roughcast mortar) which cannot be dismantled
- to stop water leaks via injection under pressure,
- or for sealing pegs or bolts, in particular for underground works.

Compaction Grouting

Compaction grouting is a ground improvement method which is used to increase the density of the soil. This method of grouting is usually used to rehabilitate settlement of sensitive structures.

Compaction grouting is carried out by injecting stiff mortar-like grout under pressure through cased boreholes to form bulbs, which pushes the surrounding soil to the side and increasing its density. This grouting method is used for treating a wide variety of loose soils, with relatively good drainage, and is performed at depths ranging from 2m, right down to several tens of meters.

The works are carried out from the surface, with the grout bulbs created from the bottom-up in successive stages of 1m. The degree of densification depends on the type of soil treated and the grid pattern selected for the injection points, with injection rates generally varying from 4 to 6m^3 per hour, with that reducing to 2m^3 per hour in particularly sensitive conditions. Injection pressure is generally in the range of 1 to 4MPa.
Compaction grouting can also be carried out from an existing basement or locations with limited headroom, and it is possible to drill through hard material to reach the low strength strata beneath for treatment.

The advantages of grouting include:

- This can be done on almost any ground condition
- It does not induce vibration and can be controlled to avoid structural damage.
- Improvement in-ground structures can be measured.
- Very useful for limited space and low headroom applications.
- Used for slab jacking that lifts or levels the deformed foundation
- It can be installed adjacent to existing walls
- Can be used to control seepage, groundwater flows and hazardous waste plumes

Disadvantages:
The one main disadvantage of this technique is that it is a bit messy and may require cleanup.

Q No 3

Part A:

CAUSE FOR GROUND IMPROVEMENT TECHNIQUIES

Ground improvement Techniques is carried out to:

- Prevent excessive settlements of the surface of the reclamation area when structures like buildings, roads and other foundations are loaded on it.

- Improve shear strength of the fill and subsoil to ensure sufficient bearing capacity of the foundations and/or sufficient stability of the slopes;
- Increase the density of the fill mass and/or subsoil to prevent liquefaction; and
- Improve soil permeability in order to increase drainage capacity
- Increasing shear strength, durability, stiffness.
- Stability and mitigating undesirable properties (e.g. Shrink/ swell potential, compressibility, liquefability
- Modifying permeability, the rate of fluid to flow through a medium; and Improving efficiency and productivity by using methods that save time and expense,

  The engineer must take a determination on how best to achieve the desired goals required by providing a workable solution for each project encountered. Ground improvement methods have provided adverse choice of approaches to solving these challenges.

Part B:

Expansive soils present significant geotechnical and structural engineering challenges the world over, with costs associated with expansive behaviour estimated to run into several billion pounds annually. Expansive soils are those which experience significant volume changes associated with changes in water content. These volume changes can either be in the form of swell or shrinkage, and are sometimes known as swell–shrink soils. Key aspects that need identification when dealing with expansive soils include soil properties, suction/water conditions, temporal and spatial water content variations that may be generated, for example, by trees, and the geometry/stiffness of foundations and associated structures. Expansive soils can be found both in humid environments where expansive problems occur with soils of high plasticity index, and in arid/semi-arid soils where soils of even moderate expansiveness can cause significant damage. This chapter reviews the nature and extent of expansive soils, highlighting key engineering issues. These include methods to investigate expansive behaviour both in the field and the laboratory, and the associated empirical and analytical tools to evaluate expansive behavior. Design options for pre- and post-construction are highlighted for both foundations and pavements, together with methods to ameliorate potentially damaging expansive behavior.

The soils around your foundation can put a lot of pressure on your foundation walls! The amount of pressure will vary depending on three factors:

Expansive Soil Can Cause Foundation Problems

Expansive spoil is distinguished by the presence of swelling clay minerals that can absorb a significant amount of water molecules. When expansive soils obtain moisture, they expand or swell up. Likewise, when expansive soils lose moisture, they begin to shrink.

Hence, when rain or improperly channeled water enters too quickly and oversaturated your backfill soil, that excess water will exert immense pressure against your foundation walls. This is known as hydrostatic pressure.

Since foundation walls are designed to support loads from above rather than lateral (sideways) bearings, expanding soil can cause foundation problems.

The Problem with Hydrostatic Pressure

Water is heavy! And it can build up underneath the floor, pushing upwards against your foundation. This is known as hydrostatic pressure and will enter the home through any weak point it can find.

When that pressure bearing down becomes greater than you're below ground basement or crawl space walls can handle, the affected walls will begin to crack, bow, and push inwards.

As pressure continues to build over time, what starts as a hairline crack will worsen and can eventually result in extreme wall failure, typically in the form of buckling, shearing, or even complete collapse.

In addition to hydrostatic pressure caused from heavy or steady rains, factors such as expansive clay (which all homes in Georgia reside on) and water thawing too quickly after a winter freeze can also create too much stress on basement walls, causing them to crack, bow, and deteriorate.

Backfill soil behaves differently than unexcavated, virgin soils farther away from the foundation. Because it is far less compact and has already been disrupted to carve out a bowl in which to build the home, backfill soil absorbs more water and expands far more quickly than the virgin soil that starts 8-10 feet away from your home.

Backfilled Soils & Virgin Foundation Soils

When your home was being built, contractors had to dig a big hole in the ground. This was created to make space for your basement. They dug up mounds of the hard-packed earth that were there some of which may have laid there untouched for hundreds of years beforehand.

As foundation walls and house framing were completed, the empty space around the foundation needed to be filled. Contractors typically backfill foundation walls using some of the excavated soil that was removed to make room for the basement. This is known as the clay bowl effect because a clay bowl is carved out from the virgin soil to make room for the house.

The excavation process breaks up and loosens the soil before it is eventually poured back into its original place (or backfilled). Because of this, backfill soils will always be more permeable, or water-absorbent, than the hard-packed earth beyond. When it rains, the water collects in backfilled soils. That water rushes through the soil and presses down in the form of hydrostatic pressure against foundation walls.

Q No 4

Part A:

Use of Stone Columns to stabilize Soil

Stone column is one of the ground improvement techniques. This technique has a proven performance, short time schedule, durability, constructability and low costs. The stone column technique has been used as a method of reinforcement of soft ground over the past 30 years. The bearing capacity of the stone column still has high level of uncertainties because the existing formulas for the estimation of the bearing capacity are general and do not take into consideration the type of the stone column whether if it’s floating or end bearing and the method of the implementation of the stone columns and the length to diameter ratio of the stone column (L/D) and many other factors that affect the bearing capacity of the stone column.

Advantages:

- This method can be used in improving the slopes.
- Post settlements are not observed in this method as the stone are every granular.
- Reduction of foundation settlements.
- Increase in resistance to soil liquefaction
- This method can also resist lateral loads.
- Construction is very simple and effective.

Blasting Method to Stabilize Soil

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.

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.

Part B:

Ground Improvement in Black Cotton Soil

Black cotton soils are boon to agriculture but are proved to be serious threat to construction founded on it. These soils have the property of high swelling due to imbibing of water in monsoon and shrinkage due to evaporation of water in summer seasons. This swelling and shrinkage nature is attributed to the presence of mineral montmorillonite. Because of this high swelling and shrinkage nature, the structures constructed on these soils experience cracks, making it unsuitable for foundation. Hence there is a need for improving black cotton soil to suite as foundation material.

Following materials can be used for ground improvement in black cotton soil;

Use of Lime

Lime stabilization helps in increasing the strength, durability and also minimizes the moisture variations in the soil and lime must be well compacted for obtaining sufficient strength and durability by maintaining OMC and the same assumption is made in the experimental determination of the required lime proportion. Quality of lime to be added depend upon the specific surface area of soil particles and it is more for fine grained soils even up to 15% by weight of soil. The stabilization of black cotton soil with lime has been done in three different ratios of lime i.e. 0%, 4%, and 6%. After the stabilization of soil with lime in above percentage the various tests have been performed.

Use of Brick Powder

Studies on use of brick powder as stabilizer for black cotton soil showed that when about 50% brick powder is mixed with black cotton soil there has been significant increase in strength aspects of the soil. But use of brick powder alone for stabilization of black cotton soil requires it in huge amounts. Mixing other materials along with brick powder for stabilizing black cotton soil reduces the problem of procuring the material. Brick aggregate when used in fly ash-lime-stabilized black cotton soil improved the strength characteristics of black cotton soil for use as base course in pavements. Brick dust along with bagasse ash used for stabilizing black cotton soil improved the unconfined compressive strength of the soil significantly

Use of Waste Material

The disposal of waste materials is a big problem. Due to lack of land required for disposal technique. The substitution of these waste materials in the form of stabilizing agent in the soil stabilization is a modern approach by which waste materials can be advantageously used. The idea behind the technique of soil stabilization used in this study is that the finer particles of soil are replaced with coarser particles of stabilizing material so that a composite having the interlocking between the particles forms resulting in a material with better geotechnical properties.

Use of Sawdust

Black cotton soil (BCS) can be stabilized and made a suitable subgrade material using sawdust, a readily and cheaply available material. Sawdust is burnt to ashes in a furnace at a temperature of 800 °C and then mixed with BCS in varying proportions of 4%, 8%, 12%, 16% and 20%. Since it is experimentally proved from trials that the use of 16% sawdust ash gave better results, the BCS treated with optimum sawdust ash content of 16% was further stabilized with 2%, 4%, 6%, 8%, and 10% lime.

Use of Sand and Cement

Sand and cement is used and in which minimum % of cement with maximum % of sand is added to black cotton soils. By utilizing this zero costing material for the purpose of stabilization, we are in one way getting the strength of soil by using this material. This soil is stabilized with the sand and cement. The cement is ordinary Portland cement and the sand is passing through 425microns and retained on pan.

*****THE END*****