THENI KAMMAVAR SANGAM COLLEGE OF TECHNOLOGY

CE2033- GROUND IMPROVEMENT TECHNIQUES

UNIT 1

INTRODUCTION

1. What is expansive soil? Give one example.

Expansive soils contain minerals such as smectite clays that are capable of absorbing water. When they absorb water they increase in volume. The more water they absorb the more their volume increases. Expansions of ten percent or more are not uncommon. This change in volume can exert enough force on a building or other structure to cause damage. Example: clay.

2. What is a collapsible soil?

Collapsible soils are also known as meta stable soils. They are unsaturated soils that undergo a large volume change upon saturation. The sudden and usually large volume change could cause considerable structural damage. The volume change may or may not occur due to an additional load.

3. What are the difficulties faced with soft clay?

Soft clays represent a well known category of problematic soils which are generally encountered under the form of deposited layers in coastal areas. Several problems are faced when dealing with the study of soft clays from field investigation, soil characterization, behavior modeling, and stability of geotechnical structures up to ground improvement solutions.

4. How is loose sand a challenging soil?

Quicksand forms in saturated loose sand when the sand is suddenly agitated. When water in the sand cannot escape, it creates a liquefied soil that loses strength and cannot support weight. Quicksand can form in standing water or in upwards flowing water (as from an artesian spring). In the case of upwards flowing water, seepage forces oppose the force of gravity and suspend the soil particles.

5. Name the various soil deposits found in India.

1 Alluvial soils

2 Desert soils

3 Black cotton soils

4 Lateritic Soils

5 Marine deposits

6. Name any four ground improvement techniques.

"The process in which in-situ soils are improved for the suppot of the foundations in known as ground improvement".

Learn more about our ground improvement techniques:

- ❖ Vibro stone columns
- ❖ Vibro concrete columns
- ❖ Vibro compaction
- ❖ Pencol rigid solutions
- ❖ Dynamic compaction
- ❖ Rapid impact compaction
- ❖ Band drains

7. What are the need for improving the ground?

1.Increase of strength

2.Reduce distortion under stress (Increases♣ stress-strain modulus)

3.Reduce compressibility (volume decreases♣ due to a reduction in air voids or water content under loads)

8. Define ground improvement.

- ❖ Little or no spoil generated - avoiding the need for expensive disposal costs

Reduced project time through fast design and implementation

- ❖ Around 30% of the aggregates we use come from recycled sources, contributing to the sustainability requirements of projects
- ❖ Treatment of a wide range of soil types
- ❖ Specifically developed equipment for restricted access and limited headroom situations.

9. What is compaction? When is it adopted?

In geotechnical engineering, soil compaction is the process in which a stress applied to a soil causes densification as air is displaced from the pores between the soil grains. When stress is applied that causes densification due to water (or other liquid) being displaced from between the soil grains then consolidation, not compaction, has occurred. Normally, compaction is the result of heavy machinery compressing the soil, but it can also occur due to the passage of (e.g.) animal feet.

10. What is dewatering? What are the various methods of dewatering?

Dewatering is the removal of water from solid material or soil by wet classification, centrifugation, filtration, or similar solid-liquid separation processes, such as removal of residual liquid from a filter cake by a filter press as part of various industrial processes.

1.Deep wells

2.Wellpoints

3.Horizontal drainage

11. What is a lime column?

Lime columns are used for the stabilisation of soils such as clay and soft silt that are then mixed with lime in order to form columns of consolidated soil. This procedure uses a mixing tool that mixes lime with the in-situ material during the treatment.

The achieved strength is generally 1 Mpa.

12. What is vibro-compaction? In which soils is it adopted?

Vibro compaction is a ground improvement technique that densifies clean, cohesionless granular soils by means of a downhole vibrator.

The vibrator is typically suspended from a crane and lowered vertically into the soil under its own weight. Penetration is usually aided by water jets integrated into the vibrator assembly. After reaching the bottom of the treatment zone, the soils are densified in lifts as the probe is extracted.

13. What are the various methods of grouting?

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.

14. What is soil reinforcement?

Reinforcement placed in horizontal layers throughout the height of the wall provides the tensile strength to hold the soil together. The reinforcement materials of MSE can vary. Originally, long steel strips 50 to 120 mm (2 to 5 in) wide were used as reinforcement. These strips are sometimes ribbed, although not always, to provide added friction. Sometimes steel grids or meshes are also used as reinforcement. Several types of geosynthetics can be used including geogrids and geotextiles. The reinforcing geosynthetics can be made of high density polyethylene, polyester, and polypropylene. These materials may be ribbed and are available in various sizes and strengths.

15. When is pre-loading adopted as a ground improvement technique?

The most common methods of ground treatment in cohesive soil to reduce the void ratio or water content of the sdoil by preconsolidation. This increase the shear strength of the soil and reduces the compressibility even before construction of the building ios commenced.

16. What is advantage of using vertical drains along with pre-loading?

The purpose of preloading and vertical drains is to increase the shear strength of the soil, to reduce the soil compressibility and to reduce the permeability of the soil prior to construction and placement of the final construction load and prevent large and/or differential settlements and potential damages to the structures.

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UNIT 5

GROUT TECHNIQUES

1. Define grouting.

Grout is generally a mixture of water, cement, sand, often color tint, and sometimes fine gravel (if it is being used to fill the cores of concrete blocks). It is applied as a thick emulsion and hardens over time, much like its close relative mortar.

2. Write the applications of grouting.

- Stopping major water inflows in mines, tunnels, parkades, dams and underground structures in general
- Soil and rock grouting
- Protective coatings, gels, mortars to protect steel, concrete reservoirs and floors against chemical attack (chemical plants, pharmaceutical industry, mills
- Environmental applications
- Rehabilitation of deteriorated, porous or leaking concrete or masonary structures, with advanced techniques, using the most suitable technology and grouts.
- Shoring and retaining systems
- Special foundations and retaining systems
- Trouble Shooting
- Soil Stabilization
- Mining Applications
- Unusual and Difficult Geotechnical and Structural Problems

3. Write the various types of grouting.

- Cement-Based Grouts
- Furan Resin Grouts
- Epoxy Grouts
- Latex-Modified Sanded Cement Grout
- Caulking Grout

4 . Name the different methods of grout injection.

1. Polymer Injection Grouts
2. Fiber-Reinforced Injection Grouts

3. Cement – Sand grouts
4. Gas-forming grouts
5. Sulfo-aluminate gouts

5. What are the two methods of mechanical stabilization?

MSE walls stabilize unstable slopes and retain the soil on steep slopes and under crest loads. The wall face is often of precast, segmental blocks, panels or geocells that can tolerate some differential movement. The walls are infilled with granular soil, with or without reinforcement, while retaining the backfill soil. Reinforced walls utilize horizontal layers typically of geogrids. The reinforced soil mass, along with the facing, forms the wall.

6. How is stabilization of soil achieved by cement?

Cement stabilization of soil is done by mixing pulverized soil and Portland cement with water and compacting the mix to attain a strong material. The material obtained by mixing soil and cement is known as soil-cement. The soil cement becomes a hard and durable structural material as the cement hydrates and develops strength.

Cement stabilization is done while the compaction process is continuing. During the compaction process we use some amount of cement. Some void space can be found in soil particle. Cement is just like paw, so cement can fill the void space of soil easily.

7. What are the various stages of action in lime stabilization?

- Scarification and Initial Pulverization
- Lime Spreading
- Preliminary Mixing and Watering
- Final mixing and pulverization
- Compaction
- Final curing

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UNIT 2

DRAINAGE AND DEWATERING

1. Define dewatering?

Dewatering means “the separation of water from the soil,” or perhaps “taking the water out of the particular construction problem completely

2. What are the various methods of dewatering?

There are several methods commonly used to drain or dewater a construction site:

_ Gravity flow

_ Pumping and Vacuum

_ Electro-Osmosis.

Gravity Flow Method

Done through channels and ditches

_ This is the less costly method.

_ The site is drained through channels placed at intervals, that permit the water to flow away from the high points.

_ This method has been used for thousands of years. _ It has the disadvantage of requiring a long time to properly drain the land.

Pumping and Vacuum

Method Done through Open sumps and Ditches, Well points system and Vacuum _ This method is more expensive than gravity, but is faster in results.

_ It requires pumps that suck the water out of the soil and remove itto a distant place or river or lake.

Electro-Osmosis

_ This method is most expensive

_ It is only effective method of dewatering in deep clay soils.

3. How are sumps and ditches used in dewatering?

A sump is merely a hole in the ground from which water is being pumped for the purpose of removing water from the adjoining area.

They are used with ditches leading to them in large excavations. Up to maximum of 8m below pump installation level; for greater depths a submersible pump is required.

4. What are the advantages of sumps and ditches in dewatering?

_ Widely used method

_ Most economical method for installation and maintenance

_ Can be applied for most soil and rock conditions

_ Most appropriate method in situation where boulders or massive obstructions are met with in the ground

5. **What is a well point system**?

A well point system comprises 50 to 60 well points to a single 150 or 200 mm pump with a separate Jetting pump. The well point pump has an air/water separator and a vacuum pump as well as the normal centrifugal pump

6. What are the different types of well point systems?

Wellpoints are typically installed at close centers in a line along or around the edge of an excavation. As a vacuum is limited to 0 bar, the height to which water can be drawn is limited to about 6 meters. Wellpoints can be installed in stages, with the first reducing the water level by up to five meters, and a second stage, installed at a lower level, lowering it further.The water trickling between the deep wells may be collected by a single row of well point at the toe. This method ensures a much thicker width free from seepage forces.

7. **When are deep wells used for dewatering**?

The deep well system is also a versatile predrainage dewatering system which can pump high and low volumes of groundwater. This method is best suited to homogeneous aquifers that extend well below the bottom of the excavation. Deep well systems consist of one or more individual wells, each of which has its own submersible pump at the bottom of the well. Deep well systems are suitable for water-table or confined aquifers and will lower the water table 100 feet or more in a single lift without staging.

8. What is the principle behind vacuum dewatering?

Ejector/Eductor dewatering systems are employed to control pore pressures and to lower groundwater levels to provide stable working conditions in excavations. They are particularly suited to operating in fine soil conditions.

Eductor systems are able to extract groundwater and generate a high vacuum at the base of wells up to 50 m deep and of as little as 50 mm diameter. Vacuum drainage can provide dramatic improvement in the stability of silty fine sands and laminated silts and clays by the control of excess pore pressures. Eductor wells have been successfully installed in raking boreholes to dewater beneath inaccessible areas such as railway lines and canals.

9. What is electro-osmotic dewatering?

Dewatering Technique of dewatering done through the use of cathodes and anodes with passage of Electrical current. Electro-osmosis is defined as "the movement of water (and whatever is contained in the water) through a porous media by applying a direct current (DC) field". It is the only effective method of dewatering in deep clay soils

10. What are the various types of drains?

Municipal Drains, Mutual Agreement Drains, Award Drains, Private Drainage Systems and Roadside Ditches

11. Define permeability.

Permeability

‡ Is a measure of how easily a fluid (water) can pass through a porous medium (soil).

Applications (examples):

1. Water wells

a. Water production

b. Dewatering

2. Earth dams
    a. Estimate quantity of water seeping through the dam
    b. Evaluating stability of dam
3. Ground improvement by preloading

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UNIT 3

INSITU TREATMENT OF COHESIONLESS AND COHESIVE SOILS

1. **What do you understand from the term in-situ densification?**

   The main goal of most soil improvement techniques used for reducing liquefaction hazards is to avoid large increases in pore water pressure during earthquake shaking. This can be achieved by densification of the soil and/or improvement of its drainage capacity.

2. **What are the various methods of in-situ densification?**

   Vibroflotation
   Dynamic Compaction
   Stone Columns
   Compaction Piles
   Compaction Grouting
   Drainage techniques

3. **How is dynamic compaction different from static compaction?**

   STATIC COMPACTION:

   Static models such as compaction wheels utilize the weight of the machine and applied downward force to compact the soil. Since no hydraulics are required, they can be very cost effective. They also tend to be effective in various soil types.

   A compaction wheel penetrates the trench fill with specially designed "feet," and achieves compaction from the bottom up rather than from the top down. Soil mixing and displacement achieved during static compaction also limit the possibility of voids and bridging.

   DYNAMIC COMPACTION:

   Compaction via dynamic means (i.e., boom-mounted hydraulic plate compactors) is accomplished through the regulated hydraulic oil flow. The oil drives an offset rotator or eccentric that, in turn, creates vibration and impulse force that compacts soil and other loose granulated materials. Essentially, soil particles are rearranged and any air trapped between them is forced out.

4. **What are the merits and demerits of dynamic compaction?**

   Advantages:

   -Versatile technique, economical and fast (Production up to 40,000 sq.m/crane/month/shift),
   -Very sustainable technique: no additional materials, no cement, no water is required,
   - Well adapted to small & large scale projects,
   - Real-time adjustment of the applied energy to the actual ground conditions,
   - Flexible with changes in the locations and dimensions of footings,

- Improve bearing capacity of soil, reduce settlement and differential settlement in addition to mitigation of soil liquefaction,
- Improve the entire site including buildings, roads and infrastructure.

Disadvantages:

Dynamic compaction involves lifting and dropping a heavy weight several times in one place. The process is repeated on a grid pattern across the site.

5. What is dynamic consolidation?

Consolidation treatment usually requires a provision of effective and suitable drainage points.

Both these techniques reduce the need for deep foundations and therefore help to reduce overall cost and the cost of site disposal. It is particularly beneficial on large areas, or where pre-bored stone columns may be required.

6. What are the advantages of Rapid impact compaction?

Rapid impact compaction(RIC) has changed the method of the compaction of reclamations. This reduces the time available for the deep compaction of a terrain in thin layers and results in the demand for compaction methods suitable to compact layers of 4 to 7 meters thick using a cheap, fast and reliable method.

7. What is vibro-flotation?

The **Vibroflotation** (vibrocompaction) is a method of improvement of non-cohesive soils by re-arranging the grain distribution pattern while applying cyclic vibrations which cause the outflow of granular soil. As a result, the**compaction** of soil and the pore volume reduction are obtained.

8. What are the applications of vibro-flotation?

Using vibrators to compact the ground is known as Vibrofloatation or Vibrocompacting. This is a technique used for stabilising granular soils such as loose sand, gravel and backfill material. The method consists in using vibration to create a suspension with the particles so that they can be rearranged to form more dense material.

9. Differentiate top feed from bottom feed method.

Top Feed System

In the Top Feed System, the poker is completely withdrawn after initial penetration to the design depth. Stone (12-75mm in size) is then tipped into the hole in controlled volumes from the ground surface allowing it to fall under gravity to the bottom side of hole. The column is compacted in layers (the stone is forced downwards and outwards) through continued penetration and withdrawal of the poker. The Top Feed System is suitable if the hole formed by the poker will remain open during construction of the column.

Bottom Feed System

The gravel may be fed from a rig-mounted hopper through a permanent delivery tube along the side of the poker, which bends inwards and allows the stone to exit at the poker tip. This Bottom Feed process requires a smaller grade of stone (2-45mm). By remaining in the ground during column construction, the poker cases its own hole and hence is suited to ground with a high water table or running sand conditions. Wet top feed process is called vibro-replacement and dry top/bottom feed process is called vibro displacement.

9. How is a rammed stone column installed?

A. Non Displacement Method

The process of installation where soil is taken out during boring is called non displacement type of installation.

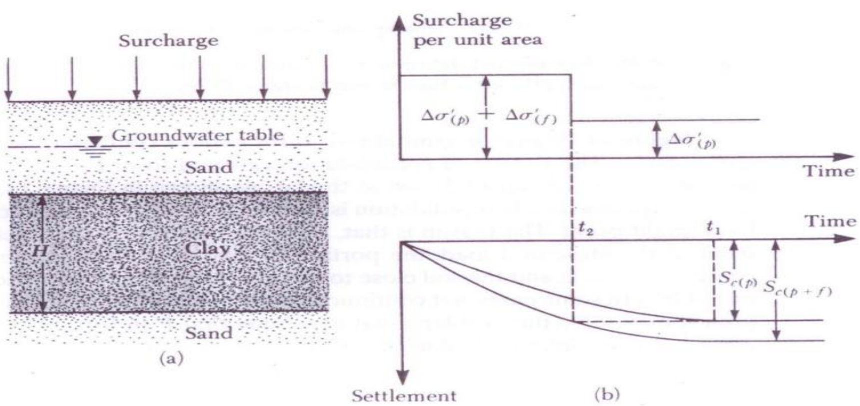
- ❖ Bored Rammed System

B. Displacement Method

If the soil is laterally displaced while making the hole due to driving of a tube or a casing, it is the displacement type of boring.

- ❖ Vibro Replacement Method

10. What is the principle behind pre-compression?



The proposed structural load per unit area is Δσ'(p) and the thickness of the clay layer undergoing consolidation is H c. The maximum primary consolidation settlement caused by the structural load is then

$$S_{c(p)} = \frac{C_c H_c}{1 + e_o} \log \frac{\sigma'_o + \Delta\sigma'_{(p)}}{\sigma'_o}$$

11. Write the various methods of preloading.

- ❖ Conventional preloading
- ❖ Vaccum preloading

12. What is the function of vertical drain?

Low permeability, the consolidation settlement of soft clays takes a long time to complete. To shorten the consolidation time, vertical drains are installed together with preloading either by an embankment or by means of vacuum pressure. Vertical drains are artificially-created drainage paths which are inserted into the soft clay subsoil. Thus, the pore water squeezed out during consolidation of the clay due to the hydraulic gradients created by the preloading, can flow faster in the horizontal direction towards the vertical drains. It is taken advantage of the fact, that most clay deposits exhibit a higher horizontal permeability compared to the vertical.

13. Compare sand drains and wick drains.

Sand Drains:

A sand drain is basically a hole drilled in a cohesive soil and filled with sand. Since the sand has larger particle size, its permeability is much higher, thus water will flow through it much more easily. As shown above, an array (it's actually a two-dimensional array) of sand drains is installed, and a load is applied on top of the drains. The load shown above is an embankment, such as is used on a highway, and an additional, or surcharge, load is used to speed up the drainage process. The excess water is collected at the top and directed away from the jobsite.

Wick Drains:

A wick drain is just what the name implies: a geosynthetic "rope," usually about 100 mm wide and 5mm thick, which acts as a high-permeability conduit for water to flow out of the soil and to the surface, in the same manner as takes places with sand drains. As is the case with sand drains, they are installed as an array, generally in 3 metre spacings.

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UNIT 4

EARTH REINFORCEMENT

1. **Write the concept behind soil reinforcement.**

   To resist the erosion of the soil during the rainy season and also to give strength to the loose soil.

2. **What are the materials required for construction of a reinforced soil structure?**

   Geo synthesis

   Geo textiles

   Normal RC materials

3. **What are the principle requirements of a reinforcing material?**

   Stable

   Should resist corrosion

   Shoulb be adoptable incase of soil erosion.

4. **Define geosynthetics.**

   Geosynthetics are human-made materials made from various types of polymers used to enhance, augment and make possible cost effective environmental, transportation and geotechnical engineering construction projects. They are used to provide one or more of the following functions; separation, reinforcement, filtration, drainage or liquid barrier.

5. **What are the various types of geosynthetics?**

   geotextiles - flexible, textile-like fabrics of controlled permeability used to provide filtration, separation or reinforcement in soil, rock and waste materials

   geomembranes - essentially impermeable polymeric sheets used as barriers for liquid or solid waste containment

   geogrids - stiff or flexible polymer grid-like sheets with large apertures used primarily as reinforcement of unstable soil and waste masses

   geonets - stiff polymer net-like sheets with in-plane openings used primarily as a drainage material within landfills or in soil and rock masses

   geosynthetic clay liners - prefabricated bentonite clay layers incorporated between geotextiles and/or geomembranes and used as a barrier for liquid or solid waste containment

geopipes - perforated or solid wall polymeric pipes used for the drainage of various liquids

geocomposites - hybrid systems of any, or all, of the above geosynthetic types which can function as specifically designed for use in soil, rock, waste and liquid related problems

6. Name a few raw materials that are used in the manufacture of geosynthetics.

The raw materials from which geosynthetics are produced are polymeric. Polymers are materials of very high molecular weight and are found to have multifarious applications in the present society. The polymers used to manufacture geosynthetics are generally thermoplastics, which may be amorphous or semi-crystalline. Such materials melt on heating and solidify on cooling. The heating and cooling cycles can be applied several times without affecting the properties.

The more commonly used types are polypropylene (PP), high density polyethylene (HDPE) and polyester (polyethylene terephthalate (PET)), Polyamide (PA) etc. Most of the geotextiles are manufactured from PP or PET.

7. How does the use of a geosynthetic as a filter differ from that of drainage?

I – Geosynthetics in Filtration. Geotextile filtration principles, practices and problems. Geotextile filter design guide. Fine fraction test to assess geotextile filter performance. A dynamic filtration test to assess geotextile filter performance. A dynamic filtration test for geotextile filters. Leachate flow rate behavior through geotextile and soil filters and possible remediation methods. Geotextile revetment filters.

II – Geosynthetics in Drainage. Drainage principles and the use of geosynthetics. Existing test methods for design of geosynthetics for drainage systems. Effect of test procedures in geonet transmissivity results. Field evaluation of geonet flow rate [transmissivity] under increasing load. Impacts of bentonite geocomposites on geonet drainage. Long–term performance of geocomposites used as highway edge drains.

8. Write a brief note on geosynthetics as reinforcement.

Geogrids or geotextiles can be used as reinforcement to increase shear strength of soils, thereby providing a more competent structural material. Examples of this application include the use of geogrid to reinforce a steep slope, or to strengthen a base course in a pavement system.

9. Define soil nailing.

Soil nailing is an earth retention technique using grouted tension-resisting steel elements (nails) that can be design for permanent or temporary support. The walls are generally constructed from the top down. Typically, 3 to 6 feet of soil is excavated from the top of the planned excavation. Near-horizontal holes are drilled into the exposed face at typically 3 to 6 foot centers. Tension-resisting steel bars are inserted into the holes and grouted.

10. Describe in a few words about rock bolting.

A steel or fiberglass bolt inserted and anchored in a hole drilled in rockto prevent caving of the roof of a tunnel or subterranean chamber.