ATME College of Engineering

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DEPARTMENT OF CIVIL ENGINEERING

(ACADEMIC YEAR 2024 -25)

SUBJECT NAME: Ground Improvement Tequniues

SUB CODE: 21CV742

SEMESTER: VIII

INSTITUTE

Vision of the Institute

Development of academically excellent, culturally vibrant, socially responsible and globally competent human resources.

Mission of the Institute

- To keep pace with advancements in knowledge and make the students competitive and capable at the global level.
- To create an environment for the students to acquire the right physical, intellectual, emotional and moral foundations and shine as tourch bearers of tomorrow's society.
- To strive to attain ever-higher benchmarks of educational excellence

DEPARTMENT

Vision of the Department

To develop globally competent Civil Engineers who excel in academics, research and are ethically responsible for the development of the society.

Mission of the Department

- To provide quality education through faculty and state of art infrastructure
- To identify the current problems in society pertaining to Civil Engineering disciplines and to address them effectively and efficiently
- To inculcate the habit of research and entrepreneurship in our graduates to address current infrastructure needs of society

Program outcomes (POs)

Engineering Graduates will be able to:

PO1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2. **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change

Program Specific Outcomes (PSOs)

PSO1: Provide necessary solutions to build infrastructure for all situations through Competitive plans, maps and designs with the aid of a thorough Engineering Survey and Quantity Estimation.

PSO2: Assess the impact of anthropogenic activities leading to environmental imbalance on land, in water & in air and provide necessary viable solutions revamping water resources and transportation for a sustainable development

Program Educational Objectives (PEOs)

PEO 1- Engaged in professional practices, such as construction, environmental, geotechnical, structural, transportation, water resource engineering by using technical, communication and management skills.

PEO 2- Engaged in higher studies and research activities in various civil engineering fields and life time commitment to learn ever changing technologies to satisfy increasing demand of sustainable infrastructural facilities.

PEO 3- Serve in a leadership position in any professional or community organization or local or state engineering board

PEO 4- Registered as professional engineer or developed a strong ability leading to professional licensure being an entrepreneur.

Ground Improvement Potential

Formation and Development of Ground

Introduction:
Ground improvement has been both a science and art, with significant developments observed through ancient history. From the use of straw as blended infill with soils for additional strength during the ancient Roman civilizations, and the use of elephants for compaction of earth dams during the early Asian civilizations, the concepts of reinforced earth with geosynthetics, use of electro kinetics and thermal modifications of soils have come a long way. The use of large and stiff stone columns and subsequent sand drains in the past has now been replaced by quicker to install and more effective prefabricated vertical drains, which have also eliminated the need for more expensive soil improvement methods.

The early selection and application of the most appropriate ground improvement techniques can improve considerably not only the design and performance of foundations and earth structures, including embankments, cut slopes, roads, railways and tailings dams, but also result in their cost-effectiveness. Ground improvement works have become increasingly challenging when more and more problematic soils and marginal land have to be utilized for infrastructure development

1.0 Need for Ground Improvement Techniques

As more engineering structures are built, it becomes increasingly difficult to find sitewith suitable soil properties. The properties at many sites must be improved by the use ofsome form of soil improvement methods, such as: static or dynamic compaction, reinforcement, drainage or by the use of admixtures. Thus, it is important for the soil engineers to know the different soil improvement methods; the degree to which soil properties may be improved; and the costs and benefits involved. In this way, the soil engineer can gain knowledge in order to design ground improvement projects as well asto advise the client regarding value engineering to save cost and obtain maximum benefits for the specific project. The following are some of the methods used as ground improvement techniques: Surface Compaction, Deep Compaction, Preloading, Vertical Drains, Stone Columns, Vacuum Drainage, Mechanically Stabilized Earth (Reinforced Earth), Granular Piles,Micropiles, Lime Stabilization, Cement Stabilization

1.1 Classification of Rocks

1. Geological classification
2. Physical classification
3. Chemical classification

1. Geological classification

Rocks are classified into three types based on their geological formation and they are :

- Sedimentary rocks
- Igneous rocks
- Metamorphic rocks

Sedimentary rocks

Sedimentary rocks are formed by the deposition of sediments obtained by the weathering of pre-existing rocks and these sediments are transported by various agents such as water, wind, frost, gravity, etc. These transported sediments form layered structures and give rise to the sedimentary deposits; If the sediments remain at the place of origin then the formed deposits are known as residual deposits. Some sediments formed by various chemical reactions such as decomposition, precipitation, evaporation, etc. give rise to the formation of chemical deposits. Similarly, the sediments formed by the action of various organisms such as plants and animals are known as Organic deposits.

Examples: **Sandstone, limestone, lignite**, etc.

Igneous rocks

Igneous rocks are formed by the solidification of magma below the earth's surface. When the magma is unable to erupt through the earth surface during its upward journey, it is held up below the earth's surface and unable to descend. This magma cools down gradually and solidifies into igneous rocks.

The structure of igneous rocks varies according to the depth at which magma solidified. If the magma hardens at a significant depth from the earth surface, then the rocks possess coarsely grained crystalline structure and these rocks are known as plutonic rocks. Granite is the best example of plutonic rock

Metamorphic rocks

Metamorphic rocks are formed by the metamorphism process. Metamorphism is the process of changing the characteristics of the pre-existing rocks under the influence of heat and pressure. The pre-existing rocks may be of the sedimentary or igneous type of rocks.

Examples: **Slate, Gneiss, Schist, marble, soapstone** etc.

2 Physical classification

Rocks are classified physically into three types as follows :

- Stratified rocks
- Unstratified rocks
- Foliated rocks

Stratified rocks

Stratified rocks consist of different layers in its structure and these layers are separated by planes of stratification. These planes are also called cleavage planes or bedding planes. These rocks can easily split up along these bedding planes. Most of the sedimentary rocks such as **sandstone, limestone, shale,** etc. are the best examples of stratified rocks.

Unstratified rocks

The structure of unstratified rocks is crystalline or compact granular. They possess a similar kind of structure throughout their whole body. Most of the igneous rocks and some sedimentary rocks come under unstratified rocks. **Granite, marble, trap** are few examples of Unstratified rocks.

Foliated rocks

Foliated rocks possess a layered or banded structure which is obtained by exposure of pressure and heat. Unlike the stratified rocks, these rocks can split up in a certain direction only. Most of the metamorphic rocks formed by metamorphism come under foliated rocks. Some examples are **gneiss, schist, slate** etc.

Chemical classification

Rocks are classified into three types based on their chemical composition and they are as follows

- Argillaceous rocks
- Calcareous rocks
- Siliceous rocks

Argillaceous rocks

The word Argil means clay. Hence, the rocks in which clay content is predominant are called argillaceous rocks. These rocks are soft in nature and with the presence of water they can be crumbled easily. In the dry state, these rocks can be crushed easily because of their brittleness. **Shale, slate, laterite**, etc. are some of the argillaceous rocks

Calcareous rocks

The rocks in which calcium carbonate is the major ingredient are known as calcareous rocks. These are generally hard but their durability is dependent on surrounding constituents which may react with calcium and affect the durability of rock. **Marble, limestone, dolomite**, etc. are some of the calcium predominant rocks.

Siliceous rocks

The rocks which contain silica in predominant amount are called as siliceous rocks. Presence of a large amount of free silica makes them harder and durable. It also provides strong resistance to weathering. **Granite, chert, quartzite,** etc. are examples of siliceous rocks.

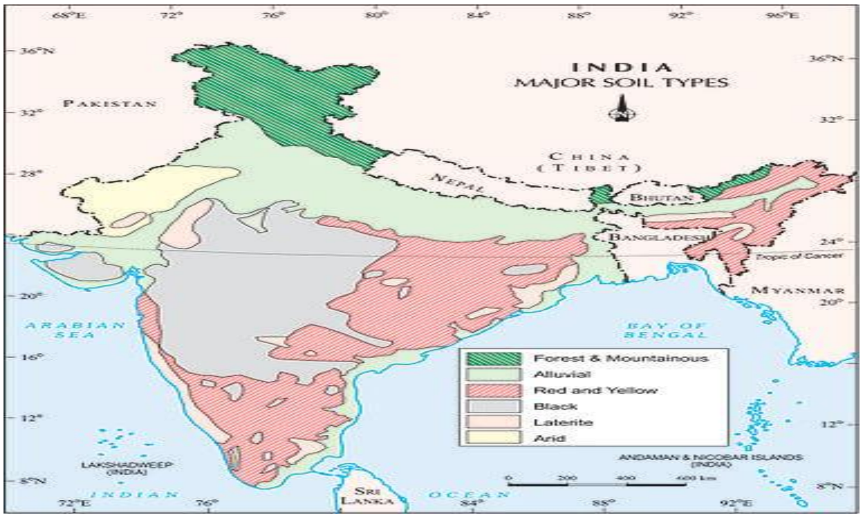
1.2 Formation of soil.

1.2.1Definition of Soil

Soil can be simply defined as a mixture of small rock particles/debris and organic materials/ humus which develop on the earth surface and support growth of plants

1.2.2 Soil Classification

- In the modern period, when men started to know about the various characteristics of soil they began to classify soil on the basis of texture, colour, moisture etc.
- When the **Soil survey of India** was established in **1956,** they studied soils of India and their characteristics.
- **The National Bureau of Soil Survey and the Land Use Planning**, an institute under the control of Indian Council of Agriculture Research did a lot of studies on Indian soil



1. Alluvial soil [43%]
2. Red soil [18.5%]
3. Black / regular soil [15%]
4. Arid / desert soil
5. Laterite soil
6. Saline soil
7. Peaty / marshy soil
8. Forest soil
9. Sub-mountain soil
10. Snowfields

1.2.4 Soil classification

1.3 There are **six major type of soil** found in **India**:

- Alluvial Soils
- Black Soils
- Red Soils
- Desert Soils
- Laterite Soils
- Mountain Soils

1. Alluvial soils: These soils occur chiefly in the Indo-Gangetic plain covering the states of Punjab and Haryana in the north-west, Uttar Pradesh and Bihar in the north, and West Bengal and parts of Meghalaya and Odisha in the north east. Besides plains, this soil also occurs in the east coast deltas and terrace, deltaic and lagoon alluvium of peninsular India. The soil is rich in loams and clay components in Punjab and Western Ganga plains, the loam component increasing and sand decreasing in the Central Ganga plains, where the much calcareous kankar is common. The soil is generally alkaline or neutral in reaction. In Ganga-Brahmaputra plains soil contains very fine particles varying from loams to very fine silt clay.

2. Black or Regur soils: Black or regur soils are concentrated over the Deccan lava tract which extends over part of Maharastra, Madhya Pradesh, Gujarat, Andhra Pradesh and Tamil Nadu. Black soils are generally clayey, deep and impermeable. They expand and become sticky during rainy seasons and contract during the dry season causing deep cracks into the soil. Chemically they consist of lime, iron, magnesium, alumina and potash but they lack in phosphorus, nitrogen and organic matter. Black soils are most suitable for cultivation.

3. Red soils: Red soils have a reddish colour which is due to the presence of iron in crystalline and metamorphic rocks. The physical properties of these soils vary region to region. Like black soils, red soils too have a comparatively lower fertility on the uplands than on the lowlands. In general red soils are porous and airy and need irrigation support for cultivation. They are deficient in lime, phosphoric and nitrogenous content and potash. Red soils cover almost the whole of Tamil Nadu, Karnataka, Andhra Pradesh, South-eastern Maharashtra, eastern parts of Madhya Pradesh, parts of Odisha and Chhotanagpur and Bundelkhand- all of them lying on the periphery of Peninsular Plateau.

4. Desert soils: These cover large parts of Rajasthan and the semi-desert areas of the Rann of Kutch. Desert soils contain high percentage of soluble salts and are poor in organic matter.

5. Skeletal (Mountain) soils: They occur in north-western hills or the Aravallis, where they are stony hillfoot fans and slope colluvium, and in the humid south and east of the Himalayas and in Meghalaya where these are more clayey in texture.

6. Laterite soils: These are present in the Western Ghats, the northern half of the Eastern Ghats, eastern margins of Chota Nagpur plateau, Meghalaya, few patches around Kathiawar, and in two areas in the centre of the Peninsula north of Bangalore and west

Hyderabad. These soils have porous clay rich in hydroxides of iron and aluminium. At low elevations, such soils are suitable for paddy cultivation, whereas those at higher elevations, these favour the growth of coffee, tea, rubber and Cinchona.

1.4 Ground improvement potential

Good Conditions:

- good foundation conditions, probable volume change (shrink/swell) hazard
- sulfate/sulfide might be present
- sand or silt might be frost susceptible
- possible variable ground conditions (clay and mudstone)
- low potential for collapse when loaded and saturated
- possible variable ground conditions due to lithological variability
- boulders at/just below foundation level might result in differential settlement
- possible variable ground conditions near surface due to weathering
- possible variable foundation conditions at interface between granite and altered granite
- fine-grained head deposits, if present, might contain shear surfaces affecting stability in pits and trenches
- possible variable ground conditions due to sand/sandstone lithological variability: excavations might be unstable

Poor conditions

- Generally good foundation conditions *but* might be locally moderate or possible dissolution of gypsum at or near foundation level:
- collapse breccia and differential settlement might occur
- sulfate might be present
- voids or infilled voids in limestone might result in differential settlement
- voids or infilled voids in limestone might result in differential settlement
- weathered chalk (silt) might be frost susceptible

Hazardous Conditions:

The nature of the existing ground conditions should be identified and described with reference to the "Site Investigation Report" highlighting any findings in the site investigation report that will affect the construction of the works and the health and safety of everyone affected by them including the general public

Is there any contaminated ground? If the site has been previously used for an industrial process it may well be contaminated and give rise to health risks. Examples of possible contaminants are acids, alkalis, metals, solvents, gases, asbestos, microorganisms, and toxic, flammable and/or explosive substances. Such areas may have to be cleared and full details of the nature, extent and level of such contamination must be entered in the Safety Plan in order that contractors may assess the risks to health and the precautions that may be necessary.

What is the Soil Type? What effect may the soil type have on the proposed work from a health and safety point of view? Soil types are: Clay, Sand, Chalk and Rock
Is there ground water present? What effect will any Water Table have on the proposed works? Any ground likely to be unstable during excavation should be identified and attention drawn to excavation support and de-watering that may be required

1.5 Reclaimed soils

1.7 Compaction: is a process that brings about an **increase in soil density or unit weight**, accompanied by a **decrease in air volume.** There is usually **no change in water content.** The degree of compaction is measured by dry unit weight and depends on the water content and comp active effort (weight of hammer, number of impacts, weight of roller, and number of passes). For a given comp active effort, the maximum dry unit weight occurs at an **optimum water content**.

1.8 Objectives of compaction

Compaction can be applied to improve the properties of an existing soil or in the process of placing fill.

The main objectives are to:

- increase shear strength and therefore bearing capacity
- increase stiffness and therefore reduce future settlement
- decrease voids ratio and so permeability, thus reducing potential frost heave

1.9 Factors affecting compaction

A number of factors will affect the degree of compaction that can be achieved:

- Nature and type of soil, i.e. sand or clay, grading, plasticity
- Water content at the time of compaction
- Site conditions, e.g. weather, type of site, layer thickness
- Comp active effort: type of plant (weight, vibration, number of passes)

1.10 Types of compaction plant

- Smooth-wheeled roller

- Grid roller
- Sheep foot roller
- Pneumatic-tyred roller
- Vibrating plate
- Power rammer

1.11 Factors Affecting Compaction of Soil

- **Water Content**

At low water content, the soil is stiff and offers more resistance to compaction. As the water content is increased, the soil particles get lubricated. The soil mass becomes more workable and the particles have closer packing. The dry density of the soil increases with an increase in the water content till the O.M.C is reached.

- **Amount of compaction**

The increase in compactive effort will increase the dry density at lower water content to a certain extent.

- **Type of soil**
- The dry density achieved depends upon the type of soil. The O.M.C and dry density for different soils are different

1.12 Method of compaction

The dry density achieved depends on the method of compaction

Effect of Compaction on Properties of Soil

1. Effect of Compaction on Soil Structure

Soils compacted at a water content less than the optimum generally have a flocculated structure.

Soils compacted at water content more than the optimum usually have a dispersed structure.

2. Effect of Compaction of Soil on Permeability

The permeability of a soil depends upon the size of voids. The permeability of a soil decreases with an increase in water content on the dry side of optimum water content.

3. Swelling
4. Pore water pressure
5. Shrinkage

6. Compressibility
7. Stress-strain relationship
8. Shear strength

The compaction depends upon the following factors:

- Contact pressure
- Number of passes
- Layer thickness
- Speed of roller

1.13 Types of rollers

- Smooth Wheel rollers
- Pneumatic tyred rollers
- Sheepsfoot rollers

1.14 Different Types of Soil Compaction Equipment's

The soil compaction equipment's can be divided into two groups:

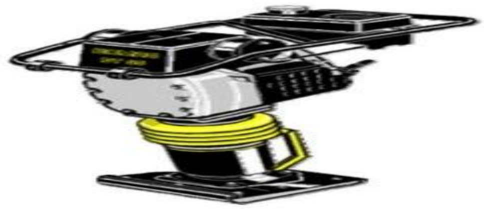
1. Light soil compacting equipment's
2. Heavy soil compacting equipment's

1.14.1 Light Soil Compacting Equipment's:

These equipment's are used for soil compacting of small areas only and where the compacting effort needed is less. Below are light equipment's for soil compaction:

(i) Rammers:

Rammers are used for compacting small areas by providing impact load to the soil. This equipment is light and can be hand or machine operated. The base size of rammers can be 15cm x 15cm or 20cm x 20cm or more. For machine operated rammers, the usual weight varies from 30kg to 10 tonnes (6 lbs to 22000 lbs). These hammers with 2- 3 tonnes (4400 to 6600 lbs) weights are allowed to free fall from a height of 1m to 2m (3ft to 7ft) on the soil for the compaction of rock fragments. Rammers are suitable for compacting cohesive soils as well as other soils. This machine in areas with difficulty in access.



(ii) Vibrating Plate Compactors:

Vibrating plate compactors are used for compaction of coarse soils with 4 to 8% fines. These equipments are used for small areas. The usual weights of these machines vary from 100 kg to 2 tonne with plate areas between 0.16 m^2 and 1.6 m^2.

Heavy Soil Compaction Equipment's:

These compacting machines are used for large areas for use on different types of soils. The heavy compaction equipment's are selected based on moisture content of soil and types of soil. Following are different types of these equipment's:

1) Smooth Wheeled Rollers:

Smooth wheeled rollers are of two types:

- Static smooth wheeled rollers
- Vibrating smooth wheeled rollers

The most suitable soils for these roller type are well graded sand, gravel, crushed rock, asphalt etc. where crushing is required. These are used on soils which does not require great pressure for compaction. These rollers are generally used for finishing the upper surface of the soil. These roller are not used for compaction of uniform sands.

The performance of smooth wheeled rollers depend on load per cm width it transfers to the soil and diameter of the drum. The load per cm width is derived from the gross weight of the drum.The smooth wheeled rollers consists of one large steel drum in front and two steel drums on the rear. The gross weight of these rollers is in the range of 8-10 tonnes (18000 to 22000 lbs). The other type of smooth wheel roller is called Tandem Roller, which weighs between 6-8 tonne (13000 to 18000 lbs).

The performance of these rollers can be increased by increasing the increasing the weight of the drum by ballasting the inside of drums with wet sand or water. Steel sections can also be used to increase the load of the drum by mounting on the steel frame attached with axle.

The desirable speed and number of passes for appropriate compaction of soil depends on the type of soil and varies from location to location. About 8 passes are adequate for compacting 20 cm layer. A speed of 3-6 mph is considered appropriate for smooth wheel rollers

2)Vibrating smooth wheeled rollers

In case of vibrating smooth wheeled rollers, the drums are made to vibrate by employing rotating or reciprocating mass.

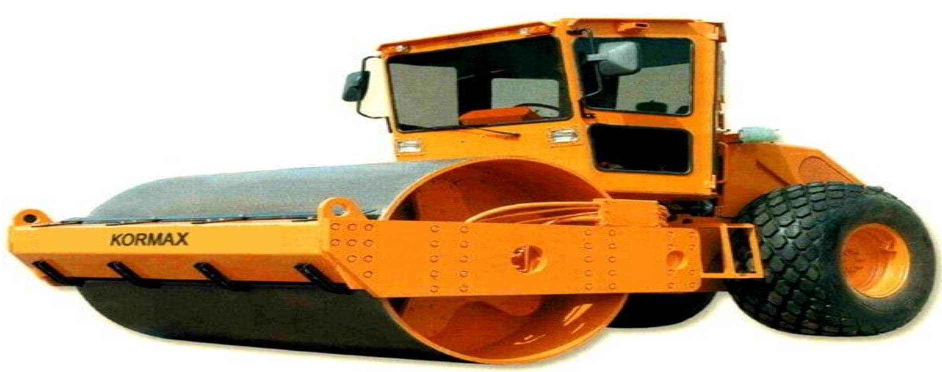
These rollers are helpful from several considerations like:-

(i) Higher compaction level can be achieved with maximum work

(ii) Compaction can be done up to greater depths

(iii) Output is many times more than conventional rollers

Although these rollers are expensive but in the long term the cost becomes economical due to their higher outputs and improved performance. The latest work specifications for excavation recommends the use of vibratory rollers due to their advantage over static smooth wheeled rollers.



3) Sheep foot roller:

Sheep foot rollers are used for compacting fine grained soils such as heavy clays and silty clays. Sheepsfoot rollers are used for compaction of soils in dams, embankments, subgrade layers in pavements and rail road construction projects.

Sheepsfoot rollers are of static and vibratory types. Vibratory types rollers are used for compaction of all fine grained soils and also soil with sand-gravel mixes. Generally this roller is used for compaction of subgrade layers in road and rail projects.

As seen in picture above, sheepsfoot rollers consist of steel drums on which projecting lugs are fixed and can apply a pressure up to 14kg/sq cm or more. Different types of lugs are namely spindle shaped with widened base, prismatic and clubfoot type.

The weight of drums can be increased as in the case of smooth wheeled rollers by ballasting with water, wet sand or by mounting steel sections.

The efficiency of sheepsfoot rollers compaction can be achieved when lugs are gradual walkout of the roller lugs with successive coverage. The efficiency is affected by the pressure on the foot and coverage of ground obtained per pass. For required pressure and coverage of ground, the parameters such as gross weight of the roller, the area of each foot, the number of lugs in contact with the ground at any time and total number of feet per drum are considered.

The compaction of soil is mainly due to foots penetrating and exerting pressure on the soil. The pressure is maximum when a foot is vertical.

4) Pneumatic Tyred Rollers:

Pneumatic tyred rollers are also called as rubber tyred rollers. These rollers are used for compaction of coarse grained soils with some fines. These rollers are least suitable for uniform coarse soils and rocks. Generally pneumatic tyred rollers are used in pavement subgrade works both earthwork and bituminous works.

Pneumatic rollers have wheels on both axles. These wheels are staggered for compaction of soil layers with uniform pressure throughout the width of the roller.

The factors which affect the degree of compaction are tyre inflation pressure and the area of the contact. The latest rollers have an arrangement to inflate the tyre to the desired pressure automatically. The total weight of the roller can be increased from 11.0 tonne to 25.0 tonne or more by ballasting with steel sections or other means

5) Grid Rollers:

Grid rollers are used for compaction of weathered rocks, well graded coarse soils. These rollers are not suitable for clayey soils, silty clays and uniform soils. The main use of these rollers is in subgrade and sub-base in road constructions.

As the name suggests, these rollers have a cylindrical heavy steel surface consisting of a network of steel bars forming a grid with squire holes. The weight of this roller can be increased by ballasting with concrete blocks.

Typical weights vary between 5.5 tonnes net and 15 tonnes ballasted. Grid rollers provide high contact pressure but little kneading action and are suitable for compacting most coarse grained soils.

6) Pad Foot / Tamping Rollers:

These rollers are similar to sheepsfoot rollers with lugs of larger area than sheepsfoot rollers

The static pad foot rollers also called tamping rollers have static weights in the range of 15 to 40 tonnes and their static linear drum loads are between 30 and 80 kg/cm. These rollers are more preferable than sheepsfoot roller due to their high production capacity, and they are replacing sheepsfoot rollers.

The degree of compaction achieved is more than sheepsfoot rollers. The density of soil achieved after compaction with this roller is more uniform.

These rollers operate at high speeds, and are capable to breaking large lumps. These rollers also consist of leveling blades to spread the material.

Pad foot or tamping rollers are best suitable for compacting cohesive soils.

1.15 Dynamic Compaction

Dynamic compaction is an efficient and cost-effective soil improvement technique that uses the dynamic effect of high energy impacts to densify weak soil. The dynamic effect is generated by dropping a static weight (15-40 tones) from a defined height (10-30 m).

The drop weight, which manufactured from steel; steel box and concrete, or reinforced mass concrete, is commonly manufactured from steel and cranes are used to lift and release it repeatedly from a certain height. These droppings exert a vibration on the soil and improve it at a depth

The dynamic compaction is used to improve weak soil such as loose medium to coarse grained sand with salt or clay content. It effectively enhances the soil to a depth of 10m, but its influences reach till 12m depth. Not only does it utilized for settlement improvement and liquefaction mitigation but also for improvement of long-term performance, and backfilling landfill sites or collapsing cavities.

Purpose

The purpose of dynamic compaction technique is to transmit high energy waves through a compressible soil layer to improve Geotechnical properties of soil at greater depths

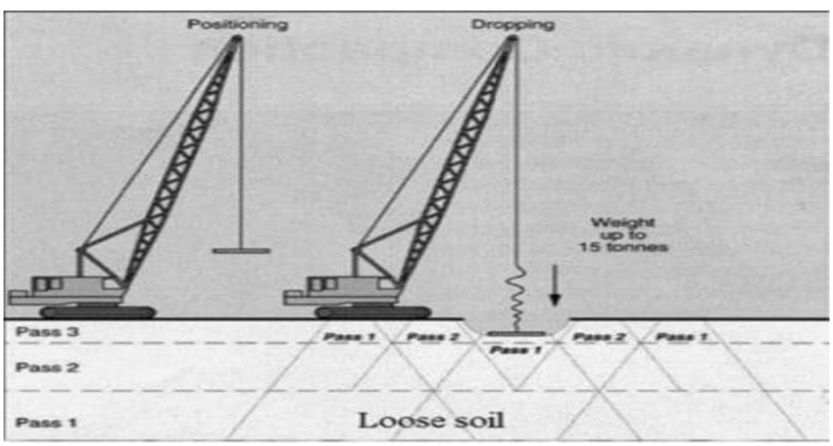


Fig.How Dynamic Compaction Improve Soil Properties

Dynamic Compaction Process

The concept of Dynamic compaction is simple but experienced engineers and good planning is essential. Dynamic compaction process includes lifting and dropping a heavy weight several times in one place.

It is repeated on a grid pattern across the site. The spacing of grid patterns is determined based on underground condition, foundation loading, and foundation geometry.

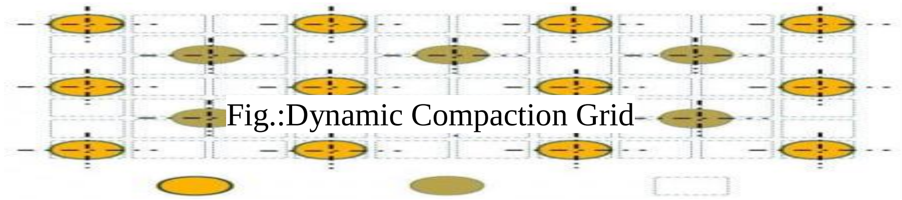


Fig.:Dynamic Compaction Grid

The resulting high energy impact transmits shock waves through the ground to the depth to be treated. This reduces air and water voids between soil particles resulting in enforced settlement.

Advantages

- Densify and compact soil to a depth of 12m
- Effective in various soil conditions
- Cost effective
- Dramatic cost savings in excess of deep foundations and most undercut and replace options
- Accelerate schedules
- Mitigate soil liquefaction
- Improves bearing capacity of soil
- Decreases the volume of landfill waste
- Reduces post-construction settlements
- Environmentally friendly

Disadvantages

- It cannot be used within 30m from buildings and 15m from underground services.
- Dynamic compaction is not appropriate if water depth is less than 1.5m.

- It cannot be applied if soft cohesive soils are located in the upper part of the compaction.
- Dynamic compaction is not effective when soils have fines content in excess of 20%.
- Requires an intensive in situ testing programme to examine the result of compaction.

Applications

- Densification of weak soil; fills, mine refuse, collapsible soils, sanitary landfills, and soils loosened by sinkholes.
- Reclamation projects.
- Treatment of industrial warehouses, port and airport platforms, roads and railways embankments, heavy storage tanks

1.16 Important Questions.

1. Expalin the importance of Ground improvement Teqnuies?
2. Explain different types of rollers?
3. Define compaction? Explain dynamic compaction in detail?
4. Explain different types of soil in india?

1.17: further reading

1. https://nptel.ac.in/content/storage2/courses/105108075/module1/Lecture03.pdf
2. https://depts.washington.edu/liquefy/html/how/soilimprovement.html

Module2: Drainage Methods

2.1 Introduction

2.1 **Seepage& permeability**

2.2 Dewatering

2.3 Sumps and sump pumping

2.4 WellPoint systems

2.5 Eductor system/ vacuum dewatering

2.6 Deep well system

2.7 Electro-osmosis

2.8 Rising method

2.9 Preloading

2.10 Electro kinetic stabilization

2.11 Important questions?

2.12 Further reading

2.0Introduction:

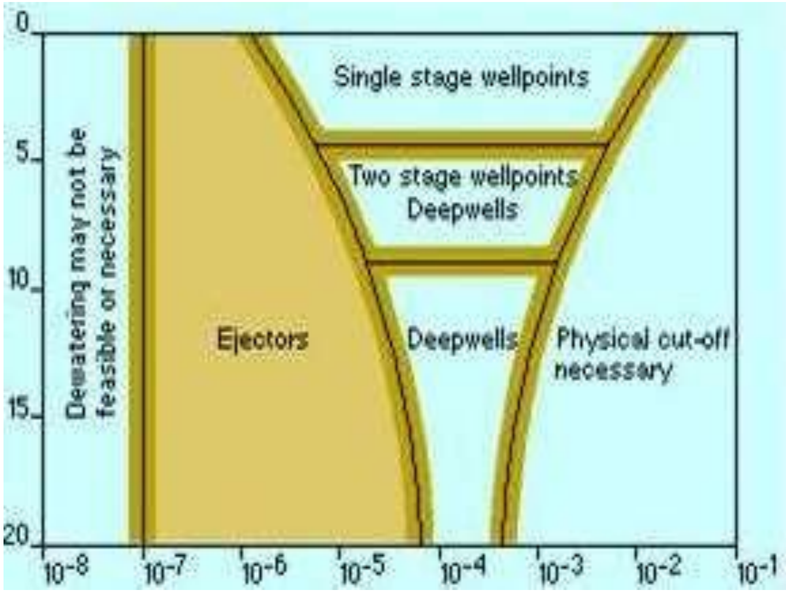
Ground water conditions play an important part in the stability of foundations. If the water table lies very close to the base of footings, the bearing capacity and settlement characteristics of the soil would be affected. The level of the water table fluctuates with season. During the end of monsoons, the water table level will be closer to the ground surface as compared to the period just before the monsoons. The difference in levels between the maximum and the minimum may fluctuate from year to year. In many big projects, it is sometimes very essential to know these fluctuations. Piezometers are therefore required to be installed in such areas for measuring the level of water table for one or more years. In some cases clients may demand the depth of water table during the period of site investigation. The depth can be measured fairly accurately during boring operation.. In a fairly draining material such as sand and gravel, the water level returns to its original position in a matter of few minutes or hours, whereas, in soils of low permeability it may take several days. Insuch cases, the water table level has to be located by some reliable method.

2.1 **Seepage**, in soil engineering, movement of water in soils, often a critical problem in building foundations. Seepage depends on several factors, including permeability of the soil and the pressure gradient, essentially the combination of forces acting on water through gravity and other factors. Permeability can vary over a wide range, depending on soil structure and composition, making possible the safe design of such structures as earth dams and reservoirs with negligible leakage loss, and other structures such as roadbeds and filtration beds in which rapid drainage is desirable

Permeability:

The ability of soil to allow the water to flow through it is called Permeability. It is very important for the structures which are in contact with water e.g. Dams, Bridge, and Canals etc. Soils have interconnected voids through which water can flow from points of high energy to points of low energy. It is necessary to estimate the quantity of underground seepage for investigating problems involving the pumping of water for underground construction, and making stability analysis of earth dams and earth-retaining structures that are subjected to seepage forces. Range of permeability for various soils is shown in Table1.1 and fig. 1.1

Type of Soil	Permeability Coefficient(k)(cm/sec)	Relative Permeability
Coarse gravel	Exceeds 10^-1	High
Clean sand	10^-1 to 10^-3	Medium
Dirty sand	10^-3 to 10^-5	Low
Silt	10^-5 to 10^-7	Very low
Clay	Less than 10^-7	Impervious



2.2 Dewatering:

Dewatering or construction dewatering are terms used to describe the action of removing groundwater or surface water from a construction site. Normally dewatering process is done by pumping or evaporation and is usually done before excavation for footings or to lower water table that might be causing problems during excavations. Dewatering can also be known as the process of removing water from soil by wet classification

Need for drainage and dewatering

- To provide suitable working surface of the bottom of the excavation.
- To stabilize the banks of the excavation thus avoiding the hazards of slides and sloughing.
- To prevent disturbance of the soil at the bottom of excavation caused by boils or piping. Such disturbances may reduce the bearing power of the soil.
- Lowering the water table can also be utilized to increase the effective weight of the soil and consolidate the soil layers. Reducing lateral loads on sheeting and bracing is another way of use

The Available Methods of Groundwater Control Fall into the Following Basic Groups:

- Surface water control like ditches, training walls, embankments. Simple methods of diverting surface water, open excavations. Simple pumping equipment.
- Gravity drainage. Relatively impermeable soils. Open excavations especially on sloping sites. Simple pumping equipment.
- Sump pumping
- Well-point systems with suction pumps
- 4Shallow (bored) wells with pumps.
- Deep (bored) wells withpumps.
- Eductor system.
- Drainage galleries. Removal of large quantities of water for dam abutments, cut-offs landslides etc. Large quantities of water can be drained into gallery (small diameter tunnel) and disposed of by conventional large – scale pumps.
- 8Electro-osmosis. Used in low permeability soils (silts, silty clays, some peats) when no other method is suitable. Direct current electricity is applied from anodes

2.3 SUMPS AND SUMP PUMPING

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 as shown in fig.2.1. 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. Shallow slopes may be required for unsupported excavations in silts and fine sands. Gravels and coarse sands are more suitable. Fines may be easily removed from ground and soils containing large percent of fines are not suitable. If there are existing foundations in the vicinity pumping may cause settlement of these foundations. Subsidence of adjacent ground and sloughing of the lower part of a slope (sloped pits) may occur. The sump should be preferably lined with a filter material which has grain size gradations in compatible with the filter rules. For prolonged pumping the sump should be prepared by first driving sheeting around the sump area for the full depth of the sump and installing a cage inside the sump made of wire mesh with internal strutting or a perforating pipe filling the filter material in the space outside the cage and at the bottom of the cage and withdrawing the sheeting. Two simple sumping.

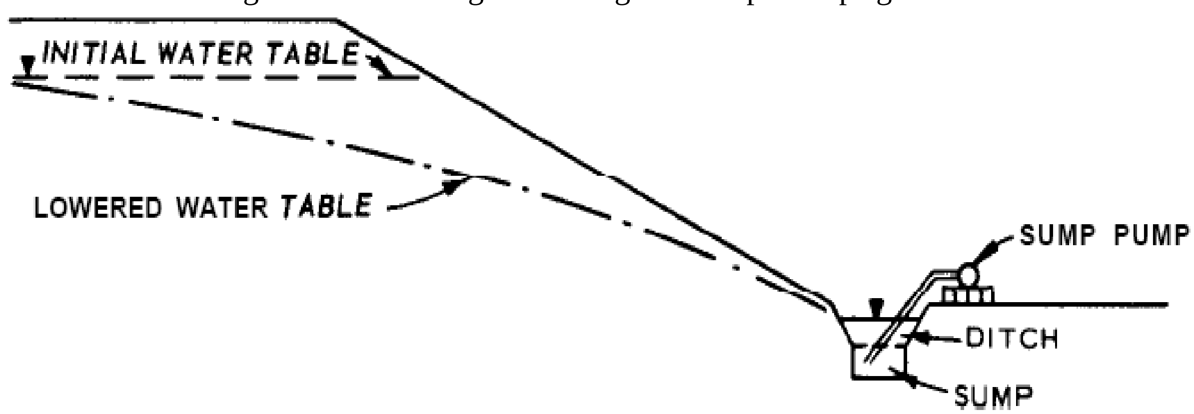


Fig.2.1 Sump Well Method of Dewatering

Advantages of Open Sump and Ditches

1. Widely used method.
2. Most economical method for installation and maintenance.
3. Can be applied for most soil and rock conditions.
4. Most appropriate method in situation where boulders or massive obstructions are met Within the ground. Greatest depth to which the water table can be lowered by this method isabout 8 m below the pump.

2.4 WELLPOINT SYSTEMS

A well-point is 5.0-7.5 cm diameter metal or plastic pipe 60 cm – 120 cm long which is perforated and covered with a screen. The lower end of the pipe has a driving head with water holes for jetting as shown in fig.2.2. Well-points are connected to 5.0-7.5 cm diameter pipes known as riser pipes and are inserted into the ground by driving or jetting. The upper ends of the riser pipes lead to a header pipe which, in turn, connected to a pump. The ground water is drawn by the pump into the well-points through the header pipe and discharged as shown in fig. 2.3. The well-points are usually installed with 0.75m – 3m spacing. This type of dewatering system is effective in soils constituted primarily of sand fraction or other soil containing seams of such materials. In gravels spacing required may be too close and impracticable. In clays it is also not used because it is too slow. In silts and silt – clay mixtures the use of well points are aided by upper (0.60m – 0.90m long) compacted clay seals and sand- filtered boreholes (20cm – 60cm diameter). Upper clay seals help to maintain higher suction (vacuum) pressures and sand filters increase the amount of discharge.

Filtered boreholes are also functional in layered soil profiles approximate time required for effective drawdown The header pipe (15-30 cm diameter, connecting all well-points) is connected to a vacuum (Suction assisted self – priming centrifugal or piston) pump. The well-points can lower a water level to a maximum of 5.5 m below the centerline of the header pipe. In silty fine sands this limit is 3-4 m. Multiple stage system of well-points are used for

owering water level to a greater depth. Two or more tiers (stages) are used as shown in fig.2.4. More pumps are needed and due to the berms required the excavation width becomes wider. A single well-point handles between 4 and 0.6 m3/hr depending on soil type. For a 120 m length (40 at 3 m centers) flowis therefore between 160 and 24 m3/hr. Nomograms for selecting preliminary wellpoint spacing in clean uniform sand and gravel, and stratified clean sand and gravel are shown in horizontal well-points are used mainly for pipeline water. They consist of perforated pipes laid horizontally in a trench and connected to a suitable pump.

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2.5 EDUCTOR SYSTEM/ Vacuum dewatering

This system also known as the 'jet eductor system' or 'ejector system' or 'eductor wellpoint system' is similar to the wellpoint system. Instead of employing a vacuum to draw water to the well-points, the eductor system uses high pressure water and riser units, each about 30-40mm in diameter. A high pressure supply main feeds water through a venturi tube immediately above the perforated well screen, creating a reduction in pressure which draws water through the large diameter rise pipe. The high pressure main feeds off the return water. The advantage of the eductor system is that in operating many wellpointsfrom a single pump station, the water table can be lowered in one stage from depths of 10-45 m. This method becomes economically competitive at depth in soils of low permeability.

Fig 2.5 Installed Eductor Well Point System

Working of Eductor Dewatering System

Supply pumps at ground level feed high-pressure water to each Eductor well head via a supply main. The supply flow passes down the well and through a nozzle and venturi in the Eductor. The flow of water through the nozzle generates a vacuum in the well and draws in groundwater. The supply flow and extracted groundwater mix, return to the surface and feed back to the pumping station via a return main. The return flow is used to prime the supply pumps and the excess water extracted is discharged by overflow from the priming tank. A single pumping station can be used to operate up to about 75 Eductor wells installed in an appropriate array around the works.

2.6 Deep Well System

A typical deep well consists of a drilled hole within which is a lower screened casing which admits water to the pump; an upper casing which prevents soil from reaching the pump and, within the casing, the pump and its discharge pipe. The discharge pipe supports the pump to which it is attached. Electrical wiring for the pump motor runs between the discharge pipe and the casing. The space between the drilled hole and the casing is normally packed with filter material (for example, coarse sand and/or gravel) to minimize the pumping of solid material from the soil surrounding the well

Spacing of deep well point system

Normally, individual wells are spaced at an approximate distance of 15 m (50 feet) apart. However, depending upon soil conditions and the dewatering plan the spacing may need to be just a few meters apart

Individual well capacities are from 21 to 3000 gallons per minute and with total systems the capacities can be as high as 60 000 gallons per minute. Deep well pumps can lift water 30 m (100 feet) or more in a single stage and the variation of the typical deep well system is a pressure within an aquifer. Deep well points require no pump as the water is forced to the surface by its own pressure. To boost the water flow a vacuum pump is frequently used

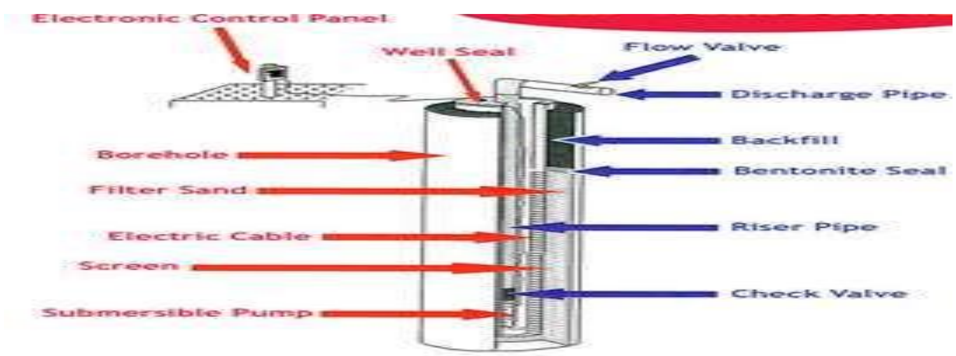


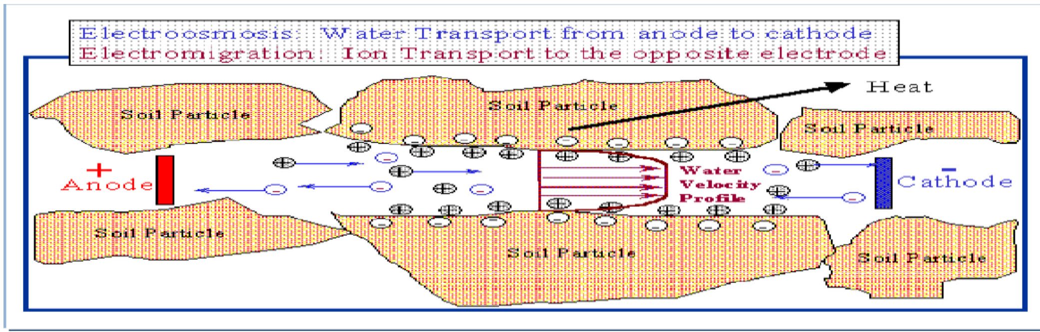
Fig. Details of a Deep Well

2.7 Electro-Osmosis

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 direct current (DC) field*".

It is the only effective method of dewatering in deep clay soils



Mechanism of Electro-osmosis

When electrodes are placed across a clay mass and a direct current is applied, water in the clay pore space is transported to the cathodically charged electrode by electro-osmosis. Electro-osmotic transport of water through a clay is a result of diffuse double layer cations in the clay pores being attracted to a negatively charged electrode or cathode. As these cations move toward the cathode, they bring with them water molecules that clump around the cations as a consequence of their dipolar nature. In addition, the frictional drag of these molecules as they move through the clay pores help transport additional water to the cathode. The macroscopic effect is a reduction of water content at the anode and an increase in water content of the clay at the cathode. In particular, free water appears at the interface between the clay and the cathode surface. This excess of free water at the cathode has lubricating effects

Effectiveness of Electro-osmosis

- Electro-osmosis provides the follwing benefits when properly applied:
- First, electro-osmosis provides uniform pore water movement in most types osoil. SThe boundary layer movement towards the cathode provides the motive force for the bulk pore water, the size of the pore is not important.

- Unlike hydraulic conductivity, electro-osmotic flow rate is NOT sensitive to pore size. Electro-osmotic flow rate is primarily a function of applied voltage. The electro-osmotic permeability for any soil at 20^oC is around 1×10^{-5} cm/s at 1 volt/cm.
- The entire soil mass between the electrodes is basically treated equally.

2.8 RISING METHOD:

This method is normally used for determining the water table location. This method is also referred to as the *time lag method or computational method*. It consists of bailing the water out of the casing and then observing the rate of rise of water level in the casing at intervals of time until the rise in water level becomes negligible. The rate is observed by measuring the elapsed time and the depth of the water surface below the top of the casing. The intervals at which the readings are required will vary somewhat with the permeability of the soil. In no case should the elapsed time for the readings be less than 5 minutes. In freely draining materials such as sands, gravels etc., the interval of time between successive readings may not exceed 1 to 2 hours, but in soils of low permeability such as fine sand, silts and clays, the intervals may rise from 12 to 24 hours, and it may take a few days to determine the stabilized water level.

Let the time be t_o when the water table level was at depth H_o below the normal water table level (Ref Fig. 2.2). Let the successive rise in water levels be h_1, h_2, h_3 etc., at times t_1, t_2, t_3 respectively, wherein the difference in time $(t_1 - t_o)$, $(t_2 - t_1)$, $(t_3 - t_2)$, etc., *is kept constant*.

Now, from Fig.

$H_o - H_1 = h_1$

$H_1 - H_2 = h_2$

$H_2 - H_3 = h_3$

Let $(t_1 - t_o) = (t_2 - t_1) = (t_3 - t_2)$ etc $= \Delta t$

The depths H_o, H_2, H_3 of the water level in the casing from the normal water table level can be computed as follows:

$$H_o = \frac{h_1^2}{h_1 - h_2}$$

$$H_1 = \frac{h_2^2}{h_1 - h_2}$$

$$H_2 = \frac{h_3^2}{h_2 - h_3}$$

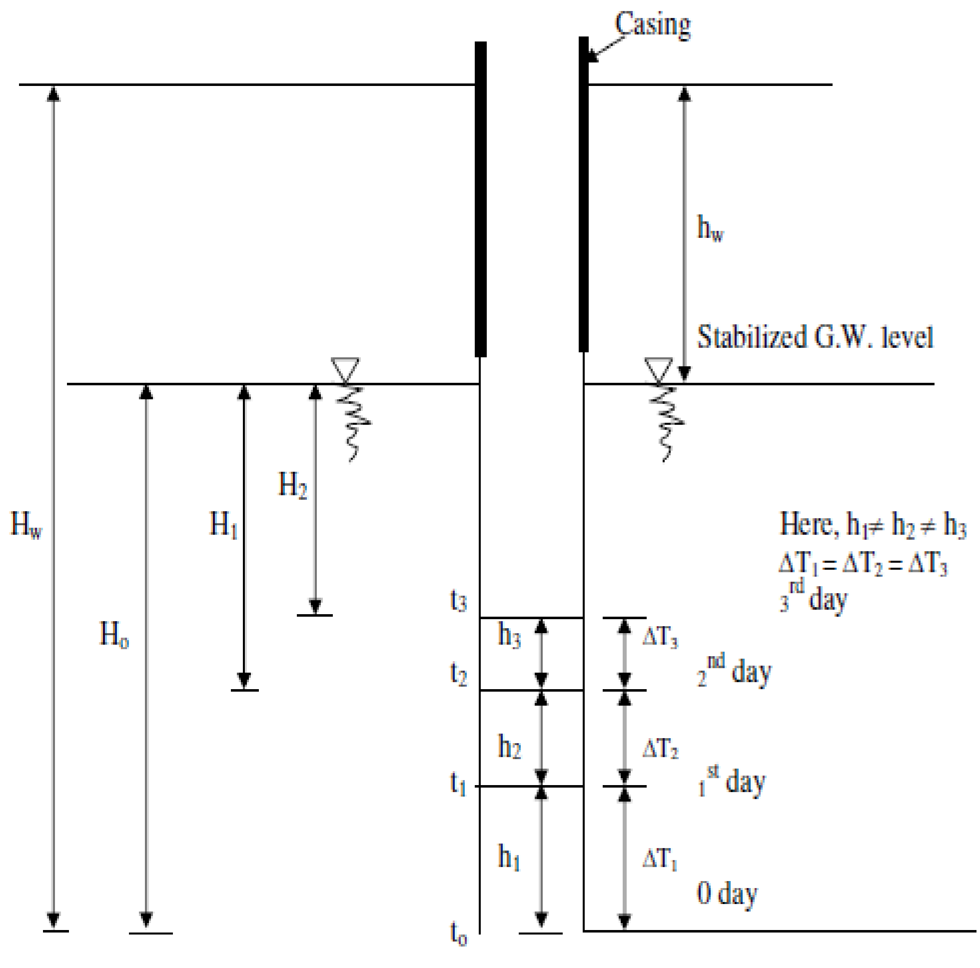
Let the corresponding depths of water table level below the ground surface be h_{w1}, h_{w2}, h_{w3} etc. Now we have

First estimate, $h_{w1} = H_w - H_o$

Second estimate, $h_{w2} = H_w - (h_1 + h_2) - H_1$

Third estimate, $h_{w3} = H_w - (h_1 + h_2 + h_3) - H_2$

Where, H_w is the depth of water level in the casing from the ground surface at the start of the test. Normally $h_{w1} = h_{w2} = h_{w3}$; if not an average value gives h_w, the depth of ground water table.



Numerical Example

2.1 Establish the location of ground water in a clayey stratum. Water in the borehole was bailed out to a depth of 10.5 m below ground surface, and the rise of water was recorded at 24 hour intervals as follows

$h_1 = 0.63$ m , $h_2 = 0.57$ m, $h_3 = 0.51$ m

Solution:

$$H_o = \frac{h_1^2}{h_1 - h_2} = \frac{0.63^2}{(0.63 - 0.57)} = 6.615m$$

$$H_1 = \frac{h_2^2}{h_1 - h_2} = \frac{0.57^2}{(0.63 - 0.57)} = 5.415m$$

$$H_2 = \frac{h_3^2}{h_2 - h_3} = \frac{0.51^2}{(0.57 - 0.51)} = 4.335m$$

1st day $h_{w1} = H_w - H_o = 10.5 - 6.615 = \underline{3.885\text{ m}}$

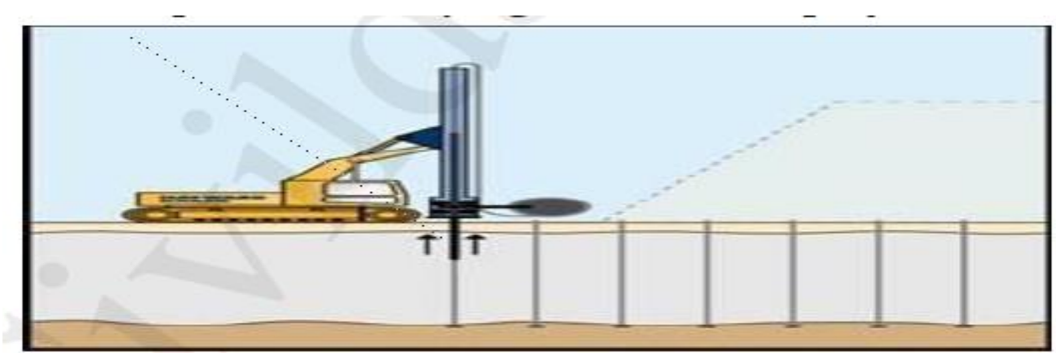
2nd day $h_{w2} = H_w - (h_1 + h_2) - H_1 = 10.5 - (0.63 + 0.57) - 5.415 = \underline{3.885\text{ m}}$

3rd day $h_{w3} = H_w - (h_1 + h_2 + h_3) - H_2 = 10.5 - (0.63 + 0.57 + 0.51) - 4.335$

$= \underline{4.455\text{ m}}$

2.9 Preloading:

Preloading has been used for many years without change in the method or application to improve soil properties. Preloading or pre-compression is the process of placing additional vertical stress on a compressible soil to remove pore water over time. The pore water dissipation reduces the total volume causing settlement. **Surcharging** is an economical method for ground improvement. However, the consolidation of the soils is time dependent, delaying construction projects making it a non-feasible alternative.



The soils treated are Organic silt, Varved silts and clays, soft clay, Dredged material The design considerations which should be made are bearing capacity, Slope stability, Degree of consolidation

The two common preloading techniques are conventional preloading, e. g.

- means of an embankment
- Vacuum induced preloading.

Preloading by means of an Embankment:

Simply places a surcharge fill (temporary, permanent or combination of both on top of the soil that requires consolidation (silty and clayey soils).

The temporary surcharge can be removed when the settlements exceeds the predicted final settlement.

Once sufficient construction, the fills can be removed and construction takes place.

Surcharge fills are typically 3-8 m thick and generally produces settlements of 300 mm – 1000 mm.

Limitations

Surcharge fill must extend horizontally atleast 10 m beyond the perimeter of the planned construction, which may not be possible at confined sites.

Transport of large quantities of soil on and off the site may not be practical, or may have unacceptable environmental (noise, traffic, dust) impacts on adjacent areas.

Surcharge must remain in place for months or years thus delaying construction

Vacuum Preloading

In its simplest form the method of vacuum consolidation consists of a systemof vertical drains and a drainage layer (sand) on top (150 mm).

It is sealed from atmosphere by an impervious membrane. Horizontal drains are installed in the drainage layer and connected to a vacuum pump.

To maintain air tightness, the ends of the membrane are placed at the bottom of a peripheral trench filled e. g. with bentonite.

Negative pressure (60 to 80 kPa) is created in the drainage layer by means of the vacuum pump.

The applied negative pressure generates negative pore water pressures, resulting in an increase in effective stress in the soil, which in turn is leading to an accelerated consolidation.

Advantages of vacuum preloading

There is no extra fill material needed, the construction times are generally shorter and it requires no heavy machinery.

No chemical admixtures will penetrate into the ground and thus it is an environmental friendly ground improvement method

Isotropic consolidation eliminates the risk of failure under additional loading of the permanent construction, there is no risk of slope instability beyond boundaries and it allows a controlled rate and magnitude of loading and settlement

Vertical Drains and Pre-loading
With increased thickness of the soft clay where the consolidation period is too long for full consolidation of primary settlements, vertical drainage may be incorporated in conjunction with preloading in order to accelerate the settlement. Vertical drains may be proposed in the areas where the thickness of soft soils is limited to less than 10 m and embankment height are low. The anticipated primary and secondary settlements in such areas are limited.

Vertical Drains
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. Therefore, the vertical drain installation reduces the length of the drainage path and, consequently, accelerates the consolidation process and allows the clay to gain rapid strength increase to carry the new load by its own

Types of Vertical Drains

- Sand Drains
- Prefabricated Drains

Sand drains
Sand drains are basically boreholes filled with sand. Are of two types:
Displacement Sand Drains
As for the displacement type of sand drains, a closed mandrel is driven or pushed into the ground with resulting displacement in both vertical and horizontal directions. The installation causes therefore disturbances, especially in soft and sensitive clays, which reduces the shear strength and horizontal permeability

Non Displacement Sand Drains
The low- or non-displacement installations are considered to have less disturbing effects on the soil. Drilling of the hole is done by means of an auger or water jets. In terms of jetting, however, installation is very complex.

Disadvantages of sand drains

- To receive adequate drainage properties, sand has to be carefully chosen which might seldom be found close to the construction site.
- Drains might become discontinuous because of careless installation or horizontal soil displacement during the consolidation process.
- During filling bulking of the sand might appear which could lead to cavities and subsequently to collapse due to flooding.
- Construction problems and/or budgetary burdens might arise due to the large diameter of sand drains.
- The disturbance of the soil surrounding each drain caused by installation may reduce the permeability, the flow of water of water to the drain and thus the efficiency of the system.

- The reinforcing effect of sand drains may reduce the effectiveness of preloading the subsoil.

Prefabricated Drains

The installation of prefabricated vertical drains is also done by a mandrel and it is a displacement installation. Figure shows a typical mandrel and the typical shape of a prefabricated drain. The dimensions of the prefabricated drains are much smaller compared to sand drains and subsequently are the dimensions of the mandrel. Thus, the degree of soil disturbance caused by the size of the mandrel during installations is lower.

2.10 Electro kinetic Stabilization:

One of the most common causes of foundation movement is volume change of active clays in response to environmental and/or vegetation, notably clay shrinkage in long dry spells and clay swelling following the removal of large trees and hedges.

Electro kinetic stabilization is a technique of applying an electrical current through a soil mass to promote the migration of chemicals from injection points, which are usually the electrodes themselves.

This technique is particularly suited to weak clayey soils that require strengthening and yet possess a low hydraulic conductivity, thus preventing the economic introduction of chemical grout using conventional hydraulic means.

2.11 Important Questions?

- List the methods of control ground water during excavation (Dewatering methods). Explain anyone.
- Estimate the position of the Ground water table from the following data obtained from filed?
- Write short note on Vacuum method of dewatering?

2.12 Further Reading

1. https://www.groundwatereng.com/dewatering-techniques

2. https://www.thebalancesmb.com/what-is-dewatering-844520

3. https://nptel.ac.in/content/storage2/courses/105108075/module5/Lecture12.pdf

4.

Module 3 Chemical Modification:1

3.0 Introduction:

Stabilization: Stabilizing a soil is to lend it properties which are irreversible in the face of physical constraints. A great many parameters intervene, depending as much on the design of the building, on the quality of the materials used, on economic aspects of the project, or on issues of durability. For stabilization to be successful, the process used must be compatible with these various imperatives

When building with earth, one is confronted with two basic options.

- The type of soil available on site dictates the building system.
- The building system, having been predetermined, dictates the use of a particular type of soil.

In the first instance, architecture, in other words the design, takes account of the site context and determines the building systems which will ensure the durability of the buildings; architectural choices act as a "stabilizer". This is the first approach to be preferred and used.

In the second instance, it is the manufacturing technique, often alien to the site, which ensures the durability of the materials used, more or less independently of the building systems; the process and the addition of material(s) act as a «stabilizer».

There are more than a hundred products in use today for stabilization. These stabilizers can be used both in the body of the walls and in their outer "skin": in renders, for example. Stabilization has been practiced for a very long time, but despite this, it is still not an exact science and to date no "miracle" stabilizer is known among the multitude of products available, some of which should not even be considered, either because of their inefficiency, or because they are prohibitively expensive.

The main objectives being pursued are:

- obtaining better mechanical performances: increasing dry and wet compressive strength;
- reducing porosity and variations in volume: swelling and shrinking with moisture content variations;
- Improving the ability to withstand weathering by wind and rain: reducing surface abrasion and increasing waterproofing.

3.1 Stabilization Process

There are three stabilization processes:

Mechanical stabilization: the properties of the soil are modified by treating its structure: compaction of the soil modifies its density, its mechanical strength and its compressibility, its permeability and its porosity.

Physical stabilization: the properties of a soil can be modified by treating its texture, a controlled mix of the various particle fractions.

Chemical stabilization: Other materials or chemical products are added to the soil and modify its properties.

There are two ways of increasing density:

Either subjecting the soil to mechanical manipulation in order to force out as much air as possible, by kneading or compressing the soil. The texture of the soil does not change, but its structure does as the particles are redistributed. The soil is not just compressed in its original state: it is first broken up to make it more uniform, and then compressed.

Or filling as many voids as possible with other particles. For this second approach, the texture must be perfect: the void left between each group of particles is filled by another group of particles. Here the texture is being directly treated.

Cement stabilization:

Cement is probably one of the best stabilizers for CEBs. Adding cement before compaction improves the characteristics of the material, and particularly its resistance to water, thanks to the irreversible nature of the links it creates between the largest particles. Cement mainly affects sands and gravels, as in concrete or in a sand-cement mortar. This means that it is not necessary, and indeed it may be harmful, to use soils which have too high a clay content (> 20%). Its use does not require too much water which corresponds to the humid compression state of CEBs

EFFICIENCY AND HOW MUCH TO USE

In general, at least 5 to 6% cement will be needed to obtain satisfactory results. Compressive strength is highly dependent on the amount used.

With low proportions (2-3%) certain soils perform less well than when left unstabilized.

Given similar local conditions, there may be no guarantee that a CEB will use less cement than a cement block.

3.2 Soil Cement:

Cement Stabilization What is Soil-Cement? Soil-cement is a highly compacted mixture of soil/aggregate, cement and water. It is widely used as a low-cost pavement base for roads, residential streets, parking areas, airports, shoulders, and materials-handling and storage areas. Its advantages of great strength and durability combine with low first cost to make it the outstanding value in its field. A thin bituminous surface is usually placed on the soil-cement to complete the pavement. Soil-cement is sometimes called cement-stabilized base, or cement-treated aggregate base. Regardless of the name, the principles governing its composition and construction are the same

The hydrated products of cement bind the soil particles, the strength developed depending on the concentration of cement and the intimacy with which the soil particles are mixed with cement. A high cement content of the order of 7-10% can produce a hard mass having a 7-day compressive strength of 20 kg/cm2 or more, and this usually goes by the term soil-cement. However, a smaller proportion of 2-3% cement can improve the CBR value to more than 25, and the material goes by the term "cement-modified soil", which can be advantageously used as sub -base/base for rural roads. Cement stabilization is ideally suited for well graded aggregates with a sufficient amount of fines to effectively fill the available voids space and float the coarse aggregate particles. General guidelines for stabilization are that the plasticity index should be less than 30 for sandy materials. For finegrained soils, soils with more than 50 percent by weight passing 75µm sieve, the general consistency guidelines are that the plasticity index should be less than 20 and the liquid limit (LL) should be less than 40 in order to ensure proper mixing. A more specific general guideline based on the fines content is given in the equation below which defines the upper limit of PI for selecting soil for cement stabilization. 6 Cement is appropriate to stabilize gravel soils with not more than 45 percent retained on the no. 4 sieve. The Federal Highway Administration recommends the use of cement in materials with less than 35 percent passing no. 200 sieve and a plasticity index (PI) less than 20. Based on this system, soils with AASHTO classifications A-2 and A-3 are ideal for stabilization with cement, but certainly cement can be successfully used to stabilize A-4 through A-7 soils as well. The Portland cement Association (PCA) established guidelines to for stabilizing a wide range of soils from gravels to clays

Factors Affecting Soil Cement Stabilization During soil cement stabilization the following factors are affecting.

- Type of soil: Cement stabilization may be applied in fine or granular soil, however granular is preferable for cement stabilization.
- Quantity of cement: A large amount of cement is needed for cement stabilization.
- Quantity of water: Adequate water is needed for the stabilization.
- Mixing, compaction and curing: Adequate mixing, compaction and curing is needed for cement stabilization.
- Admixtures: Cement has some important admixtures itself which helps them to create a proper bond. These admixtures pay a vital role in case of reaction between cement and water

Advantages of Cement Stabilization

- It is widely available.
- Cost is relatively low.

- It is highly durable.
- Soil cement is quite weather resistant and strong.
- Granular soils with sufficient fines are ideally suited for cement stabilization as it requires least amount of cement.
- Soil cement reduces the swelling characteristics of the soil.
- It is commonly used for stabilizing sandy and other low plasticity soils. Cement interacts with the silt and clay fractions and reduces their affinity for water.

Disadvantages of Cement Stabilization

- Cracks may form in soil cement.
- It requires extra labour.
- The quantity of water must be sufficient for hydration of cement and making the mixture workable.

HOW TO PROCEED FOR CEMENT STABILIZATION:

Preparation

An even mix is crucial. Lumps or sods of clay are therefore to be avoided. Care must be taken during screening with no prior preparation as apart from stones and gravel, there is a risk of also removing lumps of clay and thereby modifying the properties of the soil. To prevent lumps reforming after disintegration, the soil should be kept dry.

Mixing

Even with a well-prepared soil, the cement must be mixed in as thoroughly as possible, otherwise, as it is generally used in low proportions (4 to 8%), it will not be evenly distributed. Mixing should be done in two stages: dry and wet mixing. The cement will begin to act on contact with water, which is why water should be added to the dry mix at the last moment before compaction in order to keep the time before it is used (retention time) to a minimum, as this greatly affects the quality of the blocks (see below). The moisture content of the mix will be slightly drier than the OMC for sandy soils and slightly wetter for soils containing too much clay.

Curing

Cement stabilized blocks must be kept in a humid environment for at least 7 days. The surface of the blocks must not be allowed to dry out too quickly, as this causes shrinkage cracks. The blocks must be sheltered from direct sun and wind and kept in conditions of relative humidity

(RH) approaching 100% by covering them with waterproof plastic sheets. After 28 days there will be no further significant increase in the strength of the cement. High temperatures will increase the strength obtained and temperature can be raised using black plastic sheeting.

Examples: compared with 14 days'curing at 100% relative humidity, blocks cured for 7 days at 100% RH and 7 days at 95% RH blocks will achieve 25% less strength. Blocks cured for 7 days at 40°C will be 1.5 to 2 times stronger that blocks cured for 7 days at 20°C

Drying

After curing, water must be allowed to evaporate and the clay fraction to shrink. To prevent shrinkage occurring too quickly, exposure to wind and direct sun must be reduced. Drying out will take approximately 14 days

3.3 Fly Ash in Soil Improvement:

Soil stabilization is the alteration of soil properties to improve the engineering performance of soils. The properties most often altered are density, water content, plasticity and strength. Modification of soil properties is the temporary enhancement of subgrade stability to expedite construction.

Class C fly ash and Class F-lime product blends can be used in numerous geotechnical applications common with highway construction:

- To enhance strength properties
- Stabilize embankments
- To control shrink swell properties of expansive soils
- Drying agent to reduce soil moisture contents to permit compaction

Class C fly ash can be used as a stand-alone material because of its self-cementitious properties. Class F fly ash can be used in soil stabilization applications with the addition of a cementitious agent (lime, lime kiln dust, CKD, and cement). The self-cementitious behavior of fly ashes is determined by ASTM D 5239. This test provides a standard method for determining the compressive strength of cubes made with fly ash and water (water/fly ash weight ratio is 0.35), tested at seven days with standard moist curing. The self-cementitious characteristics are ranked as shown below:

Very self-cementing	> 500 psi (3,400 kPa)
Moderately self-cementing	100 - 500 psi (700 - 3,400 kPa)
Non self-cementing	< 100 psi (700 kPa)

Soil Stabilization to Improve Soil Strength

Fly ash has been used successfully in many projects to improve the strength characteristics of soils. Fly ash can be used to stabilize bases or subgrades, to stabilize backfill to reduce lateral earth pressures and to stabilize embankments to improve slope stability. Typical stabilized soil depths are 15 to 46 centimeters (6 to 18 inches). The primary reason fly ash is used in soil stabilization applications is to improve the compressive and shearing strength of soils. The compressive strength of fly ash treated soils is dependent on:

- In-place soil properties
- Delay time
- Moisture content at time of compaction
- Fly ash addition ratio

Delay time. Delay time is the elapsed time measured between when the fly ash first comes into contact with water and final compaction of the soil, fly ash and water mixture. Compressive strength is highly dependent upon delay time. Both densities and strength are reduced with increasing delay to final compaction. Delay time is critical due to the rapid nature of the tricalcium aluminate (C3A) reaction that occurs when Class C fly ash is mixed with water. Densities and strengths are reduced because a portion of the compactive energy must be used to overcome the bonding of the soil particle by cementation and because a portion of the cementation potential is lost. Maximum strength in soil-fly ash mixtures is attained at no delay.

Moisture content. The water content of the fly ash stabilized soil mixture affects the strength. The maximum strength realized in soil-fly ash mixtures generally occurs at moisture contents below optimum moisture content for density. For silt and clay soils the optimum moisture content for strength is generally four to eight percent below optimum for maximum density.

Addition Ratios. Typical fly ash addition rates are 8 percent to 16 percent based on dry weight of soil. The addition rate depends on the nature of the soil, the characteristics of the fly ash and the strength desired. The addition rate must be determined by laboratory mix design testing. In general the higher the addition rate the higher the realized compressive strength.

Soil Properties. The plasticity of soils treated with Class C or other high-calcium fly ash is influenced by the types of clay minerals present in the soil and their adsorbed water. Soils containing more than 10 percent sulfates have been prone to swell excessively in some applications. Also, organic soils are difficult to stabilize using fly ash.

Soil Stabilization to Control Shrink Swell:

Many clay soils (plastic soils) undergo extensive volumetric changes when subjected to fluctuating moisture contents. These volumetric changes if not controlled can lead to movements in structures and impose loads which can cause premature failure.

Fly ash reduces the potential of a plastic soil to undergo volumetric expansion by a physical cementing mechanism, which cannot be evaluated by the plasticity index. Fly ash controls shrink-swell by cementing the soil grains together much like a portland cement bonds aggregates together to make concrete. By bonding the soil grains together, soil particle movements are restricted. Typical addition rates based on dry weight of soil are 12 to 15 percent.

Soil Modification to Reduce Water Content

Soils must be compacted to their maximum practical density to provide a firm base for overlying structures. For soils to be compacted the moisture content must be controlled because of the relationship between soil density and moisture content. If the soil to be compacted is either to wet or too dry, the moisture content must be adjusted to near optimum to achieve maximum density. If a soil is too dry, moisture is simply added. If a soil is too wet, the moisture content of the soil must be lowered. Class C fly ash and other high lime fly ash have been found to be very effective drying agents, capable of reducing soil moisture content by 30 percent or more.

3.4 Chemical Modification: II

Chemical stabilization alters the chemical properties of the soil through the use of admixtures. However, there are mechanical additives too that do not alter the chemical properties of the existing soil but simply reinforce the natural properties of the parent soil. This technique is more cost effective because treating the soil on site is less expensive than importing an aggregate.

The main problem with chemical soil stabilization is that one needs to have a good sense of judgment. The type of soil, the right additive, the right amount to be used and the right application process are aspects to factor in when using this method of stabilizing soils. If either of them goes wrong, the end result can be the opposite of the desired ones resulting in a total waste of time and higher monetary losses.

The additives are combined with the soil using heavy-duty machinery. The best machine to achieve the task is a stabilization machine rotary mixer. It breaks up the soil and mixes the additive mixture as evenly as possible. The other equipment used to accomplish the task includes water tankers, motor graders, pad foot rollers, rubber tyre rollers.

There are different types of additives available. As already mentioned above, specific additives work with specific soil types. Portland cement, quicklime or hydrated lime, fly ash, calcium chloride and bitumen as some of the mechanical and chemical additives added to it. Chemical additives work differently to stabilize soils. Some act as binders, other increase soil density while a few alter the effect of moisture on the soil

Lime:

Lime can be used to treat soils in order to improve their workability and load-bearing characteristics in a number of situations. Quicklime is frequently used to dry wet soils at construction sites and elsewhere, reducing downtime and providing an improved working surface. An even more significant use of lime is in the modification and stabilization of soil beneath road and similar construction projects. Lime can substantially increase the stability, impermeability, and load-bearing capacity of the subgrade. Both quicklime and hydrated lime may be used for this purpose. Application of lime to subgrades can provide significantly improved engineering properties.

Lime is an excellent choice for short-term modification of soil properties. Lime can modify almost all fine-grained soils, but the most dramatic improvement occurs in clay soils of moderate to high plasticity. Modification occurs because calcium cations (***KAT****-eye-əns*) supplied by hydrated lime replace the cations normally present on the surface of the clay mineral, promoted by the high pH environment of the lime-water system. Thus, the clay surface mineralogy is altered, producing the following benefits:

- Plasticity reduction;
- Reduction in moisture-holding capacity (drying);
- Swell reduction;
- Improved stability; and
- Ability to construct a solid working platform.

There are basically five types of lime:

- High Calcium, quick lime (CaO) ♣
- Hydrated, high calcium lime [Ca(OH)2]
- Dolomite lime (CaO+MgO)
- Normal, hydrated dolomitic lime [Ca(OH)2+MgO]
- Pressure, hydrated dolomitic lime [Ca(OH)2+Mg(OH)2]

The quick lime is more effective than the hydrated lime, but the latter is more safe and convenient to handle. Generally, hydrated-lime is used. It is also known as slaked lime. The higher the magnesium content of the lime, the less is the affinity for water and the less is the heat generated during mixing.

The amount of lime required varies between 2 to 10% of the soil. Lime stabilization is done by adding lime to soil. It is useful for the stabilization of clayey soil.

When lime reacts with soil there is exchange of cations in the absorbed water layer and a decrease in the plasticity of the soil occurs.

The resulting material is more friable than the original clay, and is, therefore more suitable as sub-grade.

Calcium Chloride—

- It causes colloidal reaction & alters the characteristics of the soil. ♣ It is deliquescent and hygroscopic and reduces the loss of moisture.
- It reduces the chances of frost heave, as the freezing point of water is lowered.
- Effective as dust calming,
- Effective for silty and clayey soils which loose strength with an increase in water content.
- It causes a slight increase in maximum dry unit weight. Chemical Stabilization Cont.
- It forms crystallization in the pores of the soil and finally a dense hard mat with the stabilized surface. The pores in the soil filled up and retard further evaporation of water.
- It also checks the tendency for the formation of shrinkage cracks.
- It is mixed with the soil either by mix-in-place or by plant-mix method and should be applied directly to the surface.
- The quantity required is about 1% of the soil weight

Sodium Silicate:

- It is used as solution in water, known as water glass.
- It is directly injected into the soil.
- It increases the strength of the soil and makes it impervious. Chemical Stabilization Cont.
- Acts as a dispersing agent.
- It increases the maximum compacted unit weight of the soil.
- The chemical required varies between 0.1 to 0.2% of the weight of the soil.
- The method is relatively inexpensive but long-term stability is doubtful. The treated soil may lose strength when exposed to air or ground water

Polymers:

Polymers are long-chained molecules formed by polymerizing of certain organic chemicals called monomers.

They may be natural or synthetic.

Resins are natural polymers and calcium acrylate is synthetic. When added to the soil reaction takes place. Sometimes catalyst is added with the monomers to the soil. In that case polymerization occurs along with the reaction.

Chrome Lignin: Lignin is obtained as a byproduct during the manufacture of paper.

Chrome lignin is formed from black liquor in sulphite paper manufacture. Sodium bicarbonate or potassium bicarbonate is added to sulphite liquor to form chrome lignin. It slowly polymerizes into a brown gel. When added to the soil, it slowly reacts to cause binding of particles. The quantity required varies from 5 to 20% by weight. As lignin is soluble in water, its stabilizing effect is not permanent.

Other Chemicals:

Water proofers such as alkyl chloro silanes, siliconates amines and quaternary ammonium salts, have been used for soil water proofing.

Coagulating chemicals such as calcium chloride and ferric chloride have been used to increase the electrical attraction and to form flocculated structure in order to improve the permeability of soil.

Dispersant such as sodium hexa-metaphosphate are used to increase the electric repulsion and to cause dispersed structure. The compacted density of the soil is increased.

Phosphoric acid combined with a wetting agent can be used for cohesive soils. It reacts with clay minerals and forms an insoluble aluminum phosphate.

3.5 Bituminous (Cementing) Stabilization:

Bituminous soil stabilization is an effective method which is being widely used. Bituminous materials are: bitumen, asphalt and tar. Bitumens are no aqueous systems of hydrocarbons which are completely soluble in carbondisulphide. Asphalts are materials in which the primary components are natural or refined petroleum bitumen's or combine- tions thereof. Tars aie bituminous condensates produced by the destructive distillation of organic materials such as coal, oil, lignite, peat and wood.

Bituminous material stabilizes the soil either by binding the particles together or protecting the soil from the deleterious effects of water (i.e., waterproofing) or both these effects may occur together. The first mechanism takes place in cohesion less soils and the second one in cohesive soils. Among the bituminous materials, most of bitumen stabilization has been with asphalt. Therefore, soil stabilized by asphalt may be referred to as soil-asphalt

Asphalts are produced by three processes:

- Vacuum distillation producing straight-run asphalt
- High-temperature pyrolysis of refinery heavies, producing cracked asphalt
- High- temperature air blowing straight-run asphalt, producing blown asphalt.

As the straight-run asphalt has low softening temperature and low melt viscosity, it is commonly used in soil stabilization. Asphalt cannot be directly added to the soil because it is too viscous. Its fluidity can be increased by (i)heating, (ii) emulsifying in water (emulsions), or (iii) cut back with some solvent like gasoline (cutbacks). Both emulsions and cutbacks are used in soil stabilization. Although soil-asphalt has varied applications, it is mostly used in bases for highway and airfield pavements

Nature of Soil

All inorganic soils with which asphalt (emulsion or cutback) can be mixed can be stabilized. Soils satisfying the following requirements yield the best results:

- Maximum particle size less than one-third the compacted thickness of the treated soil layer.
- Greater than 50% finer than 4.76 mm size.
- Thirty five to 100% finer than 0.42 mm size.
- Greater than 10%, but less than 50% finer than 0.074 mm size.
- Liquid limit less than 40%.
- Plasticity index less than 18%.

Organic matter of acid origin is detrimental to soil-asphalt. Asphalt stabilization cannot be effective in fine grained soils with high pH and dissolved salts. It is difficult to handle plastic clays because of mixing problem.

Amount of Asphalt

An increase in asphalt content gives better results. In fine-grained soils addition of asphalt does not increase the strength but tremendously improves the waterproofing property and thereby yielding a better stabilized soil. Asphalt also should be added optimally otherwise results in a gooey mixture which cannot be properly compacted.

Mixing

A thorough incorporation of the additive with the soil yields a better stabilized soil

Compaction Conditions

The density of a mixture of soil and asphalt is governed by the volatiles content and amount and type of compaction. In general lower the volatiles content, the higher the strength. Further, samples which were cured and then immersed in water showed a maximum strength at a moulding volatiles content near or slightly above that for maximum compacted density and the water pickup and thus strength loss, is least at this moulding volatiles content (Lambe, 1962). In plastic soils the volatiles content which gives maximum cured strength and that which gives optimum density can be quite different and the difference can vary with type of compaction.

Cure Conditions

The following behavior have been reported to be true: (i) the longer the period of cure and warmer the temperature of cure, the greater the volatiles lost; (ii) the longer the period of immersion, the greater the water pickup. The strength of a soil-asphalt is inversely proportional to the volatiles content at the time of test. A general strength-volatiles content relationship was obtained regardless of the formulation employed.

Construction of Soil-Asphalt

The conventional sequence of construction operation is as follows:

- Pulverisation of the soil to be treated,
- Addition of water for proper mixing, (Hi) Adding and mixing of the bitumen,
- Aeration to the proper volatiles content for compaction, (i;) Compaction, (ui) Finishing,
- Aerating and curing, and
- (Application of surface cover.
- The important items to ensure proper stabilization which need control are mixing, compacting, drying and applying the surface protection. The mixing plants used for soil-cement can be used for soil asphalt also. The necessary field control tests are moisture content determination before and during processing, bitumen content determination after mixing and density determination after compaction.

The optimum moisture content for stability is usually below that for compaction. As good mixing is generally considered to be most easily obtained at fairly high moisture contents, it is often found necessary, except with sands, to allow a period for the mix to dry between the mixing process and compaction. In practice, treated sands are placed at about 3 to 5% volatiles content whereas cohesive soils are placed at about the optimum volatiles content for compaction. Compared to cutbacks or tars, emulsions provide more latitude in the stabilization of fine-grained soils.

3.6Thermal Stabilization of Soil:

Thermal stabilization of soil is a ground improvement technique. The concept, method and applications of thermal stabilization of soil is discussed

It has been observed that heating or cooling shows certain marked changes in the soil properties. Many types of research were conducted on the same and many impressive results were observed that is found relevant for soil stabilization.

Heating and cooling have been extensively used as soil improvement techniques. Whatever be the mode of thermal stabilization we opt for it has the following

- Thermal evaluation of heat flow
- Heating or refrigeration system has to be designed
- Strength and stress-strain -time properties of the soil have to undergo performance analysis

Concept of Thermal Stabilization of Soil

Like seepage or consolidation analysis of soil, a heat flow analysis can also be carried out. The transfer of heat in soil occurs by conduction, convection (free, forced, by thawing) and radiation.

The most predominant mechanism of transfer is through conduction, which takes place in three constituents of soil which are soil solids, water (which may be in the form of a liquid, ice or vapor) and pore air. The phenomenon of heat conduction is influenced by soil thermal properties which are its thermal conductivity, latent heat of fusion, the heat of vaporization of soil water and the heat capacity of the soil.

The behavior of heat flow in soil is mainly governed by the latent heat of fusion of water on freezing and heat of vaporization of water on heating above 100^0C. The latent heat of fusion can be defined as the heat amount that must be added to the unit mass of a substance to change it from liquid to solid or solid to liquid without any change in the temperature

Now, the heat of vaporization is defined as the heat required to change the substance from liquid to vapor.

Thermal stabilization of soil from Heating:

It is noted that higher the heat input per mass of the soil (which should be treated), the greater would be the effect. A small increase in temperature will cause a strength increase in fine-grained soils due to the reduction of electric repulsion between the particles, pore water flow due to variation in thermal gradient and due to the reduction in moisture content because of increasing evaporation rate.Therefore, it is found that it is technically feasible to stabilize fine-grained soils by heating. The following mentioned statement gives the temperature and the corresponding possible change in soil properties.

- 100^0C Cause drying and a significant increase in the strength of clays. This results in decrease in the compressibility of the soil.
- 500^0C Cause permanent changes in the structure of clays results in a decrease of plasticity as well as moisture adsorption capacity.
- 1000^0C Cause fusion of the clay particles into a solid substance like brick.

It has been experimented and found that heat was able to change an expansive clay into an essentially none- expansive material. When liquids or gas fuels are burned in boreholes or an injection of hot air into 0.15m to 0.20m diameter holes, resulted in the formation of 1.3 to 2.5m diameter stabilized zones after continuous treatment for 10 days.

Heating, therefore, would cause permanent changes in the soil making the soil harder as well as durable. So, treatment would cause overall decrease in

- Compressibility
- Increase in cohesion
- Increase in Internal friction angle
- Increase in modulus of elasticity

3.7 Important questions?

1. Explain different types of stabilization?

2.Explain cement soil stabilization in detail?

3. Explain chemical stabilization in detail?

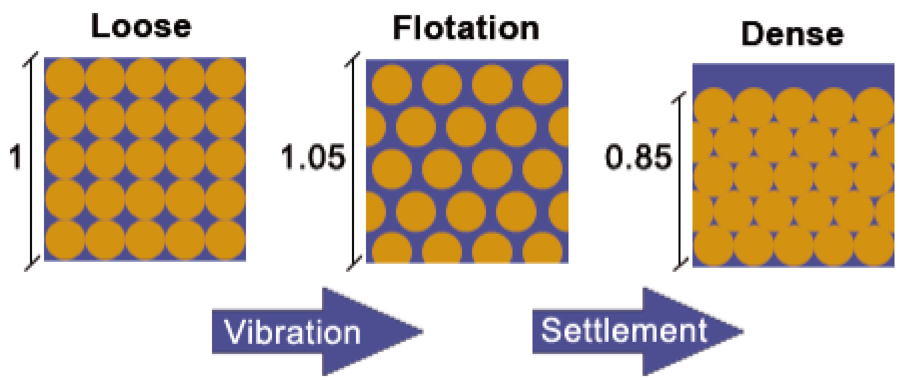
3.8 Further Reading:

1. https://www.diva-portal.org/smash/get/diva2:997144/FULLTEXT01.pdf
2. https://www.researchgate.net/publication/317971126_Soil_stabilisation_using_cement
3. http://www.nzdl.org/gsdlmod?e=d-00000-00---off-0hdl--00-0----0-10-0---0---0direct-10---4-------0-1l--11-en-50---20-about---00-0-1-00-0--4----0-0-11-10-0utfZz-8-00&cl=CL1.3&d=HASH01cf0835ed104fa479c5cc9b.5.3&gt=1
4. https://theconstructor.org/geotechnical/soil-stabilization-methods-and-materials/9439/

Module 4

4.0 VIBROCOMPACTION

Compaction of granular soils by depth vibrators is known as Vibro Compaction. The method is also known as "Vibroflotation". Natural deposits as well as artificially reclaimed sands can be compacted to a depth of up to 70 m. The intensity of compaction can be varied to meet bearing capacity criteria. Other improvement effects such as reduction of both total and differential settlements are achieved. The risk of liquefaction in a earthquake prone area is also drastically reduced.



The principle of sand compaction (Vibroflotation):

The compaction process consists of a flotation of the soil particles as a result of vibration, which then allows for a rearrangement of the particles into a denser state

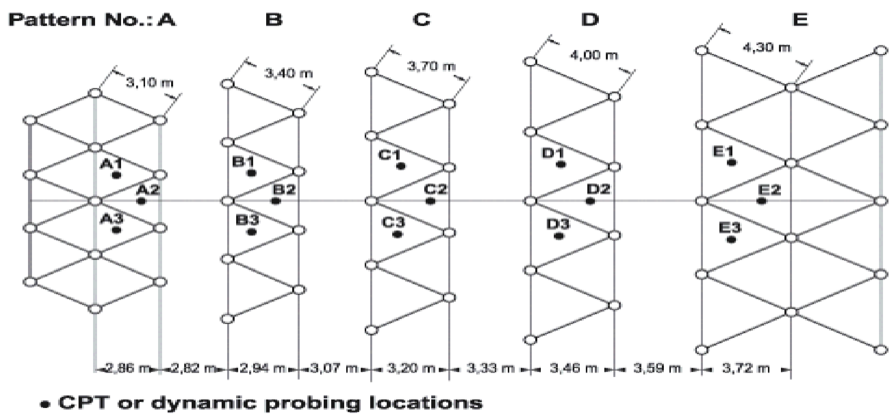
Effects of Compaction

- The sand and gravel particles rearrange into a denser state.
- The ratio of horizontal to vertical effective stress is increased significantly.
- The permeability of the soil is reduced 2 to 10 fold, depending on many factors.
- The friction angle typically increases by up to 8 degrees.
- Enforced settlements of the compacted soil mass are in the range of 2 % to 15 %, typically 5 %
- The stiffness modulus can be increased 2 to 4 fold

Test Pattern

On large projects the optimal compaction grid spacing has to be determined by test grids.

The compaction effect in the test grids should be as close as possible to the treatment in the later production areas. In order to achieve this it is advisable to arrange the test grids close to each other. The distance between grid A (3.10 m) and grid B (3.40 m) should be



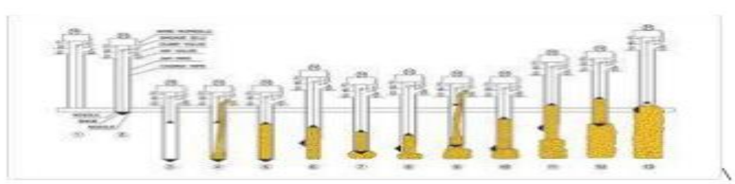
DYNAMIC TAMPING

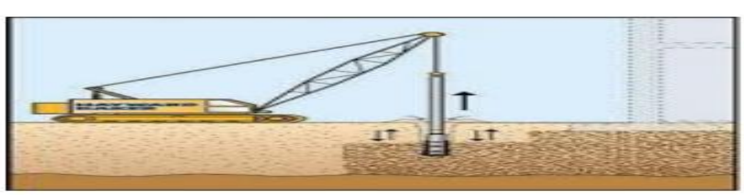
A tamping machine or ballast tamper is a machine used to pack (or tamp) the track ballast under railway tracks to make the tracks more durable. Prior to the introduction of mechanical tampers, this task was done by manual labour with the help of beaters. As well as being faster, more accurate, more efficient and less labour-intensive, tamping machines are essential for the use of concrete sleepers since they are too heavy (usually over 250 kg (551 lb)) to be packed into the ballast by hand. Early machines only lifted the track and packed the ballast. More modern machines, sometimes known as a tamper-liner or tamping and lining machine, also correct the alignment of the rails to make them parallel and level, in order to achieve a more comfortable ride for passengers and freight and to reduce the mechanical strain applied to the rails by passing trains. This is done by finding places where the sleepers have sunk from the weight of the passing trains or frost action, causing the track to sag. The tamper lifts each sleeper and the rails up, and packs ballast underneath. When the sleeper is laid down again, the sagged rails now sit at the proper level. In cases where frost action has caused adjacent rails to rise higher, ballast tampers can raise rails above their original level to make the line level again. "Lining" rails doesn't involve ballast tamping, it merely ensures the rails are perfectly parallel and straight as possible. Combining tamping and lining into a single machine saves time and money, as only one machine needs to be run over the track to perform both functions.

4.1 COMPACTION PILES

Sand compaction piling (SCP) is a cost-effective method of ground improvement which is commonly used to improve soft seabed soils prior to land reclamation works. This method involves driving closely-spaced sand columns into the soft seabed to form a grid of sand columns, which imparts higher strength and stiffness to the improved ground. The installation of these sand compaction piles often involves a large amount of cavity expansion displacement of the soft clay around the sand piles, which in turn, leads to significant changes in the strength and stiffness of the soft clay around the sand piles. In practice and research, the properties of the soft clay are taken to be those of the in-situ soil.

The improvement in the strength of the softy clay is around 25% to 50%. The results of these experiments allow the changes in total stress and pore pressure due to the installation of sand compaction piles to be quantified. Comparison of the measured changes in lateral stress and pore pressure with conventional plane strain cavity expansion theory shows that the latter gives a reasonably good estimate at large depth for the entire installation process. However, deviation from plane strain cavity expansion theory was noted at shallow depths. To account for the effect of the ground surface, a semi-empirical plane stress cavity expansion theory was proposed for the shallow zones. The establishment of the two limits formed by the plane strain and plane stress theories allows semi-empirical relations to be fitted to the data. These findings also indicated that, in order to mobilize significant set-up of stress in the improved ground, there must be substantial further cavity expansion during the sand injection stage of SCP. The cumulative total stress and pore pressure increment at a given location due to the installation of multiple piles in a grid is also reasonably estimated by superimposing the increments due to the installation of each pile. The measured and computed undrained shear strength after the dissipation of the excess pore pressure is also higher in the clays enclosed within the SCPs. The quantum of improvement in the strength of the soft clay due to the cavity expansion displacement is typically of the order of 25% to 50%.





4.2 VIBRO REPLACEMENT

Where fines content of the soils in the target treatment interval exceeds the acceptable range for vibro compaction, another ground improvement process of Vibro-Replacement/Displacement by installation of stone columns can be applied.

Type of soil

Vibro Replacement is an accepted method for subsoil improvement, at which large-sized columns of coarse backfill material are installed in the soil by means of special depth vibrators.

Vibro replacement is part of the deep vibratory compaction techniques whereby loose or soft soil is improved for building purposes by means of special depth vibrators.

Contrary to vibro compaction which densifies non-cohesive soil by the aid of vibrations and improves it thereby directly, vibro replacement improves non compactable cohesive soil by the installation of load bearing columns of well compacted, coarse grained backfill material.

Equipment and execution

For the construction of Vibro Replacement columns the bottom feed process is frequently employed, which feeds coarse granular material to the tip of the vibrator with the aid of pressurized air.

To optimize the performance of this process and to accommodate the specialized equipment, vibrocat is developed at base unit which guides the vibrator on its leader and allows the exertion of an additional pull-down pressure during penetration and compaction.

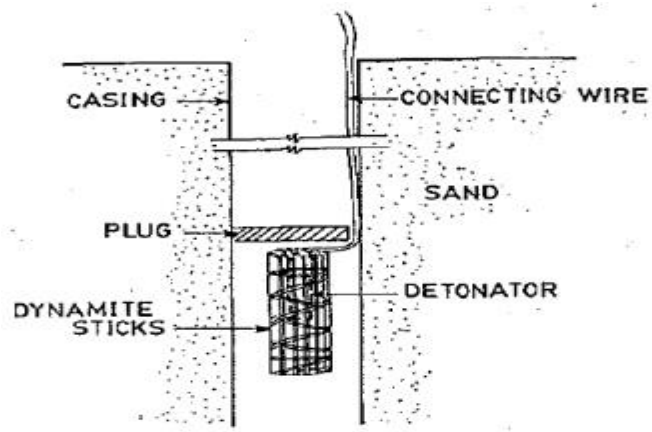
The Vibro Replacement process consists of alternating steps.

During the retraction (pull away) step, gravel runs from the vibrator tip into the annular space created and is then compacted and pressed into the surrounding soil during the following re-penetration step.

In this manner stone columns are created from the bottom up, which act as a composite with the surrounding soil under load.

4.3 Blasting

In this technique a certain amount of explosive charge is buried at a certain depth of a cohesion less soil required to be compacted and is then detonated. A pipe of 7.5 to 10 cm is driven to the required depth in the soil strata. The sticks of dynamite and an electric detonator are wrapped in the water proof bundles and, lowered through the casing



- The casing is withdrawn and a wad of paper or wood is placed against the charge of explosives to protect it from misfire.
- The hole is backfilled with sand in order to obtain the full force of the blast.
- The electrical circuit is closed to fire the charge.
- A series of holes are thus made ready.
- Each hole is detonated in succession and the resulting large diameter holes formed by lateral displacement are backfilled.
- The surface settlements are measured by taking levels or from screw plates embedded at certain depth below the ground surface.
- Usually the explosives are arranged in the form of a horizontal grid.
- The spacing of the charges is decided by the depth of strata to be densified, the size of charge and the overlapping of the charges.
- A spacing of 3 to 8 m is typical and a spacing less than 3 m should be avoided o Compaction is carried out in a single tier only if the depth of stratum to be densified is 10m or less.
- In such a case the depth of explosive charge should be below half the depth of the mass or stratum to be dens fled (approximately at 2/3 point).

- More than one tier should be planned, if the depth of stratum to be densified is more than 10m. Generally the depth of charge should be greater than the radius of sphere of influence (R).
- Successive blasts of small charges at appropriate spacing's are likely to be more effective than a single large blast.
- Theoretically, one charge densifies the surrounding adjacent soil and the soil beneath the blast. Charges should be timed to explode such that the bottom of the layer being densified upwards in a uniform manner.
- The uppermost portion of the stratum may be less densified which may be compacted by vibratory rollers.
- The amount of charge to be used should be optimal such that it is just enough to shatter the soil mass uniformly but not to create permanent surface craters.
- A carefully placed charge with required amount and depth shall not create a surface heave more than 0.15 m.

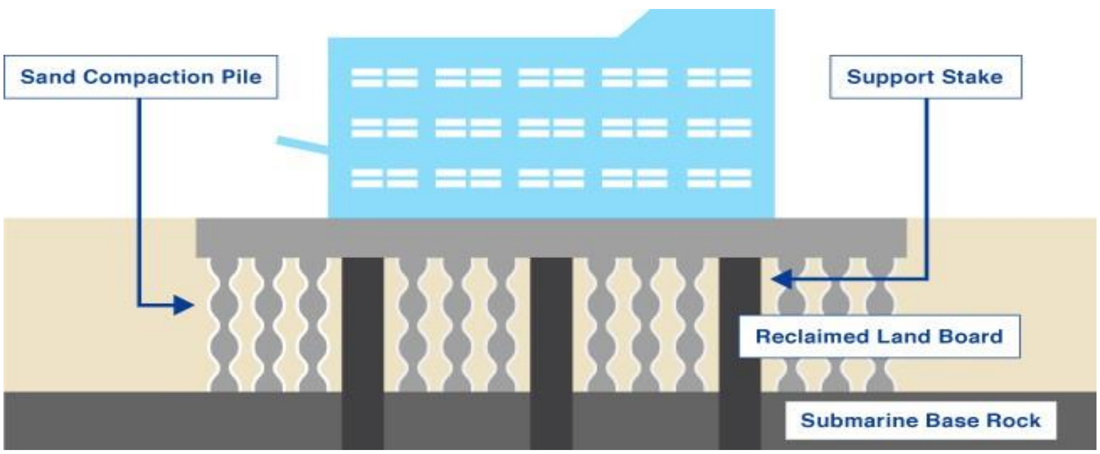
Disadvantages of Blasting Technique

- Although blasting is one of the most economical ground improvement techniques, it suffers the disadvantages of non-uniformity, potential adverse effects on adjacent structures and the danger associated with the use of explosives in populated areas.
- Very fine grained soils which have high cohesive forces cannot be compacted by this method.
- Maximum compaction is obtained only when the soil is dry or completely saturated.
- In case of any loose sand, good results are obtained due to free fall of small size particles into the voids between the soil grains thus making a dense soil.
- But in partially saturated soils due to capillary tension between the soil grains, less densification is achieved.
- Theoretically there is no limit for the depth of densification by this technique.
- However, if the dept is more than l0 m, compaction should be done in more than one tier for which a careful planning is needed to achieve the result.
- Thus it is emphasized that adequate data with regard to type of soil, degree of saturation, depth of deposit to be densified and degree of densification required should be collected.
- A preliminary test may be necessary to ascertain the spacing, depth, amount of charge and sequence of operation

4.4 Sand compaction:

Piles are one of the potential methods for improving ground stability, preventing liquefaction, reducing settlement and similar applications. This method involves driving a hollow steel pipe into the ground. The bottom is closed with a collapsible plate down to the required depth and then pipe is filled with sand. The pipe is withdrawn while the air pressure is directed against the sand inside

The bottom plate opens during withdrawal and the sand backfills the voids created earlier during the driving of the pipe. The sand backfill prevents the soil surrounding the compaction pipe from collapsing as the pipe is withdrawn. During this process, the soil gets densified



There are two types of Sand compaction piles method depending on the system deployed.

First one is vibratory system with vibro-hammer and the other one has a non-vibratory system with forced lifting or driving device.

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But the vibro-hammer used in this method has a negative effect in the form of vibration and noise to the surrounding environment which makes it difficult to use this method in the urban areas or at locations close to existing structures.

To avoid these problems, a system with a non-vibratory Sand compaction pile method was developed, which does not require impact or vibration on the driving device to penetrate into the ground. The equipment consists mainly of a sand compaction pile driving device used as a base machine and a forced lifting or driving device with a rotary drive motor to rotate the casing pipe.

Advantages and disadvantages of sand compaction piles:

The primary advantage of these sand piles is that the sand used is often considerably cheaper when compared to other similar ground improvement techniques like stone columns. Construction of the sand columns is extremely fast. After creating the hole, it's fully supported by casing during construction that prevents the possibility of collapse.

Sand compaction piles have a low stiffness when compared to other methods. Hence larger percentage replacement of weak soil is required. These piles do not have sufficiently high permeability to function as effective vertical drains during earthquakes.

Sand compaction piles are a possible solution for strengthening pervious embankment foundations found to be susceptible to liquefaction or impervious foundations susceptible to stability problems like during an earthquake

4.5 Stone Column

It is a ground improvement technique used to improve the load bearing capacity and reduce the settlement of the soil. It is also called as granular columns or granular piles. This technique is also known as vibro replacement. In this technique dense aggregate column (stone columns) is constructed by means of a crane-suspended down hole vibrator. Greater stiffness of stone columns compared to that of the surrounding soil causes a large portion of the vertical load to be transferred to the columns. The entire soil below a foundation, therefore, acts as a reinforced soil with higher load carrying capacity than the virgin ground

Function

Installation of stone column improves ground by reducing soil settlement. Due to its higher modulus of elasticity than that of soil, it absorbs more load than soil and reduces overall settlement.

Since applied load distributes in between soil and stone column in the ratio of their stiffness, the load carrying capacity of soil also increases.

Stone aggregates are used to fill stone column. Water can easily pass into the stone column. So, stone column helps in excess pore water pressure mitigation and accelerates the consolidation process

Displacement method

In this method, boring is done by displacing nearby soil. The soil is displaced laterally, due to which engineering property of soil gets change.

Hole can be made by driving casing or tube into the ground. Best example of displacement method is vibro float method which is being used widely.

It is done by two methods.

1. Wet, Top feed method
2. Dry, Bottom feed method

Non-displacement method

In this method, boring is done without displacing nearby soil. Although there will be some displacement that can be neglected. Example – bored rammed method.

Advantages

- Reduce total and differential settlement.
- Increase the bearing capacity of strata to make it possible to use shallow foundation hence, saving money and time.
- Accelerates the rate of consolidation in cohesive soil by providing drainage to water.

How are stone columns constructed?

Stone columns are constructed by experienced contractors using specialist equipment. The construction uses an excavator with a vibrating probe to feed stone into the ground, forming a vertical column of stone. Some stone column rigs feed stone into the ground through the vibrating probe, exiting at the bottom, and other rigs require the stone to be fed in from the ground surface down the vertical hole in the ground. Both types use a vibrating probe that densifies the surrounding soils to help feed the stone into the ground

4.6 Heavy Tamping

The pounding method is used to compact the soil deposit to a great depth. It is very effective for densifying loose sandy deposits. Recently, the method has been successfully used to compact fine-grained soil deposits as well. The depth (D) of influence is proportional to the square root of the tamper weight times the drop height, in meters can be determined from the following relations:

D = C MH (1)
Where C = coefficient (0.5 to 0.75), M = mass (Mg), H = height of drop (m)

Menard (1975) increased the impact energy tremendously, introduced systematic repetition of tamping and improved this as a modern technique of deep compaction.

4.7 GROUTING

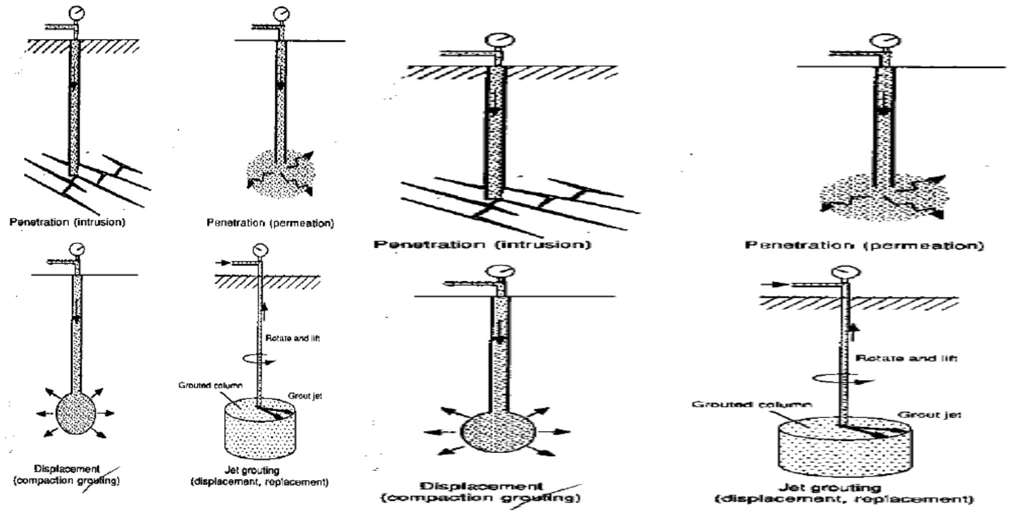
INTRODUCTION

Grouting refers to the injection of suitable fluid (colloidal solution, chemicals etc.) into voids, cracks, fissures of the ground or spaces between the ground and adjacent structures, generally through boreholes and under pressure. The main objectives of grouting are to produce a stronger, denser, and/or less permeable soil or rock; it may also simply serve to fill voids, which are otherwise inaccessible and may prevent adequate stress transfer within the ground or from a structure to the ground

4.8 TYPES OF GROUTING

- Penetration grouting (intrusion, permeation)
- Displacement grouting
- Compaction grouting (including slab-jacking)
- Grouting of voids Jet grouting (replacement)
- Special grouting applications and techniques, including electro grouting

Penetration grouting describes the process of filling joints or fractures in rock or pore spaces in soil with a grout without disturbing the formation. More specifically, permeation grouting refers to the replacement of water in voids between soil particles with a grout fluid at low injection pressure so as to prevent fracturing.
Displacement grouting is the injection of grout into a formation in such a manner as to move the formation; it may be controlled, as in compaction grouting or uncontrolled, as in high-pressure soil or rock grouting which leads to splitting of the ground, also called hydro fracture.
compaction grouting a very stiff (say 25-mm. slump) mortar is injected into loose soils, forming grout bulbs, which displace and densify the surrounding ground, without penetrating the soil pores. With slightly more fluid grant, thick fissures rather than bulbs may form; this is sometimes referred to as squeeze grouting.



Jet grouting is a technique where high-speed water jets emanating from a drill bit cut into alluvial soils; as the drill bit is withdrawn, grout is pumped through horizontal nozzles and mixes with or displaces the soil. The original foundation material is thus replaced with a stronger and/or more impermeable grout-soil mixture. Jet grouting may be used to form cutoff walls, do underpinning, or form deep foundations similar to grouted auger piles.

Electro grouting is a term used for promoting electrochemical hardening during electro osmosis by adding chemicals, such as sodium silicate or calcium chloride, at the anode. Under the influence of the electric field, these chemicals permeate the ground, flowing in the direction of the cathode, while the anode becomes a grout injection pipe. An overview of typical grouting applications is given in fig

GROUT MATERIALS

4.9 CLASSIFICATION OF GROUT MATERIALS

Three basic types of grout are differentiated according to composition:

1) **Suspensions:** Small particles of solids are distributed in a liquid dispersion medium. **Examples:** cement and clay in water.

2)**Emulsions**: A two-phase system containing minute (colloidal) droplets of liquid in a disperse phase. Example: bitumen and water. Also in this category are foams, created by emulsifying a gas into the grout material, which could be cement or an organic chemical. Foaming agents, such as additives, which increase surface tension, assist in forming bubbles by agitation; alternatively, they may induce gas-forming chemical reactions.

3)Solutions: Liquid homogeneous molecular mixtures of two or more substan. Examples: sodium silicate, organic resins, and a wide variety of other so-called chemical grouts. A difference may be made between colloidal solutions (e.g., silica or lignochrome gels) and pure solutions (e.g., phenolic and acrylic resins, aminoplasts).

4.10 BASIC PROPERTIES

Important basic characteristics of grouts are stability, setting time, and viscosity.

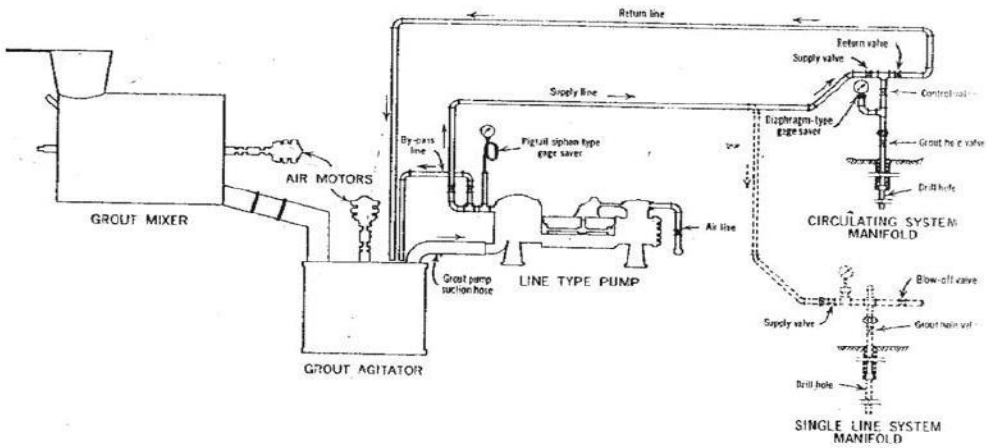
1**)Stability**. A grout is referred to as stable, if its particles remain in suspension of solution until it has reached the destination in the ground. If sedimentation occurs as soon as the grout is no longer agitated by the mixer or through turbulence in the grout pipes, it would be considered unstable. The breaking of an emulsion and the exudation of liquids from colloidal gels (syneresis) could also be considered a sedimentation process The settling out of solid particles from a suspension while the liquid component travels further into the soil or rock mass is also referred to as "filtration," although the process is not just related to the relative sizes of the particles and the voids, but more importantly to the flow velocity of the grout. Settling of particles out of suspension when the grout becomes stationary results in part of the voids containing water rather than grout.

2)**Setting time**. Setting time is the time required for the grout to harden. Cement-based grouts normally set within 4 to 24 h, depending on the additives used. Setting or geltime can be critical for chemical grouts, which can set very rapidly, possibly within minutes.

3)**Viscosity**. Viscosity μ is defined by Newton's law of viscosity as the proportionality factor relating the shear resistance τ in a fluid to the velocity gradient dv/dz. Which represents the rate at which one layer of fluid moves relative to an adjacent layer. The viscosity of "evolutive" grouts, like silica gels, increases gradually until they set. Acrylic and other resins and other "nonevolutive" grouts show constant viscosity until they set almost instantaneously; their setting time, usually measured in minutes, is controlled by the type of catalyst present and the temperature. Ideally, a grout should have low viscosity, a controllable setting time, and high strength once it is in the ground. In addition it should be nontoxic, permanent, and cheap. In order that a grout may bring about the desired effect it is necessary that it should have the correct fluid properties for injection into the formation, that its set properties satisfy the design specifications, and that the transformation between the fluid and final set states should be sufficiently rapid for displacement of the grout to be unlikely under the others to which it will probably be subjected Other factors which are important in particular circumstances include the chemical stability of the grout components and their deterioration under exceptionally high or low site temperatures.

4.11 GROUT PLANT EQUIPMENT

The mixing plants and delivery systems for suspension and solution grouts differ mainly in their storage and mixing configurations. A typical cement (suspension) grouting plant is shown in Fig. In essence it consists of a mixer, an agitator, a pump, and piping connected to the grout holes. For solution grouts, separate ingredients are stored in stationary tanks or tank trucks and metered out (on a flow volume basis), mixed at junction points, and brought to the intended grout pipe.



4.14 APPLICATION OF GROUTING

Seepage Control

- **For making vertical seepage barriers beneath hydraulic structures**
- **Stoppage of seepage through joints of undergroundstructures such as tunnel lining/ basement wall, etc**

4.13Assignment Questions?

1) Explain The Different Types Of Grouting?
2) Explain vibrocompaction in details?
3) Explain the application of grouting?
4) Write short notes on stone coloum?
5) What do you mean by heavy compacting?

4.14 Further study

1) https://www.designingbuildings.co.uk/wiki/Grouting_in_civil_engineering
2) https://www.keller-na.com/expertise/techniques/vibro-compaction
3) https://www.menard-group.com/en/techniques/stone-columns/
4) https://theconstructor.org/structural-engg/design-stone-columns-heinz-j-priebes-method/10938/

MODULE 5

GEOSYNTHETICS

Contents

5.1 Introduction

Geosynthetics are materials made from various types of polymers, used with geological materials like soil, rock etc. to enhance, improve or modify the behaviour of various civil engineering works.

Geosynthetics are available in a wide range of forms and materials, each to suit a slightly different use. These products have a wide range of applications and are currently used in many geotechnical, transportation, hydraulic, and private development applications including roads, airfields, embankments, retaining structures, reservoirs, canals, dams, erosion control, sediment control, landfill liners, landfill covers, mining, and agriculture.

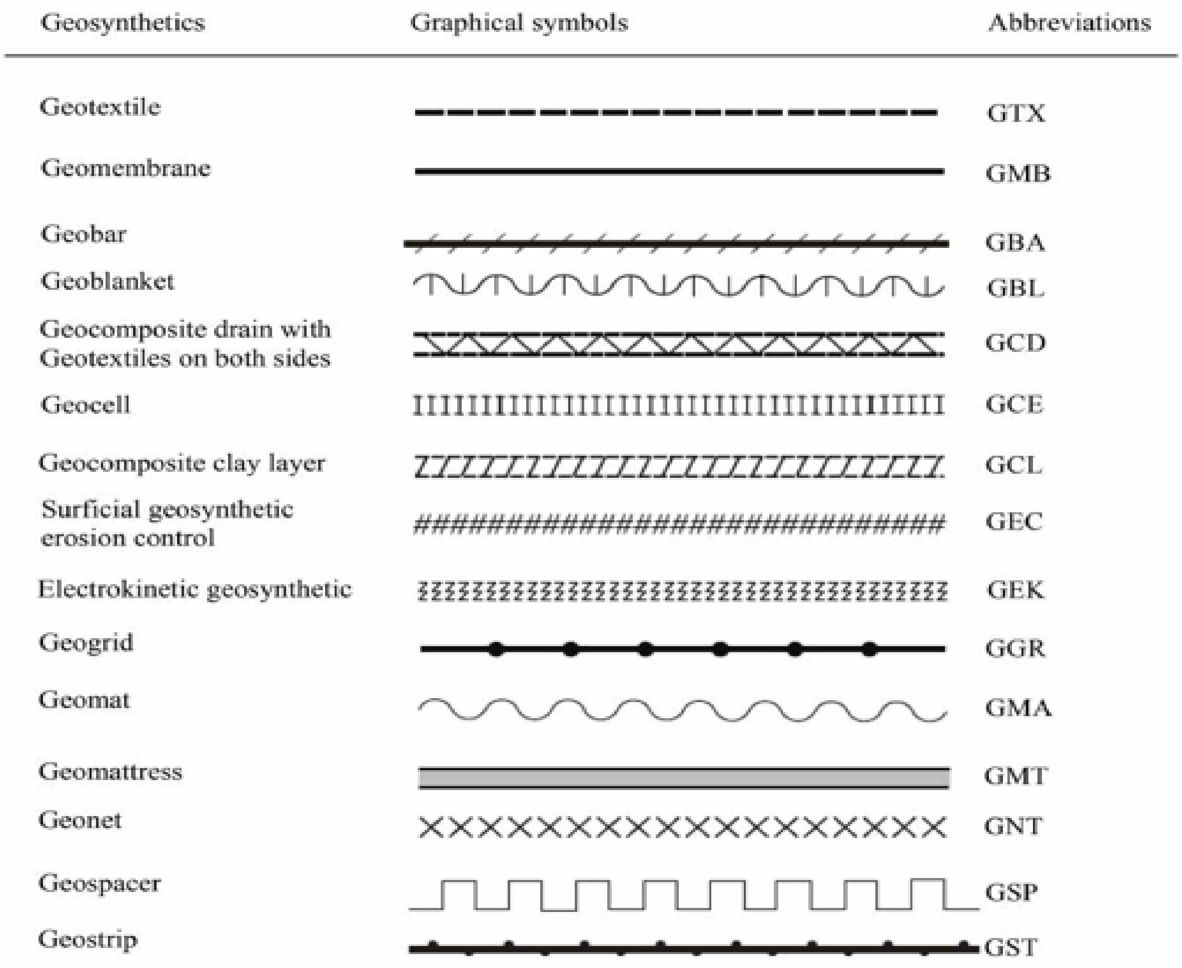
5.2 Objective

Able to understand the concepts of Geosynthetics and its application related to Geotechnical Engineering field

5.3 Types of Geosynthetics

- Geotextiles
- Geogrids
- Geonets
- Geomembranes
- Geosynthetic clay liners
- Geocells /geo web members
- GeoPipes
- Geofoam
- Geocomposite

Graphical Symbols proposed by IGS



❖ **Geo-Textiles**

Geotextiles are permeable fabrics which when used in association with soil, have the ability to separate, filter, reinforce, protect, or drain.

Characteristics

- Porous and allow flow of water through it.
- Most used Geosynthetics.
- Available in rolls of 5.6m wide and 50 - 150m long.

Geotextiles are used for separation, filtration, drainage, reinforcement and erosion control applications

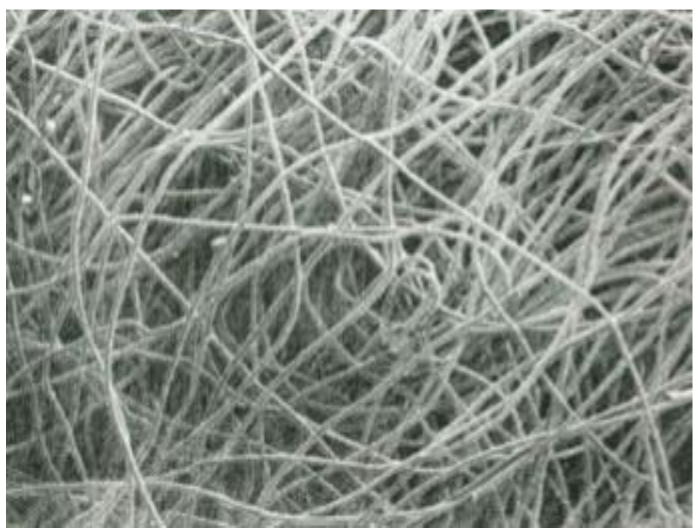
Geo-textiles are of two basic forms

Woven geotextile

Produced by interlacing, usually at right angles, two or more sets of yarns (made of one or several fibers) or other elements using a conventional weaving process with a weaving loom

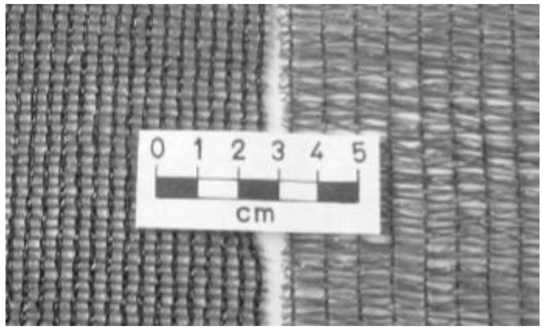

Nonwoven geotextile

A geotextile produced from directionally or randomly oriented fibers into a loose web by bonding with partial melting, needle-punching, or chemical binding agents (glue, rubber, latex, cellulose derivative, etc.).

Knitted geotextile

Produced by inter-looping one or more yarns (or other elements) together with a knitting machine, instead of a weaving loom



Stitched geotextile

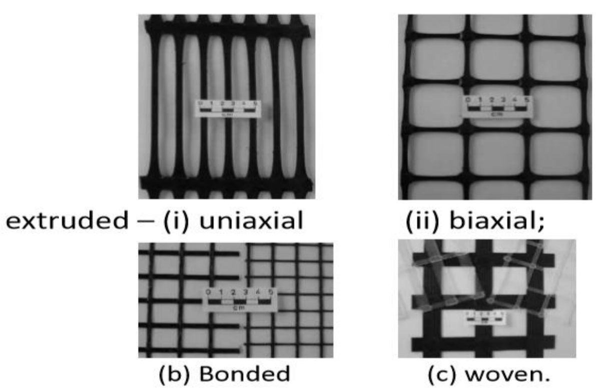
A geotextile in which fibers or yarns or both are interlocked/bonded by stitching or sewing.

❖ **Geo-grids**

A Geo-grid is geo-synthetic material used to reinforce soils and similar materials. Geogrids are commonly used to reinforce retaining walls, as well as sub bases or subsoil's below roads or structures.

Characteristics

- They have open grid like configuration i.e. they have large aperture between individual ribs.
- They have Low strain and stretch about 2% under load.
- Strength is more than other common geotextiles.
- Function: Used exclusively for reinforcement



Uniaxial geo-grid – Produced by the longitudinal stretching of a regularly punched polymer sheet – Possesses a much higher tensile strength in the longitudinal direction than the tensile strength in the transverse direction. •

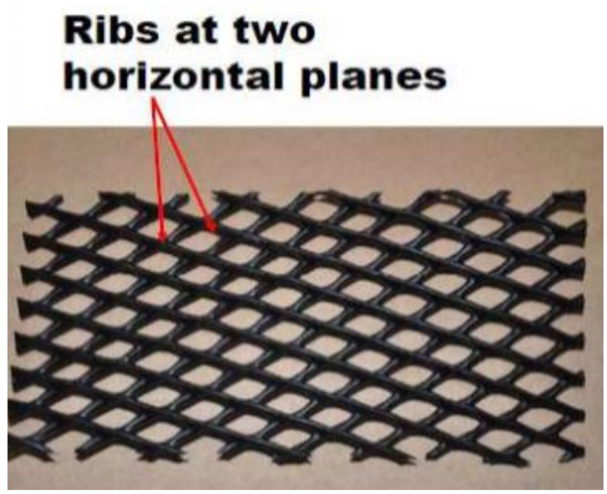
Biaxial geo-grid – Produced by stretching in both the longitudinal and the transverse directions of a regularly punched polymer sheet – Possesses equal tensile strength in both the longitudinal and the transverse directions.

Geo-Nets

A geo-net is a geo-synthetic material consisting of integrally connected parallel sets of ribs overlying similar sets at various angles for in-plane drainage of liquids or gases

Characteristics

- Geonets are made of stacked, crisscrossing polymer strands that provide in-plane drainage.
- Two layers of strands are called “bi-planar”.
- Three layers are called “tri-planar”

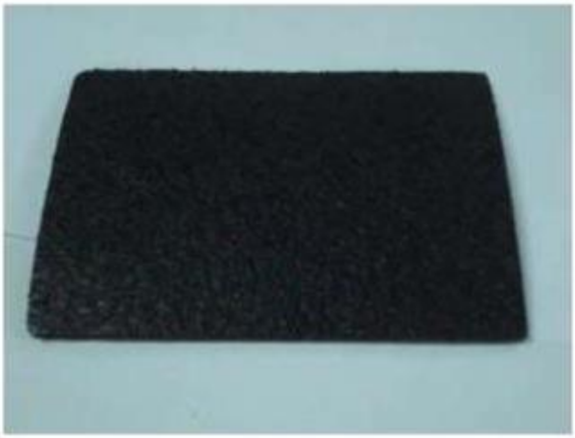


Geo-membranes

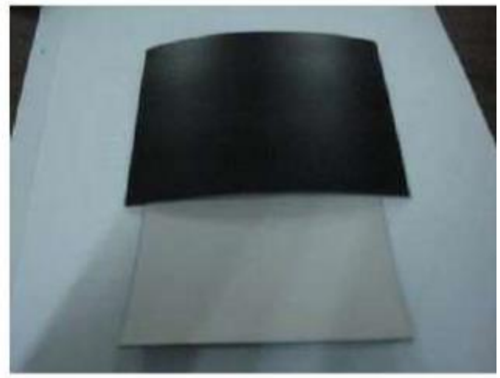
A Geo-membrane is very low permeability synthetic membrane barrier used to control fluid or gas migration in a structure, or system.

Characteristics

- Impermeable and usually non-woven
- Used as a fluid barrier in designing drainage systems, etc.
- Used as damp proof course in floors, roofs etc.



Rough surface texture



Smooth – double sided membrane

Geosynthetic Clay Liners

It is a woven fabric-like material, combination of geotextiles and geo-membranes used as a barrier for liquid or solid waste containment. primarily used for the lining of landfills.

GCLs are manufactured by sandwiching the bentonite within or layering it on geotextiles and geo-membranes, bonding the layers with needling, stitching or chemical adhesives. Primarily used for the lining of landfills.

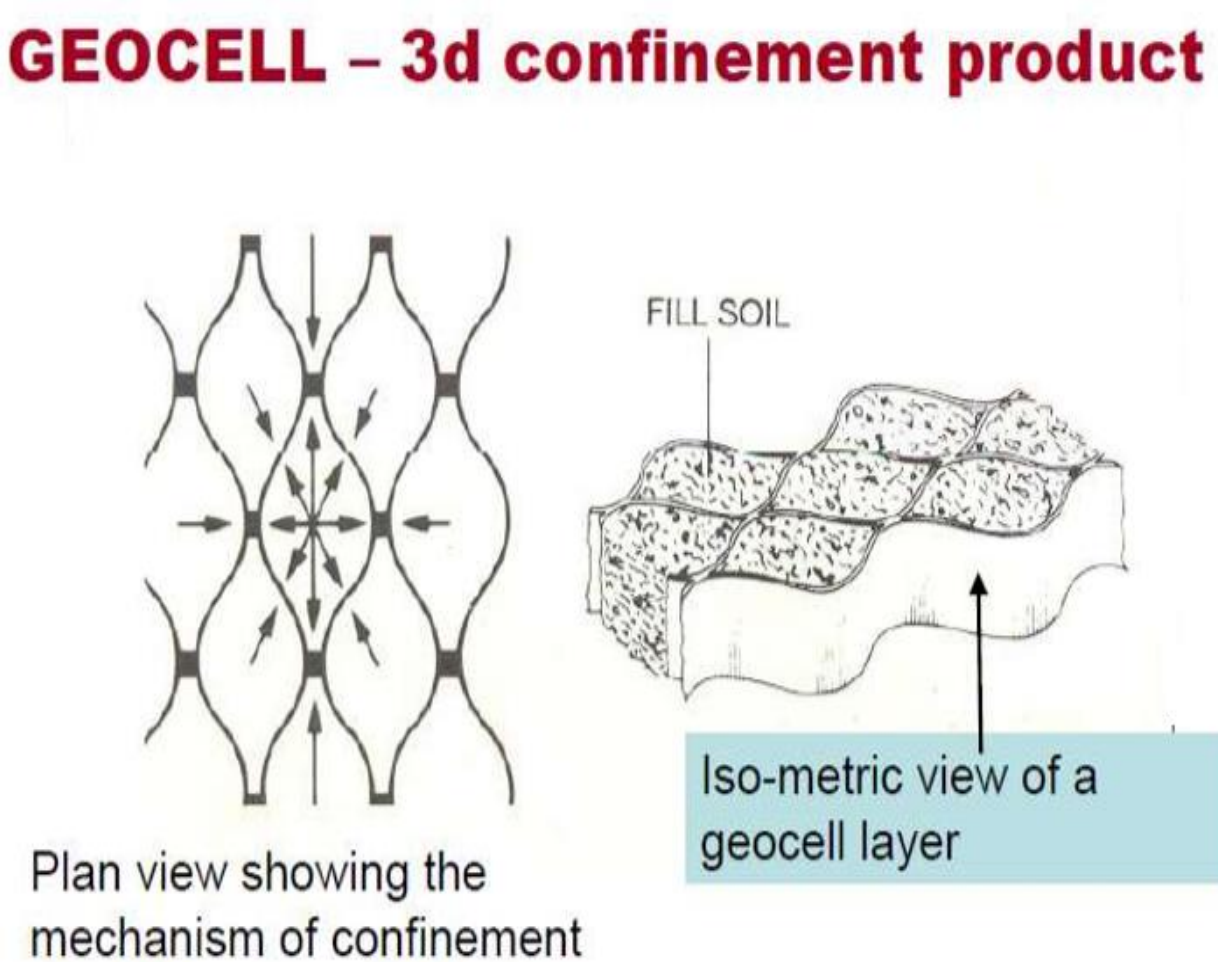
Geosynthetic Clay Liners

Geo-cells

Geocells are 3-dimensional honeycomb-like structures, made of strips of polymer sheet.

Characteristics

- Similar to geotextiles or geo-grids but have depth.
- Provides both a physical containment of a depth of soil and a transfer of load through
- Allow water through it.
- Used in slopes with soft sub-grade
- Used in erosion control in channels



Geo-foams

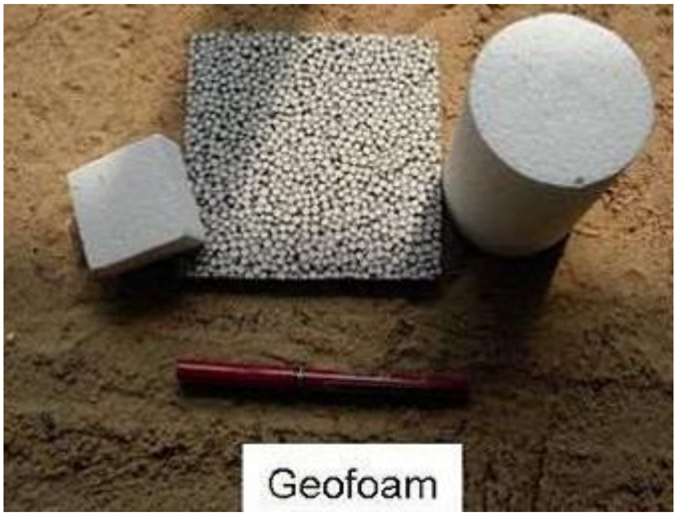
Geofoam is manufactured into large lightweight blocks by polymeric expansion process. They are large but extremely light materials with gas filled cells.

Characteristics

- Low density/ high strength: Geofoam is 1% to 2% the density of soil with equal strength.
- Quick to install and can be installed during any type of weather.
- If geofoam comes in contact with a petroleum solvent, it will immediately turn into a glue-type substance, making it unable to support any load.
- Untreated geofoam is a Fire hazard

Uses

- Within soil embankments built over soft, weak soils;
- Under roads, airfield pavements and railway track systems subject to excessive freeze-thaw conditions.
- Thermal insulation in storage tanks containing cold liquids.
- Separation, lightweight fill, compressible inclusions



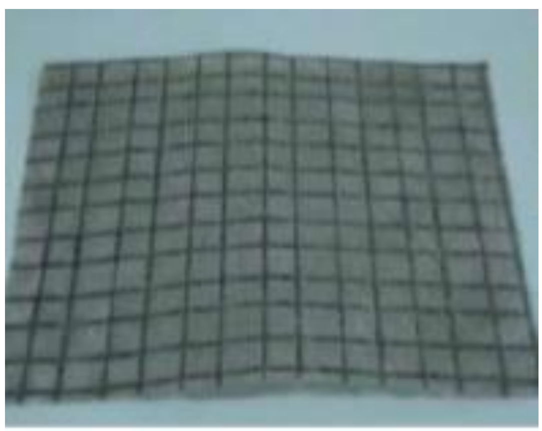
Geo-composites

These are products manufactured by combining the superior features of various types of geo-synthetics.

This is prepared to extract all the major properties of the geo-synthetics into a single unit with minimum cost

The various types of Geo-composites are

- Geotextile-Geo-net Composites
- Geotextile –Geo-membrane Composites
- Geotextile –Geo-grid Composites
- Geo-membrane –Geo-grid Composite
- Geo-textile-Polymer Core Composite



Properties of Geo-synthetics

Physical properties

- Specific gravity
- Unit mass (weight)
- Thickness
- Stiffness

Specific gravity

$$Specific\ Gravity = \frac{\text{Unit weight of Geosynthetic (without any voids)}}{\text{Unit volume weight of water (at 4°C)}}$$

- Determined by the displacement method.
- In case of geo-membranes, a known mass is weighed in air and then in water.
- Given by the ratio of its weight in air to the difference between its weight in air and in water.
- Specific gravity is widely used in geo-membrane identification and quality control

Sr.No.	Material	Specific Gravity
1	Polypropylene	0.91
2	Polyester	1.22- 1.38
3	Nylon	1.05-1.14
4	Polyethylene	0.91-0.95
5	Polyvinyl Chloride	1.69

Weight:

1. This is usually given in GSM (g/m^2)
2. Tested in circular specimens, which is not less than 100 cm^2
3. For geo-synthetics, the values vary from 100-1000 g/m^2
4. Unit weight of geotextiles < Unit weight of geo-membranes

Thickness

1. This is the distance between the upper and lower surfaces, measured normal to the surfaces at a specified normal compressive stress
2. Measured to the accuracy of .02 mm, and thickness varies from .25mm to 7.5mm

3. It is important to determine the permittivity and transmissivity

Stiffness (Flexural Rigidity):

1. It is the ability to resist flexure under its own weight
2. Can be measured by its capacity to form a cantilever beam without exceeding a certain amount of downward bending
3. The stiffness of a geo-synthetic indicates the feasibility of providing a suitable working surface for installation

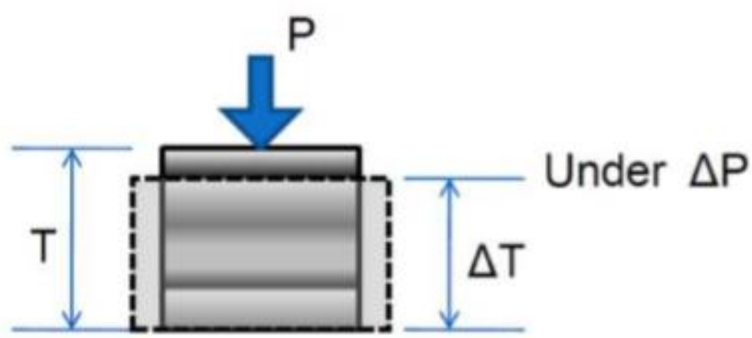
Mechanical Properties

- Compressibility
- Tensile strength

Compressibility

Is very important for nonwoven geotextiles, because they are often used to convey liquid within the plane of their structure.

Compressibility can be studied by applying compressive stress, by placing the geo-synthetic between two plates and constant stress applied.

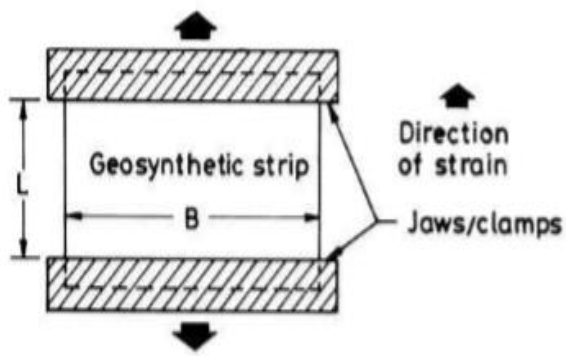


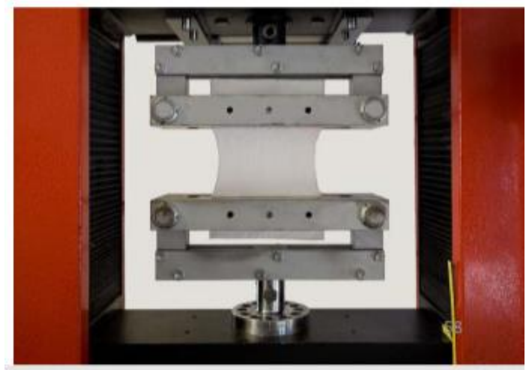
Tensile strength

Determination

Tensile test on a 200-mm wide geo-synthetic strip with a gauge length of 100 mm.

Entire width of a 200-mm wide geo-synthetic specimen is gripped in the jaws of a tensile strength testing machine and it is stretched in one direction at a prescribed constant rate of extension until the specimen ruptures (breaks).





Other survival properties:

1. **Tearing strength:** Ability of geotextiles to withstand stresses causing it to propagate a tear.
2. **Puncture strength:** Resistance to sharp impacts as a impulse
3. **Bursting strength:** Resistance to uniform and high magnitude forces
4. **Fatigue strength:** Resistance to cycles of loads applied, lower the cycles, lower the fatigue

Hydraulic Properties

1. Porosity
2. Permeability
3. Permittivity

A. Porosity:

1. It is the ability of geo-synthetics to allow fluid to flow right through it

2. Voids or holes on the material act as pores

B. Permeability:

1. Dependent on the fabric materials as well as construction of fabric
2. Non-woven have minimal permeability
3. Knitted fabrics have most permeability
4. Mostly hydrophobic geo-synthetics are a best choice for slow flow of water with greater strength

C. Transmissivity:

1. This indicates the flow of liquid along the length of geotextile planes with respect to the compressive stress

Durability

The durability of a geo-synthetic may be regarded as its ability to maintain requisite properties against environmental or other influences over the selected design life

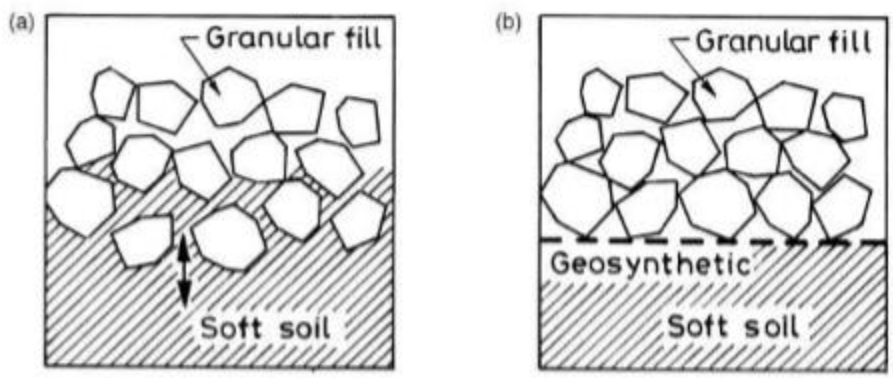
Functions / Applications of Geosynthetics

- **Separation** - Prevent the mixing of two different soils or materials (using geotextiles, geo-composites)
- **Reinforcement** - Provide tensile forces in the soil (using geo-grids, and geotextiles)
- **Confinement** - Restrain the lateral movement of a soil mass geo-cells
- **Filtration -** Allow the passage of fluids preventing the migration of soil particles (geotextiles, geo-composites)
- **Drainage** - Transport of fluids (geo-nets, geo-composites)
- **Barrier or Containment** - Fluid barrier (using Geomembranes, geo-composites)
- **Erosion Control** - Avoid the detachment and transport of soil particles by rain, runoff and wind; root anchorage using geo-mats, geo-cells, bio-mats, bio-nets
- **Protection** - Avoid damages to a structure, a material or another geo-synthetic (using nonwoven geotextiles, geo-nets, geo-composites)

Separation

Prevention of intermixing of adjacent dissimilar soils and/or fill materials during construction and over a projected service lifetime

Provided at the soil subgrade level in pavements or railway tracks to prevent pumping of soil fines into the granular subbase/base course and/or to prevent intrusion of granular particles into soil subgrade.

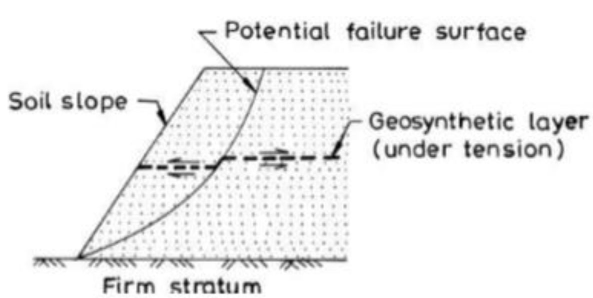


Basic mechanism involved in the separation function: (a) granular fill–soft soil system without the geo-synthetic separator; (b) granular fill–soft soil system with the geo-synthetic separator.

Reinforcement

A geo-synthetic performs the reinforcement function by improving the mechanical properties of a soil mass as a result of its inclusion.

Reinforced soil possess high compressive and tensile strength (and similar, in principle, to the reinforced concrete)

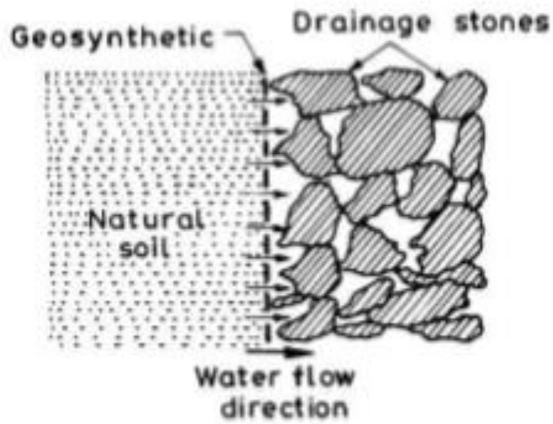


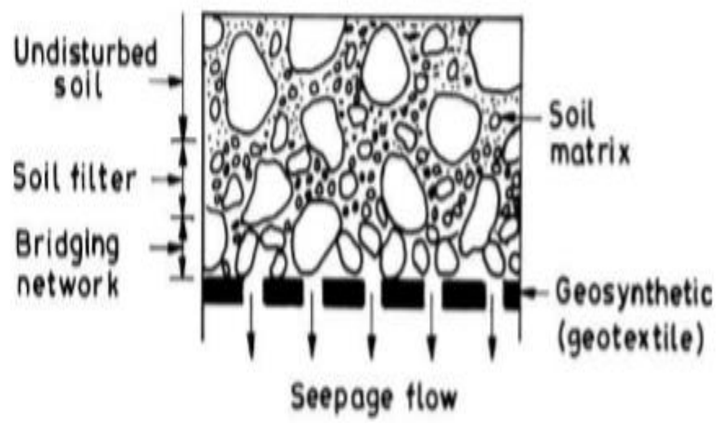
Filtration

A geo-synthetic may function as a filter that allows for adequate fluid flow with limited migration of soil particles across its plane over a projected service lifetime.

When a geo-synthetic filter is placed adjacent to a base soil (the soil to be filtered), a discontinuity arises between the original soil structure and the structure of the geo-synthetic.

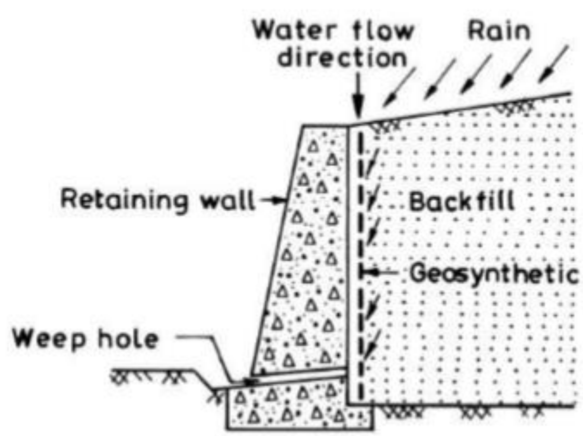
This discontinuity allows some soil particles, particularly particles closest to the geo-synthetic filter and having diameters smaller than the filter opening size





Fluid Transmission / Drainage

If a geo-synthetic allows for adequate fluid flow with limited migration of soil particles within its plane from surrounding soil mass to various outlets

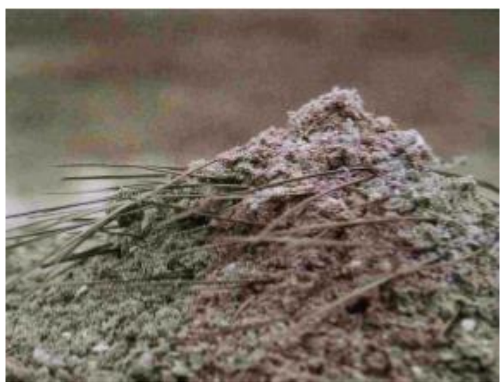


5.4 Miscellaneous Methods (Only Concepts & Uses):

Soil Reinforcements

In simple terms, soil reinforcement is a technique used to improve the stiffness and strength of soil using geo-engineering methods. A long time ago, natural fiber was used to reinforce the soil. This old technique did not have a high yield and required a lot of time for the soil to recover

In geotechnical engineering, soil is restored and reinforced with the distribution of minerals and soil nutrients. Soil reinforcement is necessary in lands where chances of erosion are high. It is particularly useful in areas with soft soil as it cannot provide adequate support to any construction or building. This type of soil is also highly susceptible to various environmental and natural factors such as high compressibility, poor shear strength, temperature changes, etc.



Uses

- Cost savings relative to alternative designs
- Use of locally available and poor quality soils
- Less construction time on projects

Thermal methods

By applying thermal treatment on soil its strength related properties can be influenced. There are two methods of thermal treatment; soil heating and soil freezing. These methods seem to be effective but its use is limited because of its high cost.

Soil Heating

The increase in temperature of especially fine soil can cause significant increase in its strength, by reducing electric repulsion between the grains and also flow of pour water takes place due to thermal gradient and a reduction in moisture content because of increasing evaporation rate.

Soil Freezing

Lowering the temperature of soil causes its pore water or moisture to freeze down and thus increase in volume of water and this acts as a cementing agent between the soil particles thereby increasing the shear strength of soil and decreasing its permeability. A refrigeration plant is used to maintain the coolant's temperature. Soil contaminated with radioactive elements that leaked from Japan's Fukushima Daiichi nuclear power plant was contained through ground freezing.

Micro Piles

Micro piles are deep foundation elements constructed using high-strength, small-diameter steel casing and/or threaded bar. Micro piles were first used in Italy in the early 1950s for underpinning of those monuments and historic buildings that were getting damaged with time.

Micro-piles have a small diameter (up to 300 mm), and have a high load bearing capacity (up to 5000KN in compression). They can be installed through virtually any ground condition, obstruction and foundation and at any inclination and ensure minimum vibration or other damage to foundation and subsoil. Micro piles be installed in as little headroom as 6' and close to existing walls. The advantage of micro piles is that they can resist compressive, tensile or lateral loads, or even combinations of all the three loads. Micro piles can be designed as soil frictional piles and rock socketed piles either under tension and compression. Micro piles can be used as a foundation for new structures or repair / replacement of existing foundations. Soil strengthening, protection and Arresting / Prevention of movement Embankment are also some of the common applications of micro piles

Ground Anchors

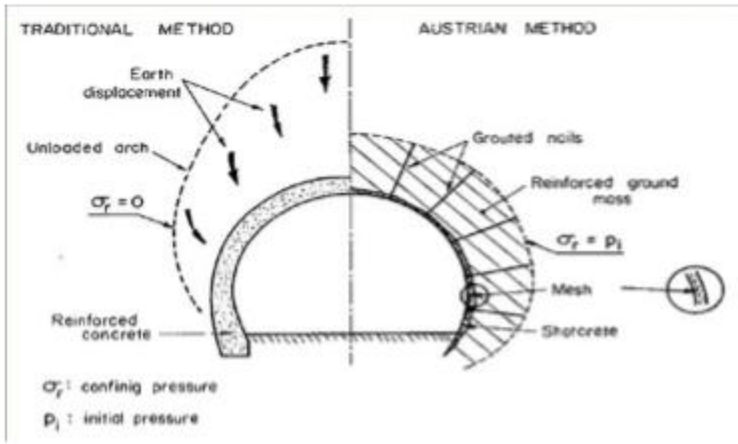
An earth anchor is a device designed to support structures, most commonly used in geotechnical and construction applications. Also known as a ground anchor, percussion driven earth anchor or mechanical anchor, it may be impact driven into the ground or run in spirally, depending on its design and intended force-resistance characteristics. Earth anchors are used in both temporary or permanent applications, including supporting retaining walls, guyed masts, and circus tents.

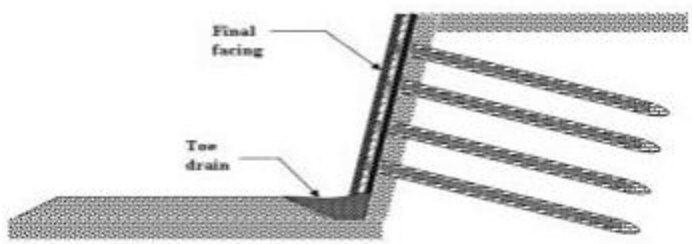
Earth anchors are typically used in civil engineering and construction projects, and have a variety of applications, including:

1. Retaining walls, as part of erosion control systems.
2. Structural support of temporary buildings and structures, such as circus tents and outdoor stages.
3. Tethering marine structures, such as floating docks and pipelines. • Supporting guyed masts, such as radio transmission towers.
4. Anchoring utility poles and similar structures.
5. Drainage systems, for load locking and restraining capability to happen simultaneously
6. Landscape, anchoring trees, often semi-mature transplants.
7. General security, as in anchoring small aircraft.
8. Sporting activities, such as slacklining or abseiling.

Soil Nailing

Soil nailing is a method of earth retention which uses grouted tension-resisting steel elements (nails) designed for permanent or temporary support. The fundamental concept of soil nailing consists of reinforcing the ground by passive inclusions, closely spaced, to create in-situ soil and restrain its displacements. Soil nailing is normally used for stabilizing existing slopes or excavations where top to bottom construction is beneficial as compared to other retaining wall systems. For certain conditions, soil nailing offers a feasible alternate from the viewpoint of technical viability, construction costs and duration when compared to ground anchor walls, which is another popular top-to bottom retaining system. Soil nailing technique has proved well in excavation applications for ground conditions that require vertical or near-vertical cuts. The other field of application of soil nailing is in railway and roadway cut excavations (Figure 3), road widening under an existing bridge end, repair and reconstruction of existing retaining structures, and temporary/permanent excavations in an urban environment. Excavation retaining structures in urban areas for high-rise buildings and underground facilities and construction and retrofitting of bridge abutments with complex boundaries involving wall support under piled foundations are also sometimes done using this technique.





Advantages of Soil nailing cannot replace all other methods of soil retention technically or economically. Notwithstanding the same, it has the following advantages.

1) It is not dependent on heavy equipment,

2) It is economical where the geometry of the wall is complex and where space space restrictions exist,

3) Since nails are of low strength steel, the need for corrosion protection stands reduced, 4) Construction can be carried out with little disturbance to the environment in terms of noise and vibration.

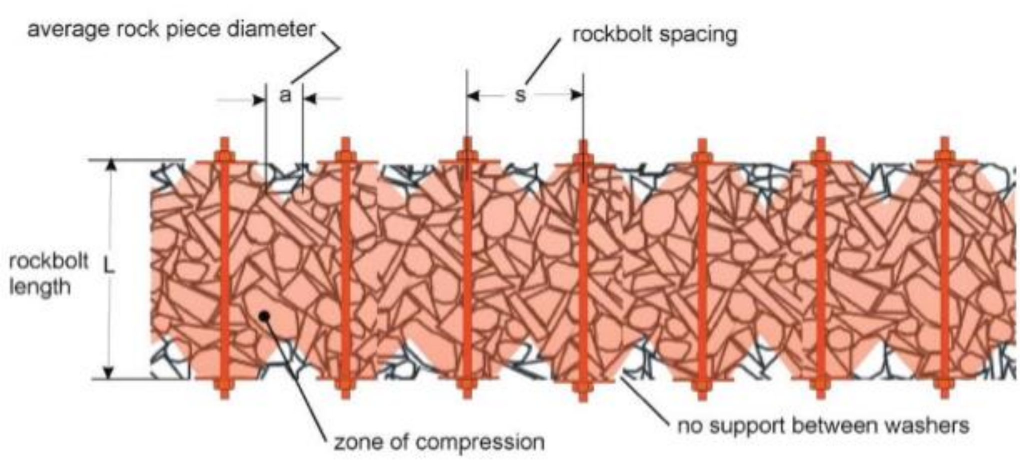
Rock Bolting

Intended to mobilize the inherent strength of a jointed and fragmented mass of rock by active or passive confinement.

Principles of rock mass modification by bolting

- Rock is like soil a natural material occurring in on infinite variety of forms. Its engineering properties show enormous unexpected variability
- While designing major tunnels, underground openings excavations, foundation abutments and slopes in rock the civil engineers are teamed up with a geologist for best possible understanding of the structure and quality of rock formation.
- The mechanical behavior of a rock mass differs because of joints, fractures and other discontinues.
- In-situ modification of rock is mainly aimed at changing rock mass properties rather their rock substance.
- Rock bolting is involved in tunneling and is the construction of large underground openings. Rock bolts have two basic functions
- To pin or nail well-defined blocks or slabs of rock on to a more stable formation.

To form a new structural entity cut of jointed rock by applying compressive stresses. In both cases attempt is made to preserve or mobilize the inherent shear strength of rock along existing joints and potential fractures by a direct increase of the normal stresses in the failure planes or by controlling deformations so that no loosening of rock mass occurs.



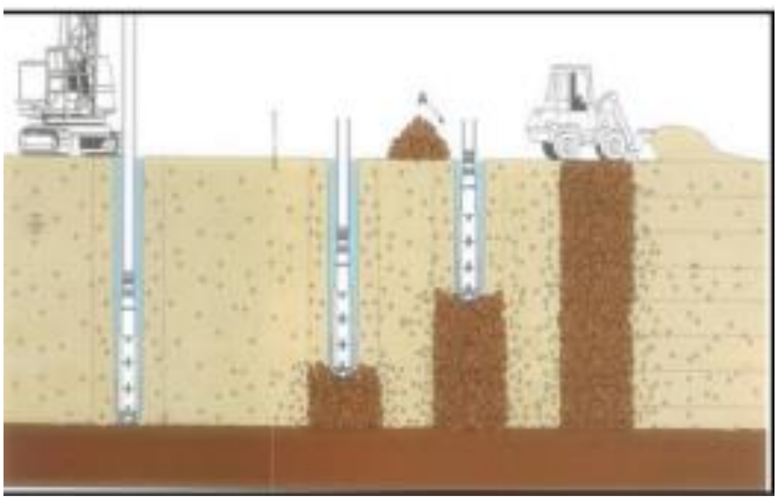
Advantages

- Simple handling and optimized installation time
- Immediate loading-bearing capacity
- Field-proven and reliable anchors

Stones Columns

Stone columns are popularly used in cohesive soils to improve shear strength, to reduce the excessive settlement and to speed up the consolidation by shortening horizontal drainage paths for pore-water flow. Stone columns are constructed by drilling holes that extend through clay to firmer soil. Then the hole is filled with compacted gravel. They can be installed as either independent columns or as continuous walls or panels of columns.

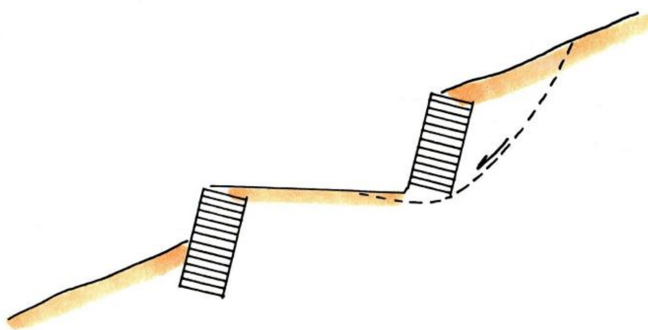
Stone columns are more preferable than sand drains because of its granular nature which provide additional shear strength to the surrounding soils. They reduce settlements by promoting soil arching which transfers the loads from the surrounding soil to the stiffer columns. The geo-synthetic-reinforced fill and stone column system can provide an economic and effective solution for structures constructed on clay soil. The use of geo-synthetic reinforcement transfers the stress from soil to stone columns due to stiffness difference between the stone columns and soil, and this may prevent large displacement and reduce the total as well as differential settlement.



Crib Walls

Crib walls are one of the oldest gravity wall systems, comprised of a series of stacked members creating hollow cells filled with soil or rock

Crib wall is available in sizes during the last four decades a number of manufacturers have begun producing precast concrete and treated timber crib wall elements, suitable for “back yard” applications, where there is restricted site access.



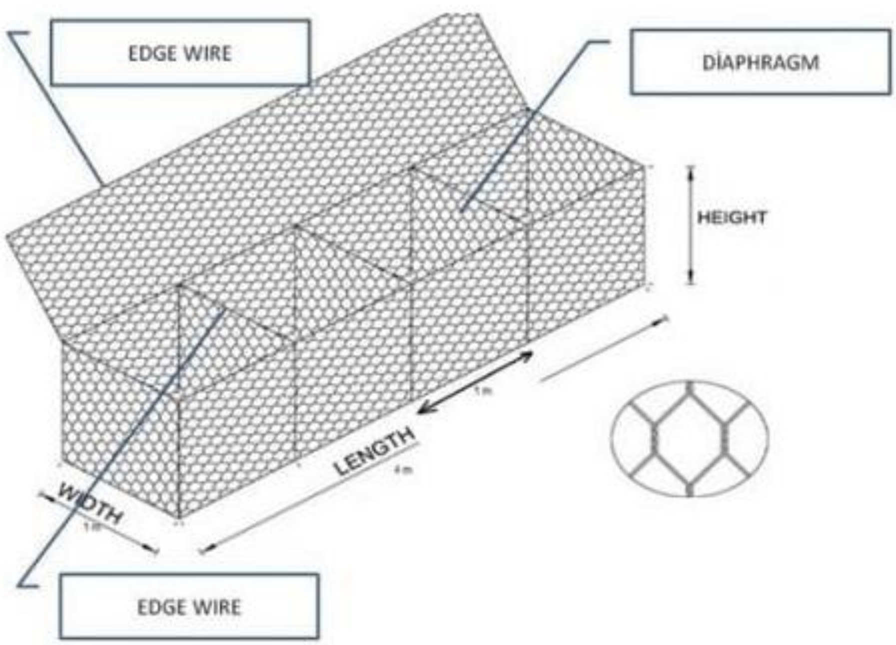
One of the common failure modes for crib walls is inadequate toe embedment, on both uphill and downhill walls, as sketched above.

These crib wall failures occurred because of inadequate toe embedment. The contractor constructed the walls, but did not place the aggregate base and pavement because the job was shut down for the winter.

The pavement section was included in the original design and assumed to buttress the toe of the walls, which were supporting road cuts.

Gabions

Gabion is a welded wire cage or box filled with materials such as stone, concrete, sand, or soil. So, gabion is a partially flexible block construction used for slope stability and erosion protection in construction. Various types of gabions are constructed and used in different engineering constructions.



Types of Gabions

There are number of gabion configurations that can be selected based on their cost and function. Common types of Gabion are as follows:

1. Gabion baskets

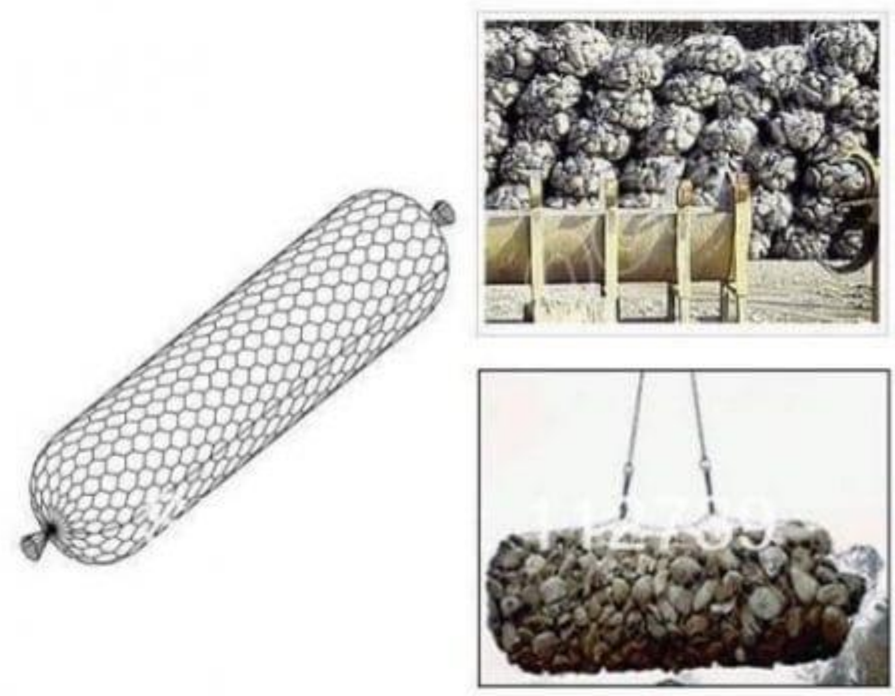
- It is a net wire mesh that produced in box-shaped and in different sizes.
- Used in highway and railway works.
- It would be economical unless filling materials are not available from quarries near the project site.

2. Gabion mattresses

- Gabion mattresses, also known as reno mattresses.
- Gabion mattresses height is shorter than the other types of measurements as it might be observed from the Fig. 3.
- It is employed in the channel coating for preventing erosion. So, it tackles wave and erosion induced velocity.
- Common size, 6 m long by 2 m wide by 0,3 m high.

3. Gabion sacks

- This type of gabions is formed quickly.
- It has a porous and flexible structure.
- Gabion sacks are usually used in hydraulic works in emergency conditions.



4. Gabion wire mesh

- It is utilized to keep the possible rock and stone fall on the highway and railway surfaces.
- Gabion wire mesh maintains stability of the slope close to highway and railways.
- It is applied for anti-erosion to slope.
- It enhances embankment soil strength in combination with geogrid reinforcement.

5. Decorative Gabion Elements

- It is used indoor and outdoor decoration, garden design and landscaping.

- Gabion elements offer suitable environment for the growth of plant roots

Applications of gabions

Gabions are used in several engineering projects and serve various purposes. common applications of gabions are as follows:

- Retaining structures such as retaining walls (Fig. 7), revetment and toe walls to embankments and cuttings.
- Corrosion prevention structures for instance sea walls, river bank defenses, canal banks (Fig. 8), dams, weirs, groynes and for the protection of reservoirs and lakesides.
- cylindrical metal gabion is used for dams or in foundation construction.
- It is employed as a noise barrier.
- Gabions are also used as a temporary flood walls.
- It is utilized to change the direction of the force of flood water around weak structure
- Stepped gabions improve energy dissipation in channels.
- Finally, it is used for aesthetic purposes

Advantages of gabions

1. Durability

Gabion has a very high resistance to atmospheric corrosion because of the well bonded zinc coating on the wire and their ability to support vegetation growth.

2. Flexibility

This feature permits the gabion to settle and deform without failure and loss of efficiency. Specifically, when unstable ground and moving water are encountered.

3. Permeability

It provides automatic and easy drainage which eliminates the need for the installation of drainage pipes.

4. Strength

Gabions are satisfactory strong that is it is capable of resisting flood force, torrential force, and ice and earth pressure.

5. Economical

It is more economical in terms of both material and labor in comparison with other gabion alternatives.

6. Environmentally friendly

Recycled materials can be placed into the gabion cage. The gaps in the soil between filling materials allow the plantation to grow over time. Gabion elements are not affected by natural phenomena.

5.6 Assignment questions

1. Define Geo-synthetics
2. Explain the types of geo-synthetics
3. Explain the properties of geo-synthetics

4. Explain different methods of ground confinement

Outcome

Able to apply the concepts and techniques of geo-synthetics in improving the soil condition

5.7 Future Study:

https://nptel.ac.in/courses/105101143/