UNIT-3

STABILISATION

Stabilization of soils

Soil stabilization is the process which is used to improve the engineering properties of the soil and thus making it more stable. Soil stabilization is required when the soil available for construction is not suitable for the intended purpose. It includes compaction, preconsolidation, drainage and many other such processes.

1. Mechanical stabilization
2. Cement stabilization
3. Lime stabilization
4. Bituminous stabilization
5. Chemical stabilization with
   a. Calcium Chloride
   b. Sodium silicate
   c. Gypsum
6. Use of industrial wastes

For **Mechanical stabilization**, the soils are grouped into two categories. They comprise aggregates and binders. Aggregates are sands and gravels and binders are silts and clays. When mixed together in a definite proportion, a soil possessing required internal friction and cohesion is obtained. When properly placed and compacted, the material becomes mechanically stable.

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

Lime stabilization is not effective for sandy soils. However these soils can be stabilized with clay, fly ash etc which serve as hydraulically reactive ingredients. The ratio of fly ash to lime generally varies in between 3 to 5. The fly ash is used is about 10 to 20% of the soil weight.

Bituminous stabilization

Bituminous materials such as asphalts, tars, and pitches are used in various consistencies to improve the engineering properties of soils.

Mixed with cohesive soils, bituminous materials improve the bearing capacity and soil strength at low moisture content.

The purpose of incorporating bitumen into such soils is to water proof them as a means to maintain low moisture content.

Chemical stabilization

Chemical stabilization with Calcium chloride

Calcium chloride being hygroscopic and deliquescent is used as a water retentive additive in mechanically stabilized soil bases and surfacing. The vapor pressure gets lowered, surface tension increases and rate of evaporation decreases. The freezing point of pure water gets lowered and it results in prevention or reduction of frostheave.

Chemical stabilization with Sodium silicate

Sodium silicate is yet another chemical used for this purpose in combination with other chemicals such as calcium chloride, polymers, chrome lignin, alkyl chlorosilanes, siliconites, amines and quarternary ammonium salts, sodium hexametaphosphate, phosphoric acid combined with a wetting agent.

Use of industrial wastes

Utilization of industrial wastes such as RHA and FA for soil improvement is a sustainable and cost-effective technique.

Geotechnical properties includes Index properties like liquid limit, plastic limit, and differential free swell index, and engineering properties like compaction and strength characteristics of soil are greatly improved using the industrial waste materials like **Rice husk Ash (**RHA), **Fly Ash** (FA), **Lime**

Mechanical soil stabilization:-

In this method changing the gradation of virgin soil stabilizes the soil. To do this two or more types of soils are mixed to attain a desired property to suit a particular construction.

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There are several methods used to achieve mechanical stabilization.

(i) Compaction:

Compaction typically employs a heavy weight to increase the soil density by applying pressure from above. Machines such as large soil compactors with vibrating steel drums are often used for this purpose. Here over compaction of the soil should be avoided and given great consideration because in the case of over compaction, the aggregates get crushed and the soil loses its engineering properties.

(ii) Soil Reinforcement:

Soil problems are sometimes remedied by engineered or non-engineered mechanical solutions. Geo-textiles and engineered plastic mesh are designed to trap soils and help control erosion, moisture conditions and soil permeability. Larger aggregates such as gravel, stones and boulders are often employed where additional mass and rigidity can prevent soil migration or improve load-bearing properties.

(iii) Addition of graded aggregate materials:

A common method of improving the engineered characteristics of a soil is to add certain aggregates that lend desirable attributes to the soil such as increased strength or decreased plasticity. This method provides material economy, improves support capabilities of the subgrade and furnishes a working platform for the remaining structure.

(iv) Mechanical Remediation:

Traditionally this has been the accepted practice to deal with soil contamination. This is a technique where contaminated soil is physically removed and relocated to a designated hazardous waste facility far from centers of human population. In recent times however, chemical and bioremediation have proven to be a better solution both economically and environmentally.

Lime and Soil Stabilization: Soil stabilization occurs when lime is added to a reactive soil to generate long-term strength gain through a pozzolanic reaction. This reaction produces stable calcium silicate hydrates and calcium aluminate hydrates as the calcium from the lime reacts with the aluminates and silicates solubilized from the clay. The full-term pozzolanic reaction can continue for a very long period of time, even decades -- as long as enough lime is present and the pH remains high (above 10). As a result, lime treatment can produce high and long-lasting strength gains. The key to pozzolanic reactivity and stabilization is a reactive soil, a good mix design protocol, and reliable construction practices.

Treatment with Lime

- Drying
- Modification
- Stabilization

Lime used for Drying

At low dosage rates, quicklime dries wet soils by – Removing free water from the soil to create calcium hydroxide (slaked lime) – Generating heat to help evaporate water from the soil – Chemically reacting with clayey soils to reduce their water-holding capacity

Lime Hydration $CaO + H_2O \longrightarrow Ca(OH)_2$ + heat

Lime Lime Slaked Lime

Lime Modification

- At low dosage rates, quicklime and slaked lime modify plastic soils by changing the chemistry of the soil water so the clay particles agglomerate and flocculate
- This reduces soil plasticity, decreases optimum moisture content, reduces shrink/swell potential
- The improvement in soil properties occurs over 1-2 days and may or may not be permanent

Lime Stabilization

- At higher dosage rates quicklime and slaked lime increase the pH of the soil water (making it more alkali) and the clay particles start to break down, Releasing silica and alumina that combine with the Ca to produce CSH and CAH
- This reduces plasticity, increases strength and stiffness, reduces shrink/swell potential
- The improvement in soil properties occurs over weeks and lasts indefinitely
- Flocculate and agglomerate clay particles by replacing monovalent cations such as Na^+ with divalent cations such as Ca^{++}
- Cement clay particles together by creating a pozzolanic reaction between CaO, SiO_2 and Al_2O_3
- Cement clay particles together by creating $CaCO_3$ from CaO plus atmospheric CO_2

Lime stabilization is not difficult to carry out. After proper mix design and testing is performed, in place mixing is usually used to add the appropriate amount of lime to soil, mixed to an appropriate depth. Pulverization and mixing is used to thoroughly combine the lime and soil. For heavy clays, preliminary mixing may be followed by 24 to 48 hours (or more) of moist curing, followed by final mixing. For maximum development of strength and durability, proper compaction is necessary. Proper curing is also important. If sulfates are present at levels greater than 0.3 percent, special procedures are required.

Cement stabilization:

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

Cement stabilization is done while the compaction process is continuing. During the compaction process we use some amount of cement. Some void space can be found in soil particle. Cement is just like paw, so cement can fill the void space of soil easily. As a result, void ratio of soil may reduce. After this primary tasks, when we add water in the compaction the cement reacts with water and become hard. So unit weight of soil is also may increase. Because of the hardening of cement, shear strength and bearing capacity will be increased. Because of the stabilization, permeability of soil may decrease.

Factors Affecting Soil Cement Stabilization

During soil cement stabilization the following factors are affecting.

1. Type of soil: Cement stabilization may be applied in fine or granular soil, however granular is preferable for cement stabilization.
2. Quantity of cement: A large amount of cement is needed for cement stabilization.
3. Quantity of water: Adequate water is needed for the stabilization.
4. Mixing, compaction and curing: Adequate mixing, compaction and curing is needed for cement stabilization.
5. 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

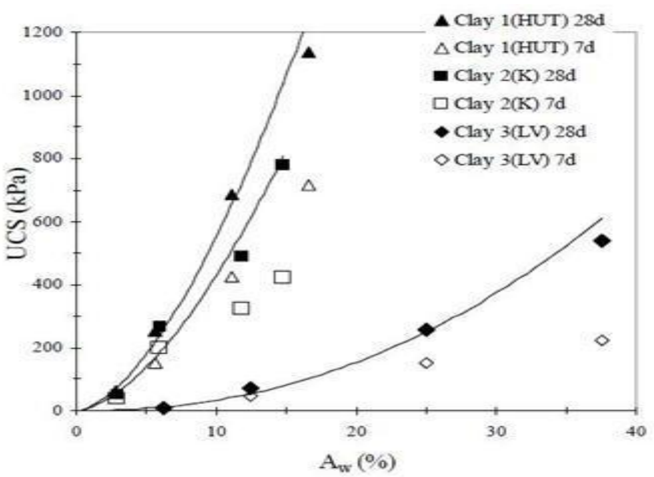
- It is widely available.
- Cost is relatively low.
- It is highly durable.
- Soil cement is quite weather resistant and strong.
- Granular soils with sufficient fines are ideally suited for cement stabilization as it requires least amount of cement.
- Soil cement reduces the swelling characteristics 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 is harmful for environment.
- It requires extra labor.
- The quantity of water must be sufficient for hydration of cement and making the mixture workable.

Effect Of Cement Stabilization On Engineering Behavior Of Soils

- The effectiveness of cement on the strength development was evaluated using unconfined compressive strength tests.
- The unconfined compressive strength increases with increasing cement amount which is obvious binder mass increases per unit volume soil.
- However the strength level different for different soil that‘s wye for any specified cement amount strength might be different for different soil.



A_w (%) Unconfined Compressive strength against cement content

Bituminous Soil Stabilization

- Bituminous materials such as asphalts, tars, and pitches are used in various consistencies to improve the engineering properties of soils.
- Mixed with cohesive soils, bituminous materials improve the bearing capacity and soil strength at low moisture content.
- The purpose of incorporating bitumen into such soils is to water proof them as a means to maintain low moisture content.
- Bituminous materials added to sand act as a cementing agent and produce a stronger, more coherent mass.
- The amount of bitumen added varies from 4 to 7 percent for cohesive materials and 4 to 10 percent for sandy materials.
- The primary use of bituminous materials is in road construction where it may be the primary ingredient for the surface course or be used in the subsurface and base courses for stabilizing soils

There are four types of Bituminous Stabilization. They include:

- Soil Bitumen
- Sand Bitumen
- Water Proof Clay Concrete
- Oiled Bitumen

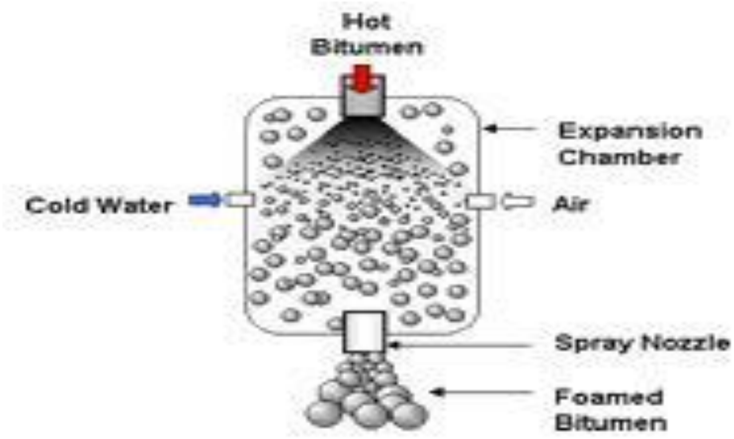
Soil Bitumen – The soil bitumen is used to stabilize clay soil. The stabilized soil becomes water- proof. The quantity of bitumen required varies from 4 to 7 % of dry weight.

Sand Bitumen – This is bitumen stabilized cohesionless soil system. The sand should be free from vegetable matter or lumps of clay. The sand should not contain more than 25 % minus 200-sieve material for dune sands and not more than 12 % in case other sands. The amount of bitumen required varies from 4 to 10 %.

Water – proofed Clay Concrete – It is water proofed soil made by adding 1 to 3 % of bitumen. In general, three gradations are in use to successfully stabilize the soil. The percentages passing 75 micron sieve are specified as:

- 8 to 12 %
- 10 to 16 %
- 13 to 30 %

Oiled Bitumen – It is a bitumen treated silty clay material. The material is made waterproof by spraying bitumen in two or three applications. Slow or medium curing bitumen or emulsions are used. The bitumen penetrates only a short depth into the soil. The amount of bitumen required is about 5 liters per square meter of the soil surface.



Bituminous Soil Stabilization

Chemical Stabilization With Calcium Chloride

- The Addition of high amounts (6%) of calcium chloride leads to high early strength (50% strength increase at 30 days), but much of this strength gain is lost over time. Limited data indicate that addition of calcium chloride beyond 2% may significantly reduce the long-term strength of the soil.
- The addition of calcium chloride has little effect on soil sensitivity, although it may tend to decrease it somewhat.
- Calcium chloride is an inorganic salt, which is a by-product of sodium carbonates.
- It is mainly used in highway constructions, dust control, and maintenance.
- Calcium chloride has hygroscopic property. This means calcium chloride attracts and absorbs water.
- This is a function of relative humidity and temperature. It can easily liquefy in moisture of its own absorption.
- Calcium chloride is highly soluble and can be dissolved easily so it can be easily washed away by rain and may require more than one treatment in a single season to maintain its effectiveness. For the same humidity and temperature the vapor pressure of calcium chloride is lower than water.
- Calcium chloride has a higher surface tension and a lower freezing point compared to water. In calcium chloride treated pavement roads this property minimizes frost, heave, and reduces freeze-thaw cycles, thus reducing maintenance cost
- Addition of calcium chloride affects engineering properties of the treated soils.
- Calcium chloride, depending on the soil type, may decrease the soil strength or increase it.
- Addition of calcium chloride has major effect on compaction characteristics of the

treated soils. The results will lead to an increase in dry density and a decrease in optimum water content.

- Another important advantage Calcium Chloride has is that it can be concentrated to a higher strength.

The Materials Obtained As Industrial Wastes And Their Re-Use In Stabilization Techniques

Soil is the basic construction material. It supports the substructure of any structure and it is the subgrade which supports the subbase/base in the pavement. The existing soil at a particular location may not be suitable for the construction due to poor bearing capacity and higher compressibility or even sometimes excessive swelling in case of expansive soils. The improvement of soil at a site is indispensable due to rising cost of the land, and there is huge demand for high rise buildings. There is a need to concentrate on improving properties of soils using cost-effective practices like treating with industrial wastes those having cementitious value.

Rice husk Ash (RHA) is an agricultural residue abundantly available in rice producing countries. Rice husk is obtained from the burning of rice husk which is the byproduct of rice milling.

Adding RHA to the concrete mix even in low replacement will dramatically enhance the workability, strength, and impermeability of concrete mixes, while making the concrete durable to chemical attacks, abrasion, and reinforcement corrosion, increasing the compressive strength.

Fly Ash (FA) is the finely divided mineral residue resulting from the combustion of ground or powdered coal in electric generating plant.

In recent years, the engineering community feels that bulk utilization of ash is possible through geotechnical applications.

Use of coal ashes for stabilization of soil resolve the clash between development and environment as it involves reuse and safe riddance of hazardous coal ashes.

At present, nearly 75 percent of India’s electricity generation is met by coal-based thermal power stations.

Lime is a classical soil stabilizer. Use of lime in the construction industry is an ancient practice from Romans and Egyptians. The most common form of lime used in soil stabilization is hydrated lime (or calcium hydroxide or slaked lime).

Uses of Industrial Wastes

Utilization of industrial wastes such as RHA and FA for soil improvement is a sustainable and cost-effective technique.

Geotechnical properties includes Index properties like liquid limit, plastic limit, and differential free swell index, and engineering properties like compaction and strength characteristics of soil are greatly improved using the industrial waste materials like RHA, FA, Lime

Results obtained after stabilization of soil with Industrial Wastes

- Unconfined compressive strength (UCS) is increased with RHA content. The UCS of original soil is 70 kPa. For the soil replaced with 4%RHA and 6%RHA, the UCS is increased to 88% and 141%, respectively, as compared to the original soil.

- In replacement of soil with 4% fly ash (FA) together with 4%RHA, the UCS after 7-day curing is increased to 70%. UCS of 7-day cured soil sample replaced with 4%RHA-4%FA-6%L mix is increased to 1620%, that is, 1204 kPa, whereas UCS of 28-day cured soil-4%L-12%RHA mix is 1120 kPa. Hence, fly ash have a significant influence on improvement of strength.

- The percentage increase in strength is higher for 7-day cured soil replaced with 4%RHA-4%FA-4%L mix. Hence, 4%L is the optimum lime content for soil-4%RHA-4%FA mix in view of strength.

- Soil replaced with 4%RHA-4%FA-4%L mix improved the properties of soil. This new geo material can be used as subbase course for pavements. DFSI for this mix is 30%. Hence, this mix can also used as a cushioning material under the expansive soil bed. Sustainable development can be achieved through making waste materials to wealthy materials.

IMPORTENT QUESTIONS

1. What are the different chemicals used in stabilization of soil?
2. (a) Discuss on suitability and applications of lime stabilization.
   (b) Explain the proportioning techniques of mechanical soil stabilization.
3. (a) Describe a method suitable to stabilize a highway foundation in a hilly terrain with high rainfall data.
   (b) Write a short note on: (i) Sodium silicate stabilization.
   (ii) Gypsum stabilization.
4. Discuss the gradation limits for soil-cement stabilization and explain its construction procedure.
5. (a) What are the factors affecting mechanical stabilized soil properties? (b) Explain the mechanics of soil stabilization
6. Write short notes on the following: (a) Bituminous stabilization.
   (b) Mechanical stabilization.
7. (a) Describe the properties of calcium chloride that are beneficial in stabilization of soils?
   (b) Explain soil-lime reactions. What are the engineering benefits of lime stabilization of soils?
8. (a) What is the necessity of soil stabilization?
   (b) Explain mechanical methods of soil stabilization. What are the different types test for soil stabilization?