Stabilization of Soils

1. Methods of Soil Stabization - Mechanical - Cement lime - bitumen and polymer Stabikzation - uses of Industrial waste like - fly ash and Granulated blast furnace slag.

1. Methods of Soil Stabilization: —

- Mechanical stabisation
- Lime stabilisation
- cement stabilisation
- Bitaminous stabilisation
- chemical stabilisation
- polymer stabilisation

1. Mechanical stabilisation: —

factors affecting Mechanical stabilization

1. Mechanical strength of Aggregation
2. Gradation 3. properties of soil
4. presence of silt Mica etc
5. Compaction 6. Effect of Efflorescence.

- Weak Aggregates have been succesfully used in Mechanical stabilization work with proportioning Technique by Rath Fitches Method.

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→ Grain size distribution of the ... mix would determine the stability of the mix.

→ High plasticity index of the material results in poor stability under soaked condition.

→ Presence of salts like sulphates and mica are undesirable.

→ Presence of calcium chloride is desirable.

→ Effect of compaction to produce high density and the stability of the mix.

Construction procedure :—

→ **Materials used :**

The construction material are collected from the selected borrow pits and are soaked along the sides of the road in desired proportions.

→ **Equipment used :—**

→ The equipment needed are for excavation upto shallow depths

→ Haulage for short distance and for compaction

→ For compaction roller of suitable type and weight is necessary depending on the material to be compacted.

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Mechanical stabilization deals with the rearrangement and improving soil particle and soil gradation.

→ The various examples for rearrangement of the soil particle are

- undisturbed soil can be remoulded
- stratified layers of soil can be blended etc.

→ In this method low cost roads can be constructed by using a properly mixed material.

→ Subgrade soil properties can be increased by applying the soil gradation principle.

* **Cement stabilisation:—**

Type of Soil-Cement:—

① **Normal soil cement:—** It consists of 5 to 14 % of cement by volume. The quantity of cement mixed with the soil is sufficient to produce a hard and durable construction material

② **plastic soil cement:—** This type of soil-cement also contains cement 5 to 14 % by volume. but it has more quantity of water to have wet consistency similar to that of plastering mortar at the time of placement.

③ **Cement-modified soil:—** It is the type of soil cement that contains less than 5 % of cement by dry volume. It is semi-hardened product of soil and cement. It interacts with the

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→ Grain size distribution of the combined mix would determine the more stability of the mix.

→ High plasticity index of the material result in poor stability under soaked condition

→ Presence of salts like sulphates and mica are undesirable.

→ presence of calcium chloride is desirable.

→ Effect of compaction to produce high density and the stability of the mix.

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silt and clay fractions and reduces their affinity for water.

(*) Factors affecting Cement Stabilisation

(1) Type of Soil:- Granular soils with sufficient fines are ideally suited for cement stabilization Such soils can be easily pulverized and mixed They require least amount of cement.

Granular soils with deficient fines such as beach sands and wind-blown sands, can also be stabilized but then soils require more cement.

(2) Quantity of cement:- A well graded soil requires about 5% cement, whereas a poorly graded, uniform sand may require about 9%. Cement. Non plastic silts require about 10-% Cement cohesive plastic clays may need about 13% Cement

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The actual Quantity of cement required for particular soil is ascertained by Laboratory Tests.

④ Quantity of water:—

The Quantity of water used must be sufficient for hydration of cement and silt-clay cement and for mixing the mix workable. Generally, the amount of water ascertained from Compaction Consideration is adequate for hydration as well.

⑤ Mixing Compaction and curing:—

The mixture of soil, cement, and water should be throughly mixed as the Succes of cement stabilization depends mainly on through mixing. If it is not properly mixed, it may result in a non homogeneous, weak product. However, the mixing should not be continued after the cement has started hydrating, as it would result in a loss of strength.

⑤ Admixture:—

It increases the effectiveness of cement as stabiliser, admixture are sometimes added to soil cement. Admixture may permit a reduction in the amount of cement required. They may also help stabilization of soils which are not responsive of cement alone.

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Construction Methods :-

1. Mix-in-place method :- In this method of construction, mixing of soil cement is done at the place where it would be finally placed.

→ Subgrade is cleared of all undesirable materials such as boulders, debris, stumps

→ The levelled subgrade is scarified to a depth equal to the proposed thickness of soil cement.

→ The scarified soil is then pulverized to a depth equal to proposed thickness of till at least 80% of soil passes 4.75 mm IS sieve.

→ The pulverized soil is properly shaped to the required grade and the required Quantity of cement is spread uniformly over the surface

→ The required quantity of water is sprinkled over the surface and wet mixing is done till the mixture has a uniform colour.

→ Compaction is done using suitable methods The thickness of the layer should not be more than 15cm.

→ The compacted soil-cement is moist cured for at least 7 days by providing a bituminous primary coat.

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⑤ Lime Stabilization :-

Lime stabilization is done by adding lime to a soil. It is useful for stabilization of clayey soils. When lime reacts with the soil, there is exchange of cations in the absorbed water layer and decrease in plasticity of the soil occurs.

Lime is produced by burning of lime stone in kilns. The Quantity of lime obtained depends upon the parent material and the production process. There is basically 5 Types of lime.

(i) High Calcium Quick lime (CaO)
(ii) Hydrated, High Calcium lime [$Ca(OH)_2$]
(iii) Dolomitic lime [$CaO+MgO$]
(iv) Normal, hydrated dolomatic lime [$Ca(OH)_2+MgO$]
(v) pressure, hydrated dolomatic lime [$Ca(OH_2)+MgO_2$]

The amount of lime required for stabilization varies between 2 to 10% of the soil. However if the lime is used only to modify some of the physico-chemical characteristics of the soil. If the amount of lime is about 1 to 3%. The following amount may be used as a rough guide.

- (i) 2 to 5% for clay gravel material having less than 50% of silt-clay fraction.
- (ii) 5 to 10% for soils with more than 50% of silt clay fraction
- for soils having particle size intermediate

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between (i) and (ii) above The quantity of lime required is between 3 to 7 %.

(iii) About 10 % for heavy clays used as bases and subbases.

(*) Chemical and physical changes in lime stabilisation :—

(1) When lime reacts with wet soil, it alters the nature of the absorbed layer by base-exchange. calcium ions replace the sodium or hydrogen ions.

(2) the double layer is usually depressed due to an increase in the cation concentration.

(3) Lime reacts chemically with available silicon and alumina in soils. A natural cement Composed of calcium alumino silicate complexes is formed which causes a cementing action.

(4) In lime stabilisation, the liquid limit of the soil generally decrease but the plastic limit increases The soil becomes more friable and workable The strength of the lime stabilized soil is generally improved.

(5) Addition of lime causes a high concentration of Calcium ions in the double layer. It causes a decreased in the tendency of attraction of water.

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(2) The lime stabilized bases or sub-bases form a water resistant barrier which stops penetration of rain water. There is increase in the optimum water content and a reduction in the maximum dry density.

(*) Construction Methods :—

Construction Methods in lime stabilization are similar to those used in cement stabilisation.

→ as in the reaction in the case of lime is slow. there is no maximum time limit between the addition of lime to the soil and the completion of Compaction

→ lime may be added in the form of slurry instead of dry powder.

→ at least period of 1 to 4 days is Generaly required. after spreading lime over a heavy clay before final mixing is done.

→ The soil lime is Compacted to the required maximum dry density.

→ After Compaction the surface is kept moist for 7 days. and then Covered with a suitable wearing course. sometime the wearing coat is applied soon after compaction to help hold the moisture.

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Bitumen Stabilisation:—

Bitumens are non-aqueous systems of hydro carbons that are soluble in carbon di-sulphide. Tars are obtained by destructive distillation of oraganic materials such as coal. Asphalt are materials in which the primary components are natural or refined petroleum bitumens.

→ Bitumen stabilisation is generally done with asphalt as binder. As asphalts are normally too viscous to be used directly.

→ These are also used as emulsions, but in this form they require a longer drying period.

Types of Soil Bitumen:—

1.(i) Soil Bitumen:— This is water proof, cohesive soil system.

→ passing NO. 4 (4.76 mm) sieve 50 %.
→ passing NO: 40 (0.425 mm) sieve 35 to 100%
→ passing NO 200 (0.074 mm) sieve 10 to 50%
→ plastic limit less than 18 %.
→ Liquid Limit less than 40 %.
→ The maximum size of the particle should not be greater than one-third the Compacted thickness of the soil Bitume.

(ii) Sand - Bitumen:— This is a bitumen stabilised cohesionless soil system. The

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Sand should be free from. the sand should be free from vegetal matter or lumps of clay. the amount of bitumen required varies from 4 to 10 %.

(iii) water proofed clay Concrete :—

A soil possessing a good gradation is water proofed by distribution of 1 to 3 % of bitumen in this system. Soils of 3 different gradation have been recommended. for that the percentage passing No. 200 sieve. varies b/w. (i) 8 to 12 (ii) 10 to 16 and 13 to 30.

(iv) Oiled Earth :- In this system, a soil surface consisting of silt-clay material is made water proof by spraying bitume in 2 or 3 application

2. Factors affecting bituminous stabilisation

1. Type of soil :- Bituminous stabilisation is very effective in stabilising sandy soils having little or no fines. If a cohesive soil has a plastic limit less than about 20% and the liquid limit less than 40% it can be effectively stabilised.

2. Amount of Asphalt :—

The quality of the bitumen stabilised soil improves with the amount of Asphalt upto a certain limit. However, if the amount of the Asphalt is excessive, it results in a high mixture that cannot be properly Compacted.

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3. Mixing :—

The quality of the product improves with more through mixing.

4. Compaction :—

The dry density of the bitumen-soil depends on the amount and type of Compaction. It is also depends on "volatile content".

In this method AASHO Test the maximum dry density occures at a volatile content of about 8 %.

(3). Construction Methods :—

→ The optimum volatile content or Compaction is generally much greater that that for stability.

→ To obtain the high stability, the Layer method of construction is prepered. Each layer is kept about 5cm thick. when the lower layer has dried up. The subsequent layer is laid. The total thickness for bases is kept b/w 10 to 20 cm.

(*) Polymer stabilisation :—

Polymer soil stabilisation refers to the addition of polymers. to improve the physical properties of soils. Various polymers have been shown to increase the water retension and reduce erosion increase soil shear strength and

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support soil structure

Types of polymers :—

polymers that have been tested for soil stabilisation effects include a range of "synthetic polymers" and Biopolymers.

Synthetic polymers :—

Alumino-silicate based, sylthetic geopolymers provide many of the same binding properties as portland cement. Many Geopolymers are quite durable with high mechanical strength and thermal stability

Bio polymer :—

Biopolymers that have been tested for use in soil stabilisation include cellulose, starch, chitosan, xanthan, curdlan, and beta-Glucan. Some Biopolymers are sensitive to water. and wetter soils exhibit weaker strengths.

What is polymer :—

A substance which has a molecular structure built up chiefly or completely from a large no. of similar units bonded together

Ex. Many synthetic organic material used as plastics and resins.

poly = many

mer = parts

or large molecule.

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Procedure :- Applications

→ Soil characteristics that have been altered by addition of polymers include Compressive strength.

→ polymers can help prevent soil erosion. and increase infiltration of water by strengthening soil aggregates and supporting soil structure.

→ Hydrogel swelling of Biopolymers reduces the amount of soil pore space, restricting the flow of water and suiting polymer hydrogels for construction projects seeking to minimize water seepage and support vegitation growth.

(*) Uses of Industrial waste like fly Ash :-

The use of flyash in concrete can lead to many improvement in overall concrete performance some key Benifits include.

→ Reduce water content → Improved workability
→ Reduced Segregation → Improved pumpability
→ Improved finishing → low heat of hydration
→ Lower drying shrinkage.
→ Improved long term streng
→ Decreased permeabily → Increased Durabi
→ Improved Resistance to Alkali silica Reactivity
→ Improved Resistance to sulfate Attack

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* uses of Blast furnace slag

uses of blast furnace slag is as

→ Sand and gravel for the Construction of road beds

→ Basic filler in Asphalt - concrete mixture for the construction of road and Airport coating.

→ unroasted cement (binder) for reinforcing roadways and preparing slow setting concrete.

→ Reduces the crack resistance of the Concrete

→ To reduce the stress, Temparature seems must be introduced in the plate.

→ Slow setting of the binder is Convenient hence material with slow setting binder will retain their thixotropic properties after a long period.

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GIT

UNIT – 3

Soil Stabilization : Soil Stabilization is referred to as a procedure in which a Special soil is proportioned/added for removed, or a Cementing material or other Chemical material is added to a natural Soil material to improve one or more of its properties.

(or)

Improving the engineering properties of a soil by admixtures is often Simply reffered as Soil Stabilization.

The purpose of mixing these additives with the ground is to

1. Increase Strength.
2. Reduce deformability.
3. provide Volume stability (control Shrinking & Swelling)
4. Reduce permeability.
5. Reduce erodibility.
6. Increase durability (inhibit degradation of aggs
7. Control variability.

methods of Soil Stabilization : ① Mechanical Stabalization.
② Chemical Stabalization.
③ Cementing Stabalization.

→ Improvement of Soil property by proportioning of coarse and fine grained Soils is commonly referred as mechanical Stabalization. (or)
Rearrangment of Soil particles by some mechanical means like compaction, vibration etc., is ~~refferd~~ referred as mechanical Stabalization.

→ Adding and mixing the Stabilizing materials ~~includes~~ like Cement, lime, & bitumen/asphalt, ~~polymers~~ etc is refferd to as Cementing Stabalization

→ Addition of Chemicals causes a physico-chemical alteration & Referred to as chemical Stabalization

→ different methods of stabilization are in use, based on their function or effect on Soil they may be classified as follows
① Mechanical : improving Soil gradient or arrangment.
② Cementing : binding the particles together without their alteration.

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③ physico-chemical alteration: changing the clay minerals or the clay water System.

~~④ Aggregate~~

④ Aggregants & dispersants: alteration of electrical forces between soil particles in a modest way.

⑤ Void filling : plugging in voids.

⑥ Consolidation.

→ In cohesionless soils strength could be improved by providing confinment or by addeing cohesion with a cementing or binding agent.

→ In cohesive soils the strength could be increase by drying, making the soil moisture resistant, altering the clay-electrolyte concentration, increasing cohe with a rigid material or by altering the forces.

→ Swelling & Shrinkage can be controlled by adding cementing agents, by altering the double layer thickn property, & by preventing moisture changes.

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→ permeability can be reduced by filling the voids with an impervious materials or by creating a dispersed structure of Soil.

Mechanical Stabalization:

Mechanical Stabalization is attained by 2 methods

(i) The rearrangment of Soil particles.
(ii) The improvement of Soil gradation.

eg of rearrangment of Soil particles is

(i) blending of the layers of Stratified soil.
(ii) remoulding of an undisturbed Soil and
(iii) Densification of Soil.

→ For the Construction of low cost roads the Correctly proportioned material is important.

→ The principle of grading Soil may be applied to the movement of Subgrade Soils.

→ The main application of the Control of the grading of Soils & low grade aggregates is to the Construction of bases & Sub-bases.

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Mechanical Stability of materials:

(1) In general weak aggregates are preferred for mechanical stabilization because they will break down under compaction to give a grain size distribution more closely approaching that required for max dry density.

(2) The aggregates should be correctly proportioned before laying and should have sufficient mechanical strength so as to maintain the same grain size distribution during compaction and subsequents use by traffic.

(3) Any material that is resistant to ~~when~~ weathering shall be suitable for use as aggregates in a mechanically stabalized road.

(4) All kinds of natural rock, gravel, sand, artific materials (such as slag, burnt ~~slag~~ shale etc) have been used in road construction with Succ

(5) In order to attain adequate mechanical stabi/° it is necessary to have a well proportioned coarse material containing some clay binder.

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(6) In the case of coarse materials it is assumed that the particle size distribution giving the greatest density has the greatest internal friction.

(7) It is observed that to obtain adequate cohesion, greater proportion of material less than 0.075mm is necessary.

(8) plasticity Index of material should be limited to a maximum of 6% for bases & should be btw 4 to 9% for surfacings.

(9) liquid limit should not exceed 25% for base and 35% for surfacings

(10) Higher liquid limits and plasticity indices are desirable for surfacing and quite undesirable for base courses.

Proportioning the materials:

Natural materials are deficient in one or more of the particle-size fractions required. Thus a mechanically stable material can be produced

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only mixing two or more of the materials in appropriate proportions.

(i) The cumulative curve of the required aggregate particle size distribution is plotted, using the usual linear ordinates for the % passing but choosing a scale of sieve size such that the particle size distribution plots as a straight line.

(ii) The particle size distribution curves of the aggregates to be mixed are plotted on this scale. It will generally be found that they are not straight lines.

(iii) With the aid of a transparent straight edge, the straight lines that most nearly approximate to the particle size distribution curves of the single aggregate are drawn

Addition or removal of Soil particles:

The engineering behaviour of a Soil also depends on the particle size distribution & the composition of the particles. It is possible to significantly change the property of a given Soil by adding some Selected Soil or by removing some Selected fraction of Soil.

→ Addition of binders to gravel for road construction
→ Addition of material to reduce permeability.
→ Removal of fines from gravel.

Portland Cement (Cementing) Stabalization.

Binding of Soil particles together without their alteration is reffered to as Soil Stabalization by Cementing.

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Cement and Soil blended material is reffered to as Soil-Cement.

Nature of Soil:

(1) All the inorganic Soils which can be pulvarized can be Stabalized using Cement.

(2) Soils Should be low in organic matter for Succesfull Stabalization Since this Constituent tends to reduce the Strength of Soil Cement.

(3) 2% of organic matter is considered to be the Safe upper limit.

(4) Soils with higher Specific Surface requires more Cement for Stabalization.

(5) Clay presence is problem for pulvarization, mixing, and Compaction of mixture (Soil–Cement). So Clay with expanding nature is difficult for Stabalizatio

(6) ions (exchangeable) influence the Soil treatment respons 'Ca' is most desirable ion for ease of Cement Stabalization, Sometime lime (or) Cacl is added to clay for Stabalizing Cement.

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(7) Chemical Composition of Soil if Contains the deleterious Salts Such as Sulphates, there is a possibility of Sulphates reacting with Setting of Cement.

Soils with the following limits can be economically Stabalized (HRB, 1943).

particle Size distribution limits :

max Size ∅ 75mm

passing 4.5mm IS Sieve 75%.
" 40mm " " 715%.
" 75μ " " < 50%.

plasticity limits

LL < 40%.
PI ∅ < 18%.

(8) In general the best results are obtained with well graded Soils having less than 50% of its particles finer than 0.074mm and a plasticity Index less than 20%.

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Amount of Cement:

Soil-Cement has been made with Cement Content Varying from 5 to 20% for Satisfactory Stabilization.

For gravels, a Cement level of 5 to 10% by weight.
For Sands, a Cement level of 7 to 12% by wt.
For Silts, a Cement level of 12 to 15% by wt.
For Clays, a Cement level of 12 to 20% by wt.

MIXING:

more uniform Soil Cement water mixture, provide Strong & durable Soil Cement. The intimacy of the mixture is not directly proportional to the mixing energy. As a matter of fact, increase in Continued mixing Causes a decrease in the degree of mixing and many lead to Segregation of Components. Thus Continued mixing Should be only upto the optimal level. further, mixing after Cement hydration has begar can have deleterious effects. mixture made in

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in laboratory have higher strengths and greater durability than similar mixtures made in the field. Soil Cement made by mix-in-place method and rotatory tiller have shown about 50% to 70% of the strength of a laboratory mixture.

Moisture Content:

It plays 2 roles in Soil Cment

(i) It influences the Compaction characteristics as with natural Soil

and

(ii) It furnishes water for Cement hydration.

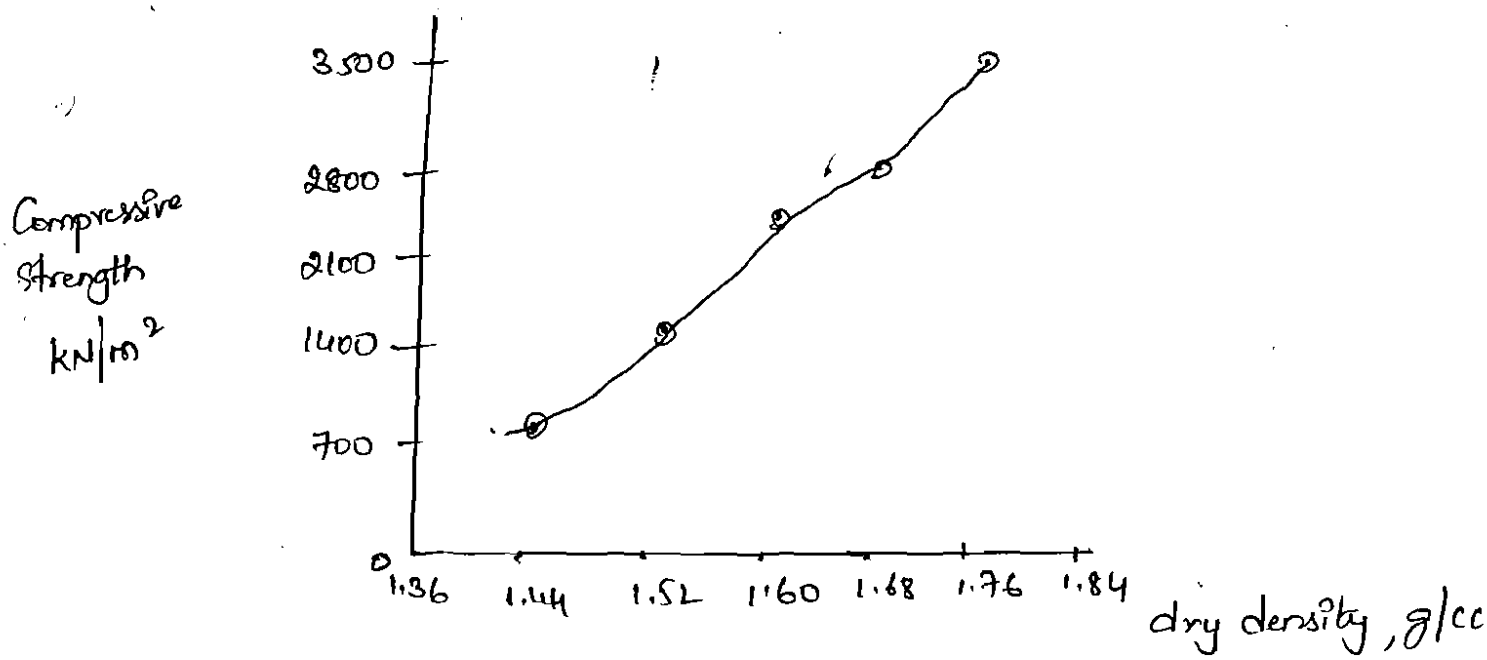
Of these 2, the effect of M/C on the quality of Soil Cement largely arises from the influence on the Compaction.

Compaction conditions:

In order to obtain Satisfactory

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Soil Cement adequate compaction is essential. A typical Compressive strength / dry density curve is obtained which relates a Sandy clay mixed with 10% of Cement.



Age & Curing:

As with Concrete, the Compressive Strength of a Soil Cement increases with age. In partices, Soil Cement is Cured after Compaction under ~~conditions~~ influences the resulting product. like Concrete, a damp environment is most desirable for Curing. Soil Cement Cures rapidly with increase in temp although it will harden at all temperatures.

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Admixture of Soil Cement:

In order to set & to improve the properties of Soil Cement, lime or Calcium chloride is added. addition of some of the Chemicals shown remarkable improvement in the strength of Soil Cement. These chemicals, by increasing the effectiveness of Cement as a stabilizer,

(i) A reduction in the amount of Cement required to treat a Soil responsive to Cement.

(ii) Stabilization of some of the Soils which are not responsive to Cement above.

Certain alkaline metal compounds, especially Sodium Carbonate, Suits most of the Soils. The type of additive which could be effective should be found by trail. Use of some chemicals along with Cement have important advantages such as

(i) reducing the additive quantity needed to perform a given job, thus Simplifying the handling & mixing &

(ii) Reducing the total Stabilizer cost.

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Construction of Soil Cement:

(i) Shaping the soil to be treated
(ii) pulverizing the soil.
(iii) Adding water & Cement.
(iv) Mixing.
(v) Compacting.
(vi) finishing &
(vii) Curing.

Bituminous Stabilization:

It is an effective method which is being widely used. Bituminous materials are

(i) Bitumen
(ii) Asphalt (redefined petrolum bitumen / ~~Con~~natural / combin
(iii) Tars. (destructive distillation).

Bituminous materials stabilizes the soil either by binding particles together or protecting the soil fro deleterious effects of water (or) both these effects may occur together.

Among the bituminous materials most of bitumen stabilization has been with asphalt.

Asphalts are produced by 3 process

(i) Vacuum distillation producing straight run asphalt.

(ii) High temperature pyrolysis of refinery heavies, producing Cracked Asphalt.

(iii) High temperature air blowing straight run asphalt, producing blown asphalt.

As the straight run asphalt has low ~~Softe~~ Softening temp and low melt viscosity, it is commonly used in soil stabilization. Asphalt can not be directly adde to the soil because it is too viscous. Its fluidity can be increased by (i) heating

(ii) emulsifying in water

(iii) cutbacks with solvents like gasoline.

* Both cutbacks & emulsions are used in soil stabilization.

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Nature of soil:

All inorganic soils with which asphalt (emulsion & cutbacks) can be mixed can be Stabilized.

(i) 7 50% finer than 4.75mm size.
(ii) 35 to 100% finer than 0.42mm size.
(iii) 710 to < 50% finer than 0.074mm size.
(iv) L.L < 40%.
(v) PI < 18%.

Amount of Asphalt:

An increase in asphalt content give better results. In fine grained soils addition of asphalt does not increase the strength but tremendously impro the waterproofing property & thereby yielding a better Stabilized Soil.

Mixing:

A thorough incorporation of the additive wi the Soil yields a better Stabilized Soil.

Compaction Conditions:

The density of a mixture of Soil & asphalt is governed by the volatiles cont

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and amount and type of compaction. In general lower the volatiles content, the higher the strength.

Cure Conditions:

(i) The longer the period of cure & warmer the temperature of cure, the greater the volatiles lost.

(ii) the longer the period of immersion, the greater the water pickup.

Construction of Soil Asphalt:

(i) pulvarization of soil to be treated.

(ii) Addition of water for proper mixing.

(iii) Adding & mixing of bitumen.

(iv) Aeration to the proper volatiles content for compaction.

(v) Compaction.

(vi) finishing.

(vii) Aerating & curing.

(viii) Application of surface cover.

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Fly ash :

It is a solid waste product created by the combustion of coal; it is carried out of the boiler by flue gases and extracted by electrostatic precipitators or cyclone seperators and filter bags.

Ash removed from the base of the furnace is termed as bottom ash or boiler slag. Boiler slag is coarser than fly ash, size ranging from fine sand to gravel. Boiler slag serves as structural fill material in road construction.

Fly ash is used as a partial replacement for cement in concrete because of its pozzolanic properties. It is also the form of ash which has the greatest potential for use in ground modification.

Around 10 to 15% to 20% of the fly ash is only used for construction or for and half of this used for in manufature of concrete. & rest is pumped in slurry form into dagoons or is conditioned by the addition of 10 to 15% water and

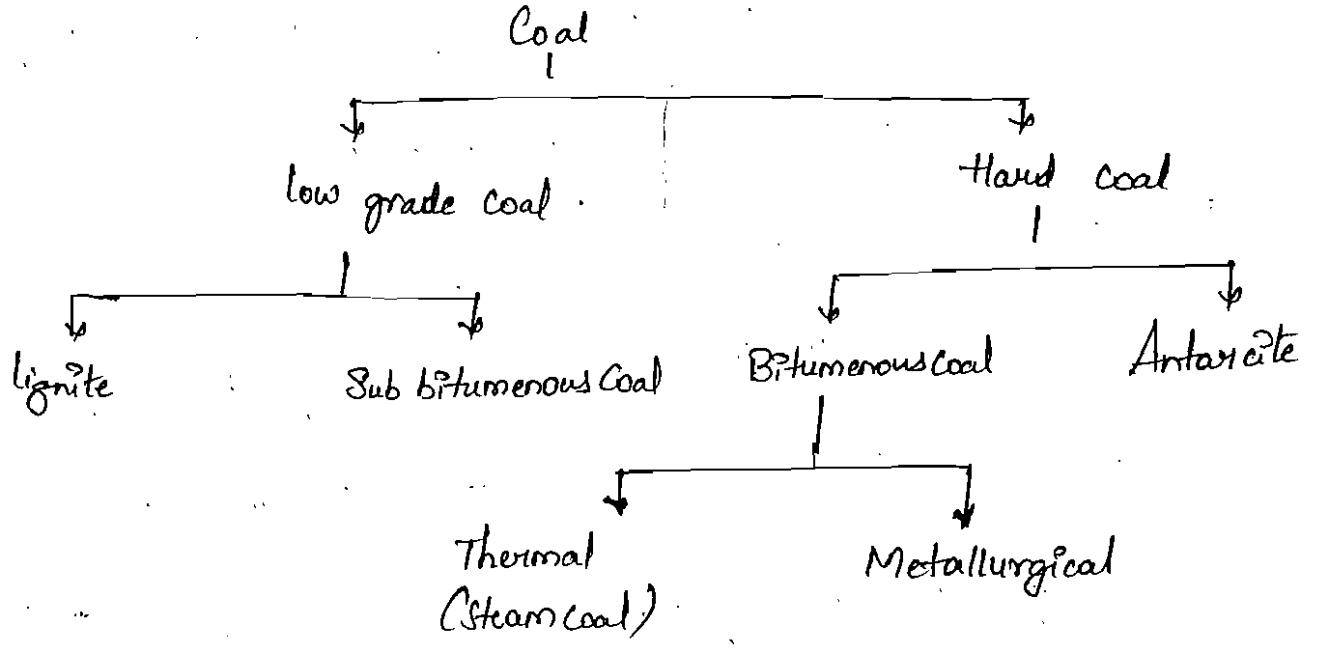
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disposed of as more or less engineered landfills. The degree of self hardening of ash is also highly dependent on the ash's density, temperature & age.

* ASTMC 618 distinguishes b/w Class F and class C fly ash.

→ Class F fly ash is normally produced from burning anthracite or bituminous coal. It has pozzolanic properties, & will react with lime to form cementitious compounds.

→ class C fly ash is produced from burning subbituminous or lignite coal. in addition to being pozzolanic, it has cementitious properties of its own.



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* The Specific gravity of the ash particle ranges from 1.9 to 2.5. Some fly ash particles float if they consists hollow glass spheres (Cenospheres)

* Average grain size D_{50} of fly ash is likely to be in the range of 0.02 to 0.06 mm.

* Fly ash is non plastic and in a dry state as collected, Completely cohesionless.

* Compacted ash may have a dry density of around 1.2 to 1.9 t/m^3.

* moisture Content ranging from 30 down to 15%.

advantages: ① used as backfill (or) embankment material.

② low unit wt means low overburde pressure & combined with a high fricti angle also low earth pressure.

* Compression Index of fly ash C_c range from 0.05 to 0.37 for initial loading. In recompre these values are much lower 0.006 to 0.04.

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disadv: Fly ash acts as frost Susceptible material which is major drawback in its use for road construction in regions with cold winters.

Fly ash Stabalization with lime Cement & Aggregate

The use of mixture of lime (L) (or) Cement and fly ash (F) with aggregate (A) giving LFA, CFA or LCFA bases or Subbases for pavements is relatively well established in most countries. Many local authorities have published criteria for the incorporation of pozzolanic materials with Cement or lime in aggregate layers either rated as bound or unbound layers, depending i.e their indirect tensile strength is above or below 80%px To build a Subbase or base Course with lime - or Cement Stabilized ash alone is not yet Common, but this is one of the high Volume ash applications.

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According to British & American experience, EPRI (1986) quoted the following criteria as part of their design recommendations for Cement-stabilized fly ash base course.

Min strength: 7 day unconfined Compressive strength of the mix when cured under moist conditions at 21 ± 2°C must exceed 2.8 to 3.1 MPa for cylindrical Specimens having length to diameter ratio of 2:1. If Cubical Specimens are used, a Strength of 3.5 Mpa is Recommended.

Max. Strength: max strength of 5.5 Mpa is Recommended to avoid cracking wh may reflect through the asphalt Surface layer.

Ageing Criteria: unconfined Compressive Strength of ther

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is observed to increase with time.

Similarly for lime - stabilized fly ash base courses, except the design criteria refer to the 28 day rather than 7 days strength, because of slow rate of Cementation.

min Strength must be 3.7 to 4.1 Mpa.

Soil modified with fly ash & Cement or lime:

For cohesionless soils or soils with very low plasticity (plasticity Index < 10), Cement will be more effective than lime, either alone or when combined with fly ash.

for more plastic soils either Cement or lime may be added with fly ash. fly ash could also serve as a filler in the bituminous stabilization of coarse grained materials.

~~Stabilization of a Sandy road base with a~~

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* fly ash Cement mix rather than Cement alone, Creates a less permeable Stiffer layer. this may results in reduced long term maintenance.

* Cement - flyash - Sand (or) Cement - flyash - gravel mixtures Shrink less than Soil Cement mixtures

Lime:

For engineering purpose lime is used in the form of quicklime, Cao (or) hydrated lime $Ca(OH)_2$. a third version of lime, $CaCO_3$ is used for agriculture purpose only.

lime has been used as a Soil Stabilizer for roads from olden days. lime is produced from natural limestones.

(i) High calcium quicklime — Cao.
(ii) Dolomite quicklime — $CaO + MgO$.
(iii) Hydrated high cal lime — $Ca(OH)_2$
(iv) Normal hydrated dolomite lime — $Ca(OH)_2 + MgO$.
(v) pressure hydrated dolomite lime — $Ca(OH)_2 + Mg(OH)_2$.

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* Quick lime is delivered in the form of a coarse grained powder with a bulk density of 0.85 to 1.05 t/m³.

* It reacts quickly with water producing hydrated or Slaked lime.

$$CaO + H_2O \rightarrow Ca(OH)_2 + 65.3 \text{ kJ/mol}.$$

* Quick lime is handeld carefully it may cause corresion of equipment.

* Slaked lime is used in the form of a fine powder with a bulk density of 0.45 to 0.6 t/m³. or as a slurry with a water content of 80 to 100%.

* Quick lime is most cost effective than Slaked lime in terms of handling & transport.

Soil lime reactions:

Short term reactions includes hydration (for quicklime) and flocculation (ion exchange).

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Long term reactions are Cementation and Carbonation. (14)

Hydration: Quicklime will immediately react with the water in the soil. The drying action is particularly benefical in the treatment of moist clays. In the placement of lime columns and layers, the heat generation and expansion of the lime further enhances the consolidation effect.

flocculation: When lime is mixed with clay, sodium & other cations adsorbed to the clay minerals surfaces are exchanged with calcium. This change in the cation exchange complex affects the way the structural components of the clay minerals are connected together. lime causes clay to coagulate, aggregate or flocculate. The clay's plasticity is reduced making it more easily workable and potentially increasing its strength & stiffness.

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Cementation: The second stage of clay lime reactions remove silica from the clay mineral lattice to form products not unlike those of cement hydration. Cementation is the main contributor to the strength of the stabalized soil. The higher the surface of the soil the more effective is the strength of the soil. The more effective is the process. Lime is not suitable for improving clean sands or gravels. Cementation is however limited by the amount of available silica. Increasing the quantity of lime added will increase strength only upto the point where all silica of the clay is used up. adding too much lime can actually be counter-productive. This is in contrast to stabalize with cement, where strength continues to improve with the amount of admixtures.

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Cementation on the surface of clay lumps causes (15)
a rapid initial strength gain, but further diffusion of the lime in the soil will bring about continued improvement in the longer term, measured in weeks or months.

Carbonation: Reaction of lime with Co_2 in open air or in voids of the ground forms a relatively weak cementing agent. This may be beneficial where lime is plentiful. the $CaCo_3$ formed will not react any further with the soil.

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