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 & ~~Shrinkage~~ Swelling)
4. Reduce permeability.
5. Reduce erodibility.
6. Increase durability (inhibit degradation of agg
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 ~~reffere~~ referred as mechanical Stabalization.

→ Adding and mixing the Stabilizing materials ~~Includes~~ like Cement, lime, & bitumen/asphalt, ~~polymers~~ etc is reffered 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.

(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 confinement or by adding 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.

→ 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 re arrangment 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.

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 stabili it is necessary to have a well proportioned coarse material containing some clay binder.

(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 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 aggreagates 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 Som. 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.

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 Stabalization

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

(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).

<u>particle Size distribution limits :</u>

max Size 75mm

passing 4.5mm IS Sieve 750%.
" 40mm " " >15%.
" 75μ " " < 50%.

<u>plasticity limits</u>

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%.

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 begun can have deleterious effects. mixture made in 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 cement

(i) It influences the compaction characteristics as with natural soil

and

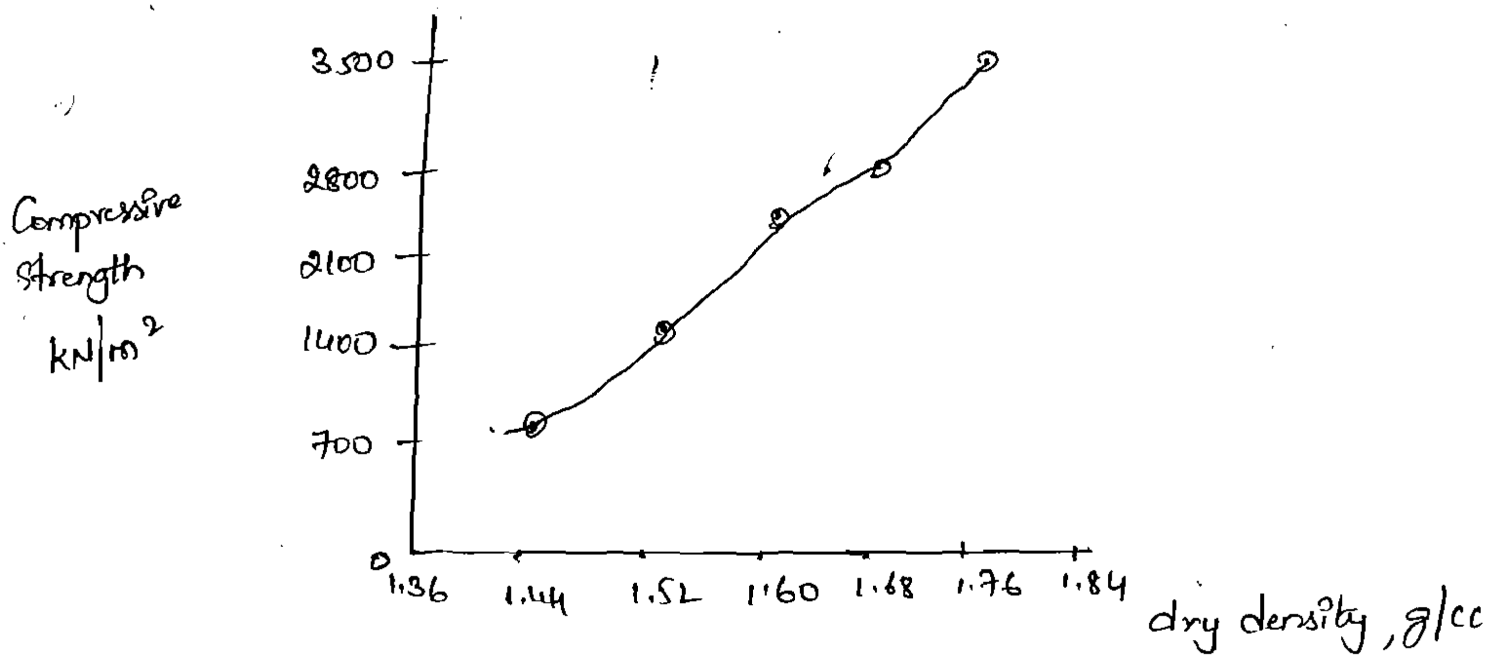
(ii) It furnishes water for cement hydration.

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

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 practices, 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.

Admixture of Soil Cement:

In order to set & to improve the properties of Soil Cement, lime or Calicum 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.

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.

Bitumenous Stabilization:

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

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

Bitumenous materials Stabilizes the Soil either by binding particles together or protecting the Soil from 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 & ~~of~~ emulsions are used in soil stabilization.

Nature of Soil:

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

1. (i) > 50% finer than 4.75mm size.
2. (ii) 35 to 100% finer than 0.420mm size.
3. (iii) > 10 to < 50% finer than 0.074mm size.
4. (iv) L.L < 40%.
5. (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 waterprofing property & thereby yielding a better stabilized soil.

Mixing:

A ~~through~~ thorough incorporation of the additive w the soil yields a better stabilized soil.

Compaction Conditions: The density of a mixture of soil & asphalt is governed by the volatiles cont and amount and type of compaction. In general lower the volatiles content, the higher the strength.

Cure Conditions:

1. The longer the period of cure & warmer the temperature of cure, the greater the volatiles lost.
2. The longer the period of immersion, the greater the water pickup.

Construction of Soil Asphalt:

1. pulvarization of soil to be treated:
2. Addition of water for proper mixing.
3. Adding & mixing of bitumen.
4. Aeration to the proper volatiles content for compaction.
5. Compaction.
6. finishing.
7. Aerating & Curing.
8. Application of surface cover.

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 furnac 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.

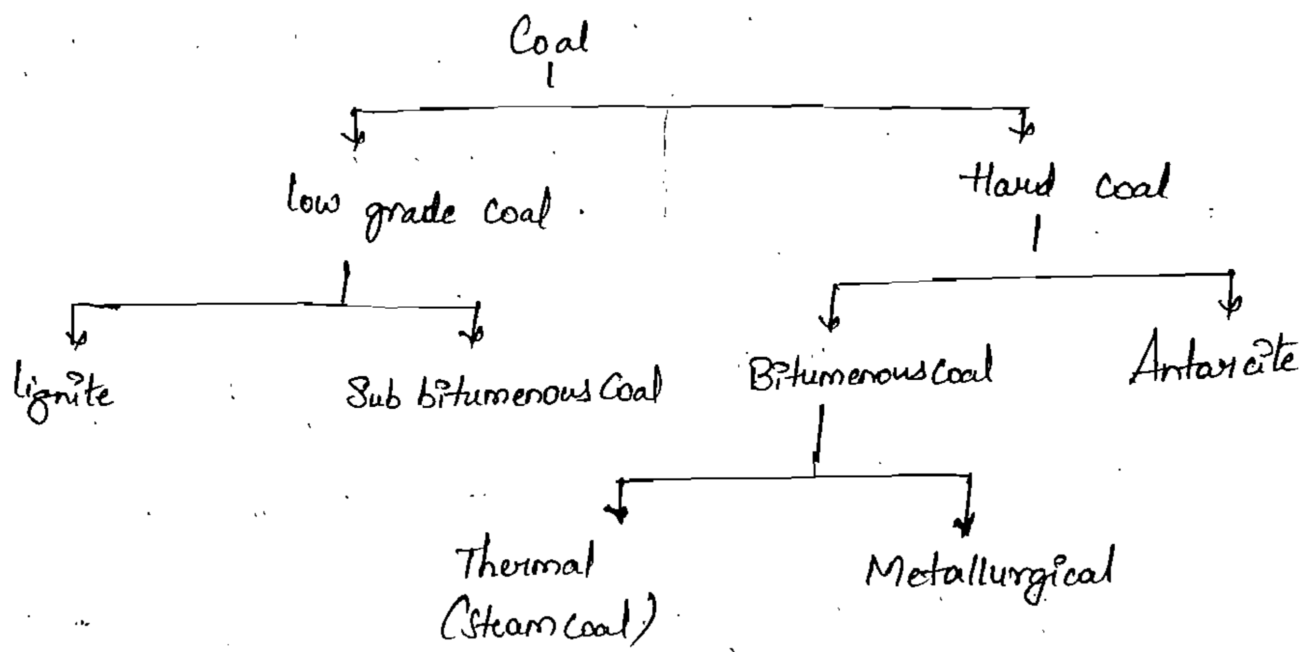
Around ~~10 to~~ 15% to 20% of the fly ash is Only used for Construction or for and half of this used for in manufacture of Concrete. & rest is pumped in Slurry form into lagoons or is Conditioned by the addition of 10 to 15% water and disposed of as more or less engineered landfills.

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.



* 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 overburden pressure & combined with a high friction angle also low earth pressure.

* Compression Index of fly ash C_c range from 0.05 to 0.37 for Initial loading. In recompre[ssion] these Values are much lower 0.006 to 0.04.

disadv: Fly ash acts as frost Susceptible material which is major draw back 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 estabilished 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 kpa

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.

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 whi may reflect through the asphalt Surface layer.

Ageing Criteria: unconfined Compressive Strength of the m is observed to increase with time.

Simillarly for lime - Stabilized fly ash base coarses, 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~~

* 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 - $Ca(OH)_2 + Mg(OH)_2$.

* 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

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

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

* Quick lime is handeld carefully it may cause corrosion 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).

Longterm 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 clays plasticity is reduced making it more easily workable and potentially increasing its Strength & Stiffness.

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.

Cementation on the Surface of clay lumps causes 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.