Study Of Stabilizing Agent For Different Soil Varieties

Swaptik Chowdhury, Mihir Mishra, Ankit Sethi, OM Suganya

Abstract - Soil species like loose sand, soft clays, black soil etc. lack adequate engineering properties to be appropriately as construction entities. Method of removing the soil and bringing in a new variety of soil is uneconomical. Thus stabilization offers economical and environment friendly remedy. The suitability and feasibility of soil for stabilization, the selection of most appropriate stabilizing agent and quantity of the agent are generally calculated by keeping in mind the chemical and mineralogical composition and texture of a soil along with physical properties and compositional indices of the soil. This research investigated some of the materials and their feasibility as stabilizers in different kind of soils. It reviewed the results of tests like CBR conducted by various researchers on soil engineering properties and strength test to determine the suitability of particular stabilizers in a specific soil condition. In the study it was also shown that although the soil engineering test and strength test like California Bearing Ratio and Atterberg limits do give a general idea about the kind of stabilizers to be used but grouping of soils according to area and field experience is also given importance.

Index Terms - California Bearing Ratio, Atterberg limits, stabilizing agent;

1 INTRODUCTION

Soil is defined as the accumulation of mineral particles and sediments produced by physical, chemical and biological degradation of parent rock due to factors like air, water, organic substance and other substance. Soil is specifically a non homogeneous, porous, earthen material whose characteristics are defined by moisture retention and density [1]. Soil is broadly defined as organic or inorganic based on the origin. Organic soil comprises of decay and accumulation of plant life and skeletons and remains of small organisms. Inorganic soil is formed by chemical or mechanical weathering of parent rock and remains on the same spot as of formation. Stabilization is employed to improve the physical characteristics when inferior soils, gravels, crushed, stones, ashes etc. are used for road and aerodrome construction or pavement or in foundations. They are also used as marginal soils like loose sands, soft clays and organics are not proper construction entity for highway construction or as base in pavements due to their inferior physical characteristics. Stabilization improves soil strength, stiffness property and overall engineering property by improving their plasticity index, their compaction properties and bearing capacity. Stabilization consists of mechanical stabilization which is achieved by blending with suitably graded material with desired gradation and physical characteristics. Chemical stabilization imparts rigidity and leads to reduced attraction of clay particles by formation of cementitous productions between chemicals, lime and cement and soil mineralogical components. In highway or pavement construction, the main aim of stabilization is to enhance durability of soil and to reduce in building cost by optimum use of locally available construction materials.

There are few guidelines which controls the suitability of soils for stabilization without resorting to testing and decisions to stabilize are usually concluded from the strength developed when trial soil stabilizing agent composition are compacted, cured and tested for unconfined compression or by the CBR method, tensile strength determination, tri-axial shear tests or durability tests as suggested by some researchers.

The objective of this paper is to study some stabilizing agents and their effects on different types of soil with respect to the physical and chemical characteristics of the soil and to evaluate the pedological and engineering classification. Thus the construction cost can be successfully optimized by selecting materials provided locally including local soil by stabilizing it in construction of entity like sub base for pavement and in low cost road construction and repairing or up gradation of road without incurring much wastage. This would be beneficial for developing countries like India for which the main challenge is to provide an adequate system of road from available resources.

2 LIME AND CEMENT

Eades and Grim (1960), Sloane (1964), Croft (1964), Hilt and Davidson (1961) studied the chemical and physical changes in the soil regarding stabilization of clay with hydrated lime. The main factors controlling the treatment process is the identification parameters for the mixture parameters like for soils (plasticity, potentially deleterious substance, natural water content, in-situ density), lime (type of lime to be added, content of free lime, grading, variation of water requirement for different type of lime, water reactivity in case of quick lime) and if needed hydraulic binder (proportions and nature of binder to affect setting kinetics of lime, performance and compatibility criteria with chemical characteristics of soil). And the mechanisms or effects were classified as:

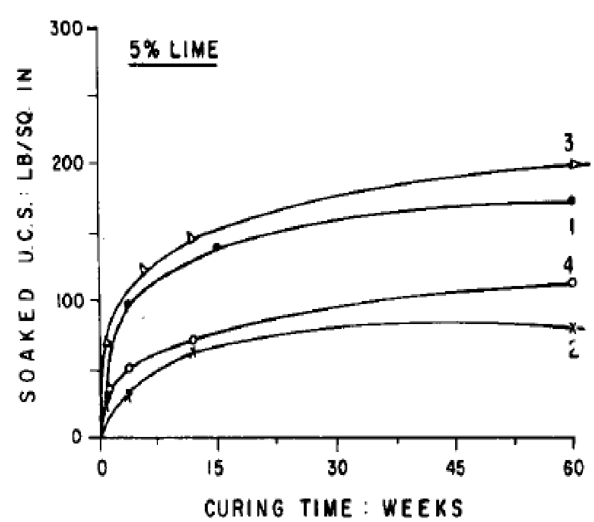
1.) Immediate effects: These are the effect observed just after the addition and mixing of lime. It may be variation of water content or geotechnical characteristics of the fine portion due to flocculation of clayey soil or changes in compaction characteristics of soil.

2.) Long term effects: These effects take place after a span of time has passed since its addition and are caused due to the pozzoloanic reaction of lime with mineralogical and chemical species of clay giving rise to products with same properties as given by hydraulic binder. In a strong basic environment with ph >12 lime gradually dissolves the silica, aluminium and iron oxides (SiO_2, Al_2O_3, Fe_2O_3) in the clay and react with water to giving rise to calcium silicate and aluminium hydrates(C-S-H and C-A-H respectively)[7].

But these products are invariably poorly ordered in structure and are formed in small amounts making it difficult for study.

Montmorrilonitic clays reacted rapidly to attack by lime and its early strength is high as compared to mixtures with illite and kaolinite but the additional strength attained after ageing was lower than as compared non expansive clay mineral. The strength developed was usually higher with mixed layered degraded clay minerals and halloysite.

Croft (1967) reviewed the behavior of cement as stabilizer in compacted soil-cement mixture. Mixed gelatinous phases were formed during hydration and it hardened due to desiccation. Then crystallized hydrated calcium silicates and aluminates were formed as product of reaction between lime produced after hydration and clay mineral. Montmorillonite and other expansive clay mineral registered lower strength which retarded the hardening by reacting with lime necessary for the production of gelatinous product. Ingles and La Faber (1966) and Croft (1967) studied the structural arrangements of product and soil particles responsible for rigidity of stabilized soil and stabilization test with non clay silicate mineral mineral described the products to be inert except gibbsite which is highly reactive to lime and retarted its hardening properties. Stabilizing reactions are also influenced by nature of cation occupying exchange position on clay mineral and rate of reactions. So, generally it can be concluded that rate of hardening is retarded in presence of expansive clay mineral and lime works best in such condition. Clay soils with illite and kaolinite as major clay minerals develop satisfactory results with cement as compared to lime. But above mentioned behavior is affected by organic matter, gibbisite, salts, nature of exchangeable cation and pH.



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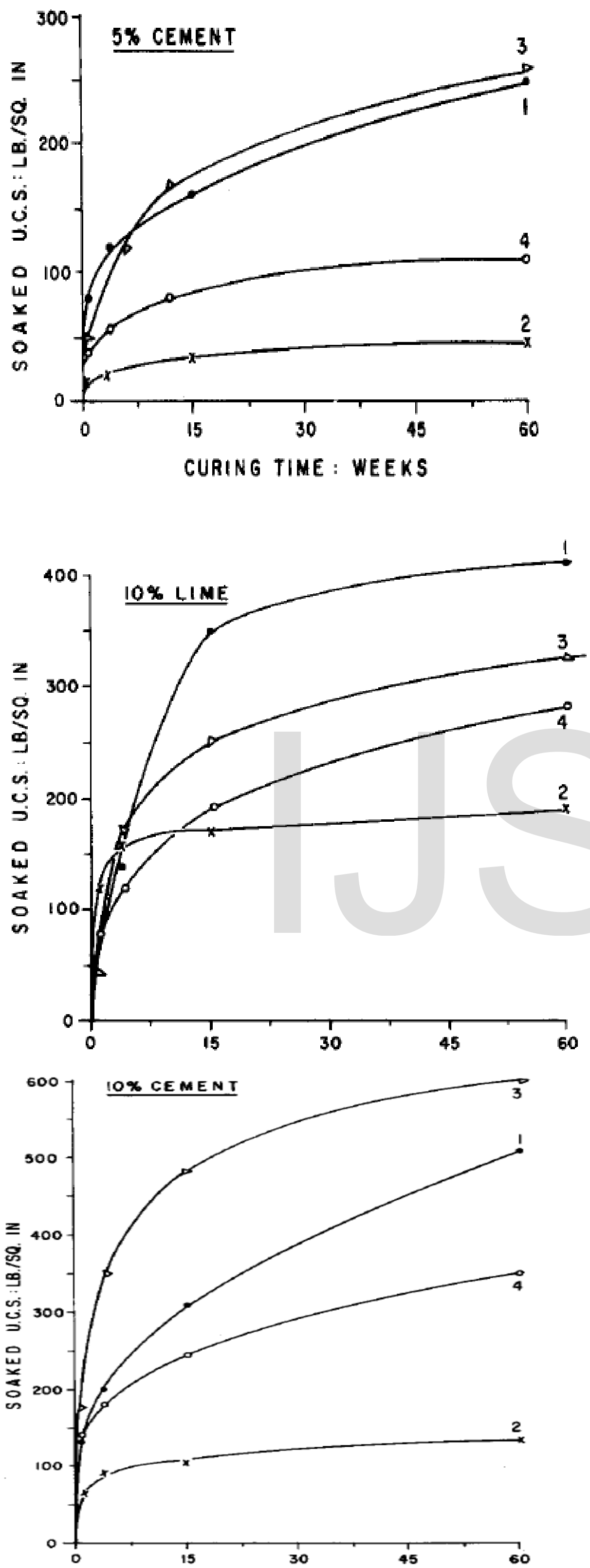

Fig. 1. Strength developed in lime-clay and cement-clay composition after curing (Croft 1964, 1967).1= poorly crystallized kaolinite; 2= Ca^{2+} montmorillonite; 3= well crystallized illite; 4= mixed illite montmorillonite

3 PODZOLIC TYPE SOIL

Fig.2 shows the general appearance and distribution of typical clay mineral in a typical podzolic profile developed on shale with illite and kaolinite. Illite partially loses potassium ion from the lattice which results in the formation of the “degraded illite”which turns into kaolinite after further weathering and in presence of ferrous ion stabilizes to vermiculite. The expansive clay mineral was concentrated in red” zone of accumulation” and in the “mottled zone”. So generally by Croft (1966) and Croft and Nettleson (1964) concluded that horizon or profile from which the soil was taken greatly influence the development of early and later strength with “organic surface”, “ zones of accumulation” and sometime “ mottled zones” being hard to stabilize with optimum additive content. He observed that cement is suited for soil with lower clay contents and lime is better for expansive clay minerals and an increase in amount of additive was registered with increasing clay content. Extremely acidic soil with pH< 5 was found unfit for economical stabilization when expansive clay mineral or organic matter with less than 1 % were present. With the exception of soils from horizon with higher organic matter contents,cement is highly suitable for podzols enriched on igneous rock with minimum concentration of organic matter contents, quartzose sandstone and some laterites with rough surface.

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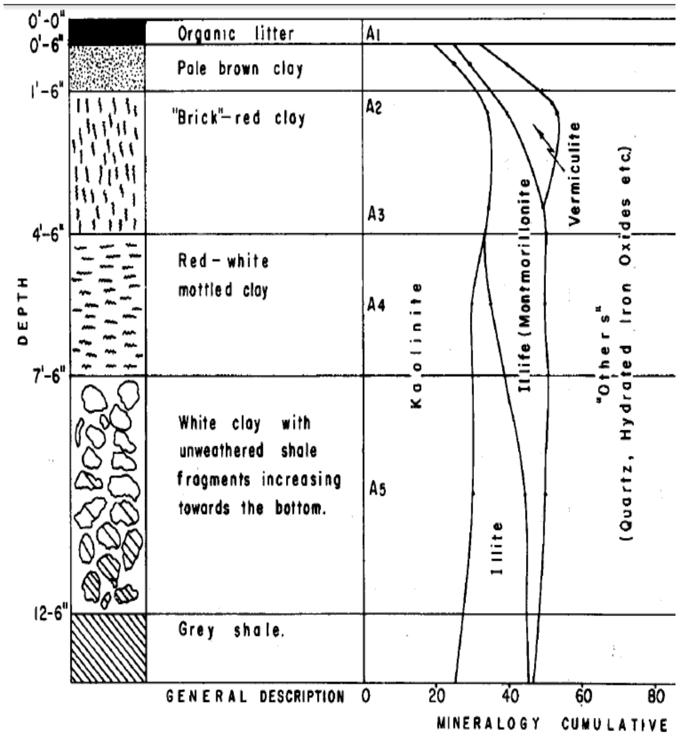
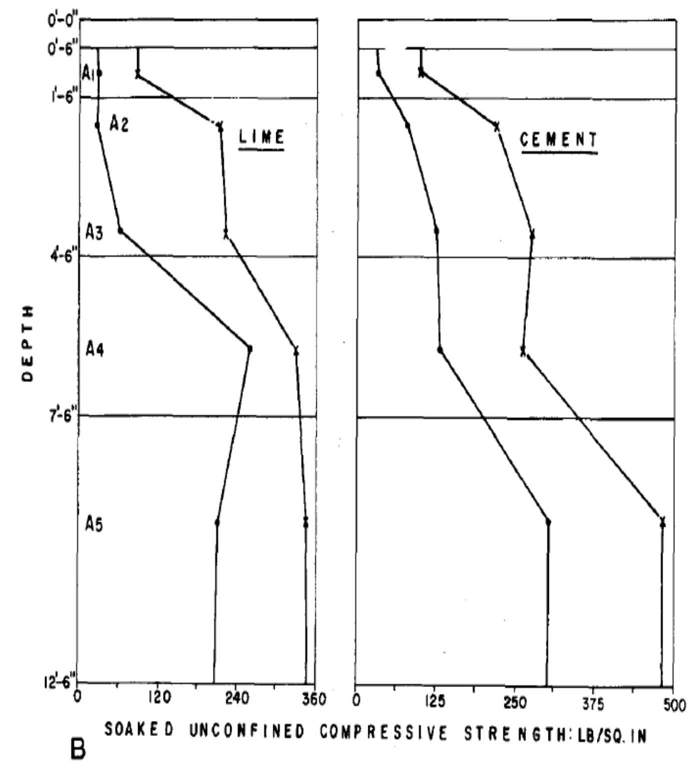


Fig. 2. Properties of podzolic profile



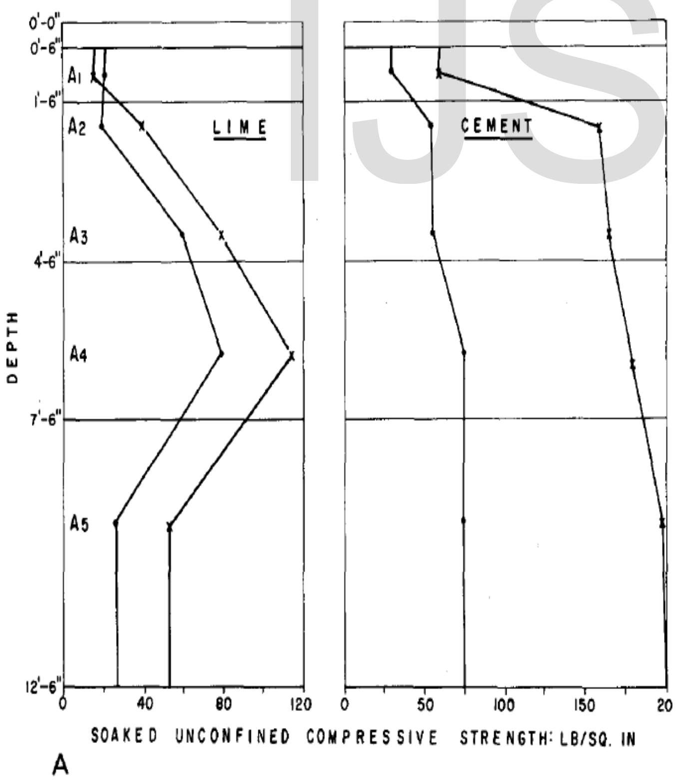


Fig. 4. Strength developed in soil from podzolic profile with ageing with lime and cement mixture for 1 week at A and 22 weeks at B (JB Croft, 1968).

4 RED BROWN EARTH

This kind of soil is chiefly formed in lower rainfall areas with less expansive clay and weathered material. In typical profiles, mica is stable at surface with carbonates accumulating in B horizon profiles [2]. Ignoring the organic surface accumulation which is preferably stripped, red brown earth respond to the optimum amount of lime and cement but cement is usually preferred.

5 BLACK SOIL

Black soil in consideration (in New South Wales) was divided in 3 main parts:

1) formed by weathering of basic igneous rocks and sometimes, limestone in a climate of less than 20inches/ year of rainfall

2) hydromorphic soil produced on parent rock mostly related to podzols, e.g., groundwater and meadow podzols 3.) riverine flood plain soil and clayey soils in arid and semi arid region.

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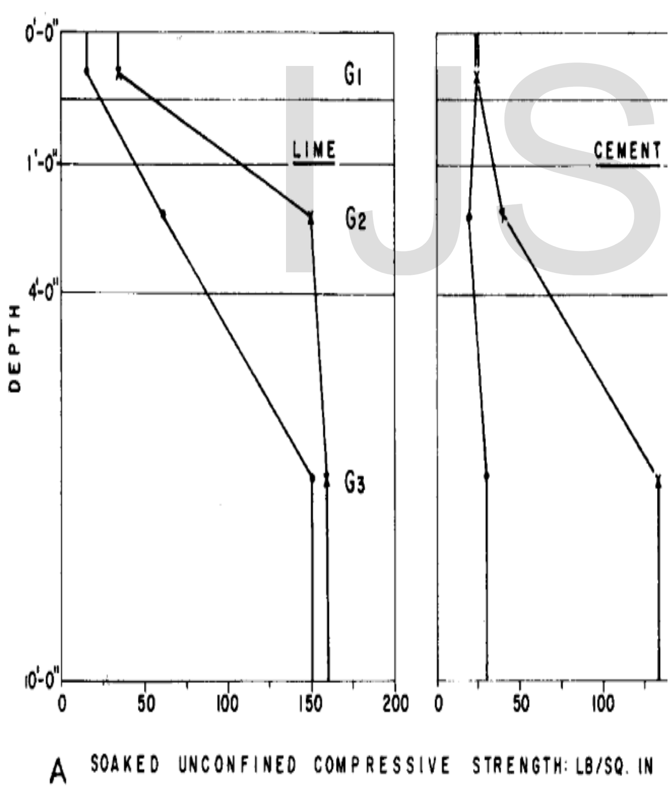
Soil in 1 and 3 generally are composed of montmorillonite as principal clay particle in both acidic and alkaline environment and 2 generally contains contain large amount of clay mineral and are acidic or alkaline depending upon drainage condition. In black soil, parent material breaks down to montmorillonite which stabilizes to produce kaolinite in some extent in upper strata but montmorillonite remains the chief clay mineral. So in general it was concluded that black soil needs uneconomical percentages of additive with high percentage of swelling varieties but lime proves to be more suitable than cement. Soil with organic matter greater than 1 % and strongly acidic soil are unfit for stabilization. Reports of Foss berg (1959) and Uppal and Bhatia (1958) on the stabilization of black soils also showed the difficulties to construct road on these materials and affirmed lime as most suitable for these kind of soil.



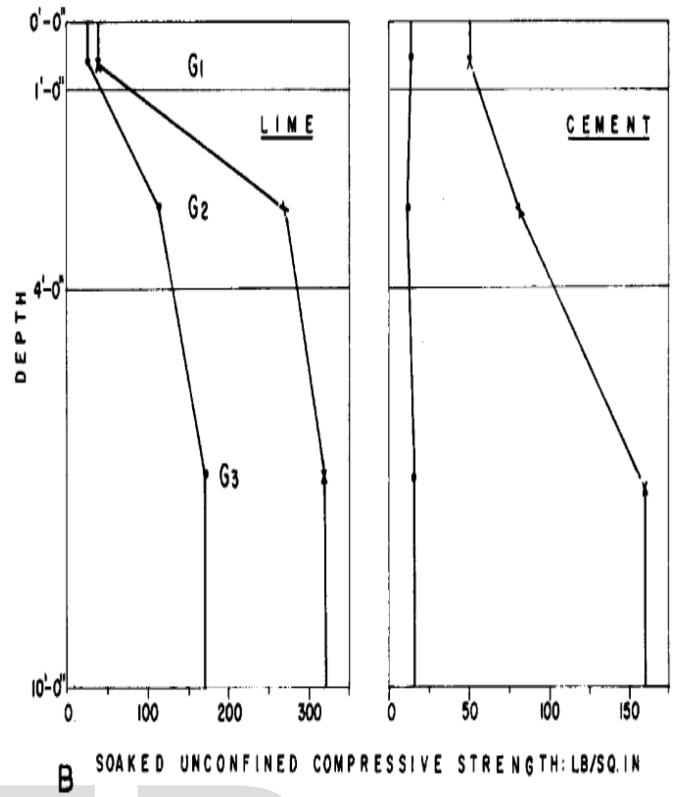


Fig. 5. Strength developed in soils from a black soil after ageing and compacting with lime and cement for 1 week A and 22 weeks B (Croft ,1968).

Relationship between Atterberg limits and indices and textural classification were also studied to observe whether common soil indices could be employed to predict the fit stabilization method. The textural classification is not enough for classifying soils according to their suitability of stabilization. Although, podzolic and black soil are usually categorized as clay and are often difficult to stabilize but can't be classified as unsuitable. Further sub division of clay field into total clay proportion is not accurate and clay fraction determination is more important. The value of textural analysis is mostly used to determine the amount of agent required not the suitability of agent in the stabilization. All other thing being constant, clay requires more agent than clay loams or sandy clays. But it is not practical to calculate amount of agent as development of strength depends on rate of reaction of lime and clay minerals or on hydration and hardening of cement and ultimately on crystallization of cementitous phases and cement. Croft (1968) obtained linear relationship when change in liquid limits after stabilization were plotted against liquid limit of the natural soil and also reported that the degree of correlation with lime was more prominent for cement. The liquid limit basically show the composition of a soil and nature and properties of clay minerals and changes in liquid limit of clay soil is is more prominent than light textured soils and lime was more efficient than cement. Unreacted stabilizing agent and changes in texture due to cementing of particles into aggregates were attributed as main reasons for increase in liquid limit after stabilization of coarse textured and illite or kaolinite containing soils. Clare and Cruchley(1956) also showed such changes. Plastic limit shows the magnitude of clay fraction and to some extent clay composition but effect of lime and cement in changing plastic limit are similar and changes occurred in the plastic limit occurred after short ageing. But large changes in plastic limit were observed in soils containing smaller clay fractions or non expansive clay minerals and it varied with the proportion and nature if expansive clay mineral. And again linear relationship between plasticity indices before and after stabilization suggested greater differences in the soil containing expansive clay minerals and again lime was proven more effective than cement. Changes observed in shrinkage limits showed that both stabilizing agent were affluent in reducing changes in volume due to drying. So as in whole, the reduction of clayey soil affinity to water was credited to the destruction of clay structure due to reaction with stabilizing agent. Soil tilth was improved due to cementing of fine minerals into aggregates which remained as it is after compacted soil was pulverized and acted as non cohesive silt like material. Also modification of the surface and support to the particles was observed due to formation of cementitious reaction products. Although soils with large liquid limits and plasticity indices contain expansive clay mineral montmorillonite and react with lime but for gaining prescribed standard rigidity cement is mixed often mixed. But with sandy and silty clays with well crystallized illites and kaolinites with lower atterberg limits could be attained with cement. However Atterberg limits doesn't work well in the presence of deleterious non clay components.

Higher strength with usage of lime developed in neutral alkaline soils containing very less amount of montmorillonite. When organic matter and expansive clay minerals were absent, pH had little effect on strength developed by cement

The poor correlation between silica- sesquioxide ratios and strength after curing with lime confirmed that strength developed increases with increase in amount of non expansive clay mineral in the clay fraction but with cement such correlation were not significant for study. So, sesquioxide ratio doesn't represent soil correctly with respect to selecting a proper stabilizing agent.

The cation exchange capacity of a soil reflects the nature and proportion of clay mineral rather than total clay content with degree of crystallinity and particle size of components being of lesser importance. Ingles and Frydman (1966) reported that cation exchange capacity may be important criteria for calculating strength at a given density but the degree of co relation was poor for dissimilar soils were included in the study.

6 CHEMICAL STABILIZATION

In general soil stabilization is regarded as any process such as chemical, thermal and mechanical by which undesirable and unwanted properties are mitigated or overcome [17]. There are various kinds of chemical stabilizers and can be chiefly classified into 3 main categories i.e, Ionic, enzyme and polymer stabilizers [18]. Generally before usage they are diluted and sprayed onto the soil before compacting it. They follow the mechanism of either encapsulating of clay mineral, exchanging of inter layer cations, break down of clay minerals by expulsing the water from double layer or internal expanding due to moisture entrapment [19, 20]. But they need careful usage and improper usage may cause millions of dollar worth of damage. S.Y. Zolfeghari Far et al (2013), studied the laterite soil (a class of pedogenics in which cementing materials are the sequioxides and constitute not less than 50 % of its constituents when analyzed[21]) and mixed shredded

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tire and crumbed waste plastic with dry clay and water was added to the dry mixture to keep the optimum moisture content. Sulphonate oils were employed as stabilizers. They are basically strongly acidic sulphur based organic mineral oil and are used as soil stabilizers as they can displace and replace exchange cations in clay and it can waterproof clay minerals by displacing the absorbed water and stopping further reabsorbing. The specimens created were tested for Unconfined Compressive Strength test in accordance to section (BS 1924-1990) and were tested under both soaked and unsoaked condition. It was observed that maximum increase in strength was observed for sulphonated oil in all three stabilizers investigated. But further increase in sulphonated oil decreased the strength marginally and attained maximum strength after 14 days of soaking independent of oil contents in the stabilization. At further curing no significant change in strength was observed. An increase of 2.19 times IN UCS was registerd as compared to the results of UCS of control mixture at 1.5 % of sulphonated oil. Sulphonated oil work better when applied for a soil containing a reactive clay mineral. The waste plastics crumbs and shredded tires showed material specific properties and gained highest strength within 56 days after construction.

7 FLY ASH

Power plants using low nitrogen oxide and sulphur dioxide burners produce fly ashes which usually contains unburned carbon. These fly ashes are non cementitous (class F or off specs fly ashes) and thus can't be reused in concrete production due its high adsorbivity with air entrainment admixtures and thus is land filled at large tract of areas [23]. But these fly ashes contain high amounts of SiO_2 and Al_2O_3 which can be activated using an activator rich in CaO like lime, cement etc which can form cementitious products and act like stabilizers. Arora and Aydilek (2005) investigated the properties of stabilized soil used as highway base with class F fly ash as stabilizer and observed that there was a significant increase in California Bearing Ratio (CBR), unconfined compressive strength and resillent modulus. Viswanathan et al (1997) also reported similar observations with sandy and silty soils which were stabilized with class f fly ash activated with lime. B Cetin et al. (2010) investigated the fly ash activated with lime kiln dust as stabilizer of soil and used an unpaved road surface material and two conventional base materials. Unpaved material and two conventional bases were mixes with fly ash activated with lime bed were tested for California Bearing Ratio, Resilient modulus and unconfined compressive strength. It was observed that Addition of lime kiln dust increased the CBR and resilient modulus drastically but increasing fly ash brought a gradual decrease in the strength due to its non cementitous nature.

8 WASTE PUMICE

Pumice is formed during explosive volcanic eruption which consist of silica and alumina depending on geological variation and chemical factors. Crushed and screened pumice is used in construction industry as light weight aggregate, wall plasters and internal and external masonry. M Saltan et al (2008) studied pumice as mechanical stabilization material to be used as subbase layer of flexible pavement. For much of the designs the main function of subbase is to reduce building cost while constructing flexible pavement and also to provide a transition layer between base which is coarse grained and that of sub grade. It also helps to control detrimental deformation such as volume changes associated with water infiltration. In the study pumice powder was used in HMA as a filler material which increases the bitumen content in the pavement but also increase the stability. In the study it was observed that when pumice was mixed with capali (granular material available in turkey) material in consideration for subbase, liquid limit and plastic index parameters were decreased. Furthermore the CBR value increased by 93 % after stabilizing process. So stabilization with pumice can deliver economic and environment friendly benefits locally depending on the availability of material. It is one of the prime example of mechanical stabilization.

9 HIGH DENSITY POLYETHENE AND GLASS

Fauzi et al (2013) investigated the utilization of high density polyethene and glass as material stabilizer in clayey soil of Kuantan valley. The soil, material stabilizer and stabilized soil were tested for engineering properties and strength such as sieve analysis, atterberg limit, linear shrinkage limit, specific gravity and California bearing ratio. It was observed that engineering properties were improved by adding HDPE and glass as stabilizer [27]. Also CBR and optimum water content when HDPE and glass content was increased to a optimum level. The increase in CBR value was dependent on amount of stabilizers and water content in the mixture. There was also decrease in plasticity with increase in stabilizer content in mixture. Thus stabilization by HDPA and glass solves their disposal problems and promote practice of sustainable construction practices.

10 CONCLUSION

The process of grouping soils based on their suitability for stabilization depends upon many factors that define successful stabilization. According to specification stabilized soil often requires a standard strength which is 250 lb/sq.inch for test mixtures mixed, compacted and cured in laboratory. But there is little relationship between strength and durability performance of stabilized soil or pavement. S this practice is often disregarded and reduction of soil response to water is taken as more feasible and realistic criteria for choosing a proper stabilizing agent. Some time higher strength is not feasible as in case of pavement when it is adequately sealed and compacted. Thus basically quantity of stabilizing agent is required to change the properties of soil to desired effects rather than high strength which is unimportant. So quantity and type of stabilizers can be estimated by field experience. Studies of changes in atterberg limits and indices before and after stabilization can help to successfully predict the suitability of stabilizers. The clay mineralogical distribution which determine the reaction between additive and soil mineral content can also prove to be a useful criteria in limited cases such as in cases of expansive clays like montmorillonite. When strength criteria was stressed upon, poor relation between chemical properties, mineralogical composition indices and strength of stabilized mixture showed that these are unsuitable for choosing suitable stabilization process but further work showed that such soil can be easily categorized into suitable stabilizing agent by cation exchange capacity. Compositional and textural variation among soil profiles also influence the selection and quantity of stabilizing agent. Also, the availability of resources and economic restriction also control the selection of suitable stabilizing process. Errors in estimation of the quantities of stabilizing agent are generally ignored like in case of medium coarse textured soils and allowances are made for construction losses and other such factors. The object of the paper has been to draw attention to some commonly used stabilizing agents and factors affecting their selection but again such procedures are not always successful in predicting quantity and type of stabilizing agent and much depend upon personal judgement.

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