The Effectiveness of Lime and Coconut Shell Powder for Expansive Soil Subgrade Stabilization

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Abstract: Expansive soils have a high tendency of swelling and shrinking behavior depending on the seasonal variations; its volume increases during a rainy season and decreases during a dry season. Due to swelling and shrinking characteristics, it brings a major problem on geotechnical engineering structures and devastation to life. A road which is being constructed on expansive soils has no strength to carry a load and cannot resist any stresses. As it was reviewed from different literatures, the combination of lime and CSP stabilizes a problematic soil. The laboratory characteristics of subgrade expansive soils was investigated before and after the addition of lime and coconut shell powder separately and both mixtures to soils at different percentage, thus the properties of these materials was discussed and analyzed for how much they are effective in soil stabilization.

Lime and coconut shell powder stabilization is the best option to control the volume changes of fine grained and expansive soils by adding appropriate percentage. Under this research the effectiveness (performance) of Lime and coconut shell powder was analyzed to determine the shear strength and swelling characteristics of expansive soils. The soil classification, Index Property, standard proctor compaction behavior, California Bearing Ratio (CBR), Optimum Moisture Content (OMC), Unconfined Compression Strength (UCS) and Free Swell properties were determined. The lime and CSP stabilized soil increases the value of CBR and UCS; the amount of the material added to the soil has a great impact for the strength being developed. Addition of lime and CSP are the most stabilizers used to reduce the plasticity of the soil and improves the strength of the soil and it brings a permanent modification with an easy manner. The optimum compressive strength of lime and CSP treated soil increases up to 6% and 5% respectively and starts to decreases as the amount of the material increases. The 8% of lime and 7% of CSP mixing together also increases the values of UCS. The increment of UCS due to lime and CSP is due to the initial increment of the moisture content. As the content of lime and CSP increases, the amount of moisture content increases and the dry density of the treated materials decreases due to the low specific gravity of lime and CSP relative to soil.

Keywords: ***California bearing ratio, expansive soil, soil stabilization, Black cotton soil, coconut shell powder.***

Introduction

A subgrade material has a great role on the pavement quality and durability. The pavement which is being constructed on subgrade expansive soils brings a major problem due to low bearing capacity and high expansion and shrinking characteristics of the material. This volume changes leads the structure to settlement by shaking and the whole structures will be damaged. Geotechnical engineering structures like canal, highways, railways, dams, embankments, foundations, retaining structures, airfields and bridges are the major structures faces this problem when constructed on expansive soils. The variations of the season are the first and main problem which plays a great role for volume change of expansive soil. For many years the researchers and scholars were studying the problem of those soils and used to give a solution.

The problematic soils can be removed and replaced by quality materials and also treated by mechanical and chemical stabilizations. Removing and replacing with a soil having a quality of borrow is not a good option for pavements due to high cost of excavation and hauling of the materials. Among the remedial measures the stabilizations with chemical admixtures is the common which has been used for many decades. As reported by many researchers that lime and fly ash were successfully used for stabilizing expansive soils. (Bell, F. G., 1993)

The main objective of this research is to analyze the effectiveness of lime and coconut shell powder stabilizers to improve the subgrade expansive soils. Lime and coconut shell stabilizers give the relative stable sub-base or pavements and provide a working platform for construction by strengthening subgrade materials. Lime and coconut shell powder stabilizers are used to treat a pavement which is being constructed on expansive soils and weak soil subgrade by filling a void space of particles.

Das (2010) suggests that the problem of failure of a soil along its failure surface is when shear stresses are higher than shear strength of a soil and when individual grain particles of a soil fails, failure of structure happens.

West (1995) defines expansive soils as it is a material which consists of clay which shrinks and swells in season variations due to montimorillonite.
According to Geotechnical Info (2012) a soil which has a high internal cohesive strength has a high clay contents and the intermolecular forces between each particles holds the soil masses together.
The alteration of physical and engineering property of the soil with additional material and making a working platform for construction is known as soil stabilization. The shear strength, the durability and the bearing capacity of the subgrade material increases as it is improved or stabilized by some other additional materials.

Objectives

The main objective of this thesis is to evaluate the performance (effectiveness) of lime and Coconut Shell Powder stabilizing of expansive soils for subgrade improvement.

- To investigate the effect of lime and CSP individually and in combination on the UCS and CBR of lime and Coconut Shell Powder (CSP) stabilized black cotton soil.
- To assess the engineering application of lime and coconut shell powder
- To determine the behavior of expansive soil with stabilizing materials.
- To determine the content of lime and CSP materials to improve the workability and effectiveness of soil stabilization.
- To compare the performance of lime and coconut shell in expansive soil stabilization.
- To know the strength of the stabilized expansive soil and the content of the materials used to touch the target required strength.

Soil stabilization

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Soil stabilization with stabilizing agent is a more economical than removing and replacing with extra soil materials due to some of the following reasons (Prof. Krishna Reddy, 2008).

- It increases the soil bearing capacity and shear strength.
- More economical to increase the bearing capacity of the soil without going for deep foundation and raft or mat foundation.
- It gives a more slope stability.
- Soil erosion will be controlled due to stabilization which is very sensitive in dry and arid weather.
- Stabilization also used to improves water proofing; it prevents the entrance of water to the soil through different means and which loosens its strength.
- The workability and the durability of the soil will be increased.

Materials and Methodology
Black Cotton Soil

Black cotton soil is a highly clay content soil which has the characteristics of swelling and shrinking depending on the variation of moisture content. In nature black cotton soil has a high content of clay soil which predominantly montimorillonite structure and a color of black or blackish. The swell-shrink behavior of this soil causes a significant stress on the soil followed by structural failure. During a rainy season, the water inters between soil particles and disintegrates the attraction bond and soil becomes like a fluid which flows easily. Due to this the ability of the soil to resist a load becomes looser. In reverse, during a dry season like summer the soil loose the moisture due to evaporation or percolation and becomes harder. Especially this type of swell-shrink occurs in semi arid and arid regions of the globe. Due to this volume change a great natural hazard can be occurred on living things and structures.

Due to its high swelling and shrinkage characteristics many highway and railway engineers faces a visible challenges. This type of soil changes its state of strength depending on the moisture content of the soil; its strength is very hard during a dry season and it loses its strength at a wet season. This soil develops a great crack which is a result for structures to be damaged, pavements failure due to vertical movement of the soil mass. Figure 1 shows the crack of black cotton soil during a dry season. The foe of the road which is constructed on a black cotton soil is the entrance of water which directly penetrates to the road pavement through three different directions; through top surface, through subgrade by capillary action and by the side of berms.

Figure 1expansive soil

Lime stabilization of soil

It is produced from the limestone which is found in nature. The physical and engineering characteristics of soil changes when stabilization happens and permanent strength and stability are the results. Lime has a performance to treat problematic soil either alone or in combination of any other binders. The mineralogical content of the soil determines the degree of stabilization and the amount of binders needed. Lime material is used to control the swelling and shrinking characteristics of expansive soil. The addition of lime material to a problematic soil can change the physical and engineering properties of the soil

Lime is produced from a parent material called limestone and has the following types (Lambe 1969).

i. High calcium quicklime……CaO
ii. Dolomitic quicklime…….CaO + MgO
iii. Hydrated high-calcium lime……$Ca(OH)_2$
iv. Normal hydrated dolomitic lime…$Ca(OH)_2$ + MgO
v. Pressure-hydrated dolomitic lime…$Ca(OH)_2$ + $Mg(OH)_2$

Using a lime as a soil improvement is used to treat the problematic soil by improving the characteristics of load bearing capacity of the soil, serviceability and workability. The permeability of the soil is decreased as the lime is added to the soil and stability increases. Lime has the ability to change the engineering properties of almost all fine-grained of soil which its plasticity ranges from moderate to high. The exchange of calcium cation which is caused by hydrated lime the modification of the soil occurs due to cation adsorption by clay mineral surface. Lime is a

material which is widely adopted in ground improvement by controlling the swelling and shrinking potential of the soil. The addition of lime to a black cotton soil reduces the plasticity index of the soil and increases the unconfined compressive strength of the soil.

Flocculation and Agglomeration

Flocculation and agglomeration of clay soil material is caused due to the addition of lime to fine grained clay soil which the results are change in texture of the soil particles clumping together into a larger sized aggregates. Flocculation and agglomeration are the chemical reactions which are affected by the formation of electrolyte content of the pore water and ion exchange with clay which forms calcium compound (Herzog A. and Mitchell, J. K, 1963). Changes in plasticity index, shrinkage and changes in characteristics of lime-soil mixture are due to the influence of flocculation and agglomeration of the particles and the exchange of cation ion between the clay particles and lime chemical particles (Marshall R. Thompson, 2007).

Coconut Shell Particle

Coconut shell is an agricultural waste product which has a risk to environment and health if not collected and re-used. This agricultural waste product has a double benefit: reducing the generation of solid wastes and using as soil stabilization by increasing the strength of the soil, with a low cost, locally available and easy to perform at site. Coconut shell particles are used as a reinforcement to stabilize a problematic soil.

Methodology

There are three main phases for this research accomplishment: pre-field works, field works and post-field works. Pre-field works contains literature review and visual identification of soil at site. Under field work stage, soil was sampled (disturbed) from site. During post-field work stage, laboratory test for collected samples were conducted. The results from laboratory test and visual identification of the soil data interpretation and final thesis preparation has been completed.

There are 3 processes of material mixing with virgin soil. First physical and engineering properties of virgin soil was determined, the combination of materials of lime with 2%, 4%, 6%, and 8% and CSP of contents 1%, 3%, 5% and 7% was added and the altered material was conducted.

Second, the combination of lime and CSP with 2% + 1%, 4% + 3%, 6% + 5% and 8% + 7% (lime + CSP) was mixed with soil and the properties were determined.

Thirdly, the maximum UCS value of CSP was selected and mixing it with each percentage of lime was combined with soil and the demonstrations are done.

Purpose of Laboratory Tests

Testing soil samples and determining its physical and engineering properties plays a crucial role in soil mechanics research and civil engineering application and related projects. Laboratory tests of soil have many advantages for civil engineering purposes and stated as follows.

- It is used for classification and description of a soil.
- To investigate and describe the mechanical and engineering behavior of soil and developing theories.
- To acquire the strength, stiffness and permeability of the soil for geotechnical engineering application and keeping it for design parameters.
- It determines the suitability of the soil for construction purposes.
- It is used to know and determine the type and depth of foundation subjected to expansive soil and high quality soils.
- To predict the probable foundation problem and the surrounding pressures of the soil itself.

Atterberg limits of soil after stabilization

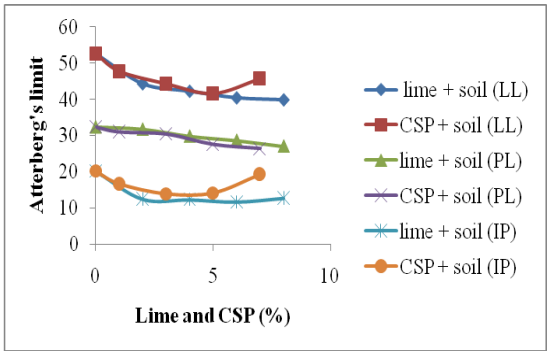

Figure 2 Atterberg limiits before and after stabilization

Increasing the amount of lime and CSP to the soil decreases the value of liquid limit, plastic limit and plasticity index of the mixed materials. The continual addition of CSP up to 5% decreases the value of plasticity index, after that it starts to increases.

Free swelling

The addition of coconut shell powder and lime to an expansive soil decreases the tendency of swelling of the soil. Lime and CSP material has the ability to decrease the swelling and shrinking characteristics of the soil, and can be used as soil stabilization. The reason for free swell

reduced is because of the lime occupies the voids between particles, and the lime and CSP fills the voids and water is absorbed by those materials, due to this swelling potential of soil decreases.

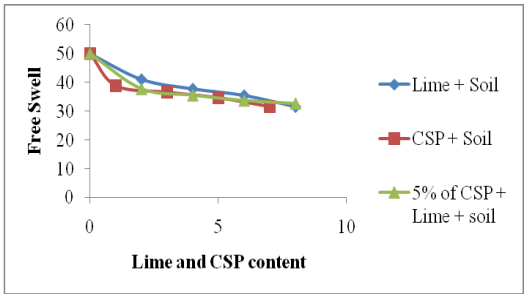

Figure 3 Free swell of materials

Standard proctor compaction test

According to (Davidson, D.T et al, 1960), the reduction of MDD in lime stabilization is due to the agglomeration and flocculation of the particles which occupy a large space

Decreasing in dry density and increasing in OMC of soil with lime and CSP is may be attributing due to the low specific gravity and high water absorption capacity of lime and CSP; it may be also the low density of lime and CSP relative to clay soil. Again reduction in dry density of lime and CSP stabilized soil is due to the formation of agglomeration and flocculation particles of soil occupy larger spaces and the reason for increasing OMC is that, the lime requires more water for the pozzolanic reactions.

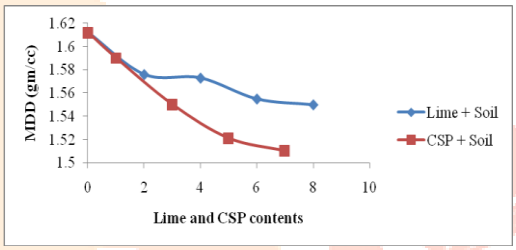

Figure 4 Maximum dry densities of the mixed materials

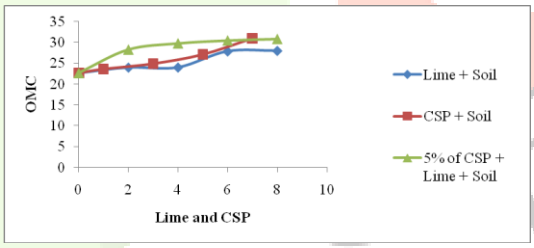

Figure 5 Optimum moisture contents of the materials

Unconfined Compression Strength

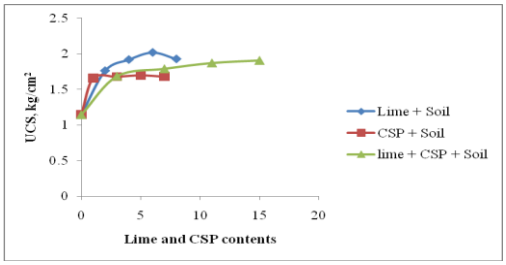

Figure 6 Unconfined compressive strength of the material

Increasing the values of lime and CSP brings increment in soil strength, and the bearing capacity of the soil becomes stronger than the unstablized material. Continuous adding of lime and CSP mixture decreases the value of unconfined compressive strength. This is due to shifting of the soil from CH to CI grade.

California Bearing Ratio

Addition of lime and CSP to expansive soil increases the value of CBR respect to virgin soil. CBR value for CSP increases up to 5% and starts to decrease with more addition. The mixture of lime with 8% and 5% of CSP increases the strength of the soil from 1.49% (virgin soil) to 3.468% and 3.13% respectively

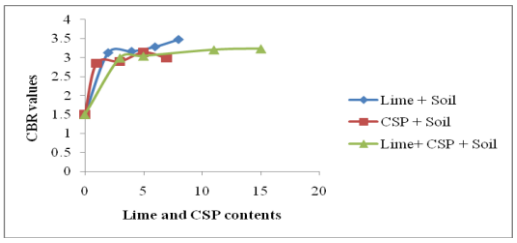

Figure 7 CBR values of soil mixed with lime and CSP

Conclusions

- Soil stabilization is the process of altering the physical and engineering properties of a problematic soil with some other materials to increase the shear strength, durability, long term performance and to make a good platform for construction.
- Addition of lime and coconut shell powder changes physical and engineering properties of soil.
- At high concentration lime is effective for reduction of swelling capacity of the soil and for increasing CBR results.
- The combination of lime and CSP in high concentration is effective than in low concentration.
- Addition of lime and CSP decreases the maximum dry density of the soil.
- The shear strength of the soil at 6% of lime and 5% of CSP is 1.03kg/cm^2 and 0.85kg/cm^2 respectively.
- Improvements of soil with lime and CSP separately, and in combinations improves the shear strength of soil almost by half.
- Maximum CBR values are obtained at 8% of lime, 5% of CSP and 8% lime + 7% CSP which the results are 3.468%, 3.13% and 3.23% respectively.
- From this result it can be concluded that the addition of lime and coconut shell powder to an expansive soil increases the strength of the soil.
- Lime has been used as soil stabilization for many years and it is effective in problematic soil stabilization with small quantity
- Coconut shell powder is effective in soil stabilization with small content and it can be applicable to use for field project where the material is easily found.
- The use of CSP for soil stabilization also used as environmental protection.
- It reduces generation of solid waste solids
- It increases the shear strength of the soil to be stabilized.
- Low cost, locally available, easy to apply at site

Recommendations

- Laboratory equipments are old; some of them are idle and needs maintenance or replace it with digital equipments.
- CSP is a newly technology of soil stabilizer and it needs more researches by different percentage and also its application at field should be well investigated.
- CBR with soaked of 4 days and UCS with curing period of 7 days, 14 days, 21 days and 28 days should be performed and the difference between Unsoaked and soaked, cured and uncured is discussed.

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