A study of using a variety of wasted materials as additives in soil stabilization

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Abstract— Soil stabilization means alteration of the soils properties to meet the specified engineering requirements. Methods for the stabilization are compaction and use of admixtures. Lime, Cement was commonly used as stabilizer for altering the properties of soils. From the recent studies it is observed that, waste materials such as flyash, rice husk ash, Waste Stone Powder, pyroclastic rock dust and Waste tire cord are used for this intended purpose with or without lime or cement. Disposal of these waste materials is essential as these may cause hazardous effects on the environment. With the same intention literature study was undertaken on utilization of waste materials for the stabilization of soils and same is presented here.

Index Terms— stabilization of soil, Waste materials, environment, ground improvement..

1 INTRODUCTION

Soil stabilisation is a technique introduced many years ago with the main purpose to render the soils capable of meeting the requirements of the specific engineering projects. In this work review of the possibility of stabilising fine-grained plastic soils with waste materials and without cement is investigated. These stabilised materials may be used as improved subgrades or capping layers or sub-bases for road or airfield pavements.

On the other hand, Marginal soils, including loose sands, soft clays, and organics are not adequate materials for Highway construction projects. These marginal soils do not possess valuable physical properties for construction applications. The usually methods for remediation of this weak subgrade such as remove the soil and change to the new one is typically expensive. Waste materials such as fly ash, bottom ash offer a cheaper method for stabilizing marginal soils [(KoteswaraRao. D et al, 2011and 2012)]. As an added benefit, utilizing waste materials in soil stabilization applications keeps these materials from being dumped into landfills, thereby saving already depleting landfill space. Included in this report is an extensive investigation into the current state of research on waste and recycled materials in construction applications. Changes in the engineering properties of soils as a result of adding these waste materials were studied and recommendations on implementing these effects into construction applications are offered.

Mohammad Jafari et al in 2012 were investigated on Effect of waste tire cord reinforcement on unconfined compressive strength of lime stabilized clayey soil under freeze–thaw condition. In their paper, stabilization and fiber reinforcement are simultaneously examined as a soil modification method. A series of unconfined compression tests was carried out to investigate the effects of tire cord waste products on mechanical characteristics of a lime stabilized and unstabilized clayey soil subjected to freezing and thawing cycles. Several specimens were prepared at three percentages of lime (i.e. 0%, 4%, and 8%) and four percentages of discrete short nylon fiber (i.e. 0%, 0.5%, 1%, and 1.5%) by weight of dry soil.

Ezekwesili Ene et al in 2009, were investigated on Some basic geotechnical properties of expansive soil modified using pyroclastic dust. They report an investigation of the influence of pyroclastic rock dust on the geotechnical properties of expansive soil. The plasticity, linear shrinkage, compaction, California bearing ratio (CBR) and shear strength characteristics of the soil when mixed with varying proportions of pyroclastic rock dust were investigated. The results show significant reduction in plasticity and linear shrinkage of expansive soil with increasing amount of pyroclastic rock dust. The maximum dry density, optimum water content, shear strength and CBR all increased with increasing pyroclastic rock dust content.

S. Kolias et al in 2005, were discussed on Stabilization of clayey soils with high calcium fly ash and cement.in their research the effectiveness of using high calcium fly ash and cement in stabilizing fine-grained clayey soils (CL,CH) was investigated in the laboratory. Strength tests in uniaxial compression, in indirect (splitting) tension and flexure were carried out on samples to which various percentages of fly ash and cement had been added. Modulus of elasticity was determined at 90 days with different types of load application and 90-day soaked CBR values are also reported.

Also Muntohar in 2005 and 2009 studied the influence of molding water content and lime content and the Influence of Plastic Waste Fibers on the Strength of Lime-Rice Husk Ash Stabilized Clay Soil, Which concluded that the clay soil was stabilized with lime and rice husk ash mixtures. The effect of the fiber length and content on the compressive and split tensile strength was investigated. The laboratory investigation results show that inclusion of the plastic waste fiber increased significantly both the unconfined compressive strength and tensile-split strength of the stabilized clay soil. The fiber length plays a significant contribution in increasing the soil strength. Also the results showed that the water content determines the UCS characteristics of unstabilized and stabilized soils. The UCS of stabilized soils decreased with increasing molding water content, but it is still higher than of the un-stabilized soils.

Kalantari et al in 2012, were experiments on use of cement, polypropylene fibers and optimum moisture content values to strengthen peat. From their laboratory study it was observed that peat with cement and fibers can be used as the base course in the pavement construction. It appears that the fibers prevent the formation and the development of the cracks upon loading and thus increasing the strength of the samples.

Kalantari in 2013 , were investigated on civil engineering significant of peat. He points out that, This type of subsoil foundation has high compressibility and low shear strength when subjected to imposed loads from civil engineering projects. It is essential to distinguish this problematic soil from better quality soils. Visual inspections including colour (dark brown to black) and odour (organic odor) tests can help to recognize peat. Field strength evaluation tests such as FVST and PLT can give good estimates of peat shear strength. Also laboratory tests such as moisture content, organic content and UCS and CBR may be used to evaluate peat physical and mechanical properties as well.

Armin Roohbakhshan et al in 2013, were experiments on influence of lime and waste stone powder on the pH values and atterberg limits of clayey soil. Then in 2014 were investigated on the effect of lime and waste stone powder variation on the pH values, moisture content and dry density of clayey soil. They investigated on the percentage of lime and WSP used on the samples varied from 0 to 11%, which treatment of the samples with lime and WSP content show that the optimal moisture and maximum dry density values of the samples were changed. The results show increasing in the pH value of clayey soil with increasing amount of waste stone powder and lime. And the optimal moisture content increased with increasing lime and WSP content for all the samples. Also the maximum dry density decreased with increasing lime, whereas the maximum dry density increased with increasing WSP content.

Firoozi et al in 2014, were investigated on Influence of Fiber and Cement on Stabilisation of Silty Clay. They were stabilized The UKM soil with 10% of Portland cement and varying percentages (0, 0.5, 0.75 and 1) polypropylene fibers, and concluded that both compressive strength and tensile strength increased with the increase in polypropylene fibers.

Otoko and Blessing (2014) have also studied the engineering behavior of stabilized marine clay with cement and lime. The authors show that the strength characteristics of the marine clay was improved as unconfined compressive strength and maximum dry density increased with increase in cement and lime content with of coarse, a corresponding decrease in the optimum moisture content.

Industrial wastes are the waste arising from industrial activities and are hazardous in nature due to presence of toxic substances. Flyash (FA) is an industrial waste being generated from thermal power plants and it is available in fine dust form. FA contain trace amount of toxic metals such as Cr, Th, Pb, Hg, Cd, etc. which may have negative impact on the health of humans, animals and plants growth too.

Rice is the primary source of food for billion peoples across the world. At present around 600mt of paddy produced annually. India is second largest producer of rice next to china. Yearly production of rice is about 0.32 million tons resulting huge husk production. Rice husk is the shell produced during dehusking of paddy. Rice husk being agricultural waste dumped near the mills or burnt in open fields.

The other stabilizing material is Waste stone powder (WSP). Waste stone powder, derived from waste slab marble was used as sludge. Waste stone powder cause environmental pollution that by reusing and recycling these waste materials as an additive in the improvement of geotechnical properties of soils will greatly contribute to the economy and to the environment by minimizing polluting effects coming from stone quarries and stone plants.

Different ways are available for enhancing engineering performances of soils are soil stabilization, soil reinforcement, etc. Admixtures like lime, cement were used traditionally for stabilization purposes. Recent studies shows waste alone or in combination with lime or cement can be used for effective stabilization of weak soils to a great extent. With the same intention author have undertaken review of utilization of these waste materials as stabilizer and same is presented here. This may found to be an economical treatment method for soils as these materials are available locally and such solution will definitely found beneficial for the developing countries like India where economy is the prime concern for adopting any new method or technique. Additionally, safe disposal mechanism can be suggested for the waste being generated which will help in reducing the hazardous effect on the environment of the region.

2 Review of Soil Stabilization using waste tire cord

The fiber is derived from waste material of tire cord factory products. The main constitutive substance of this fiber is nylon 6–6. High resistance against heat, fatigue, impact, and sunlight, and high resilience are some of the valuable characteristics of this fiber, which is usually used in tire and seat belt of vehicles, fishnet, reinforced hoses, and so on. In tire cord company, quality control unit regularly tests samples of productions based on tensile strength, tensile strain at failure point, H-adhesion test, absorption percentage of resorcinol formaldehyde latex (RFL) which is used for adhesion between the interface of fiber and rubber, and hot air thermal shrinkage.

ISSN 2229-5518

The products which do not satisfy particular standards and also, some fibers which become torn in tire production process are discarded as waste products. Usually 10% of nominal production capacity of tire cord factories is waste material. Fig. 1 shows tire cord with 20 mm length.

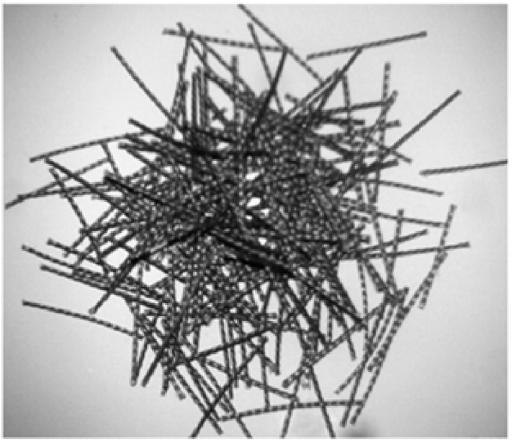

Fig..1. Tire cord with 20 mm length [12]

In order to compare stress–strain characteristics, axial stress–strain curves are plotted for five different specimens in Fig. 2. Comparing the curves of two unstabilized specimens (0 L–0 F and 0 L–1.5 F) indicates failure strain increases by inclusion of fiber slightly. The initial stiffness is not significantly affected by fiber contentwith the same lime content.

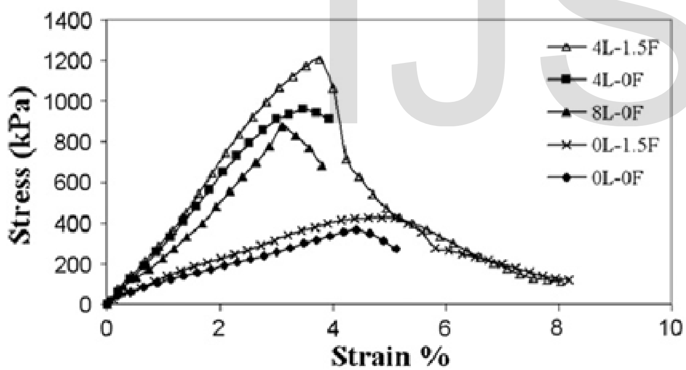

Fig. 2. Stress–strain curves of some specimens before freeze–thaw cycles [12]

On the contrary, the stiffness is affected by lime content considerably. Moreover, the lime reduces strain at failure, residual strength, and toughness of soil, which means that stabilizing by lime causes brittle behavior.

The stabilized specimens (4L–0F–28 and 8L– 0F–28) exhibit high stiffness, but they fail in low strain abruptly. After the failure, the stabilized soil loses strength with high rate, so absorbed energy before complete destruction is small. By inclusion of fiber to stabilized soil, these weaknesses in failure characteristics are improved to some extent. Without changing high stiffness of stabilized soil, fiber reinforcing promotes residual strength aswell as toughness significantly and also, increases the failure strain slightly.

3 Review of Soil Stabilization Using Fly ash

Flyash is the finely divided residue that results from the combustion of pulverized coal. Flyash is most commonly used as pozzolan in PCC applications. Pozzolans are siliceous or siliceous and aluminous materials, which in a finely divided form and in the presence of water, react with calcium hydroxide at ordinary temperature to produce cementitious compounds. Flyash is typically finer than Portland cement and lime. Flyash consists of silt-sized particles which are generally spherical, typically ranging in size between 10 & 100 µm. Fineness is one of the important properties contributing to pozzolanic reactivity of flyash. Flyash consists primarily of oxides of silicon, aluminum, iron and calcium. Magnesium, potassium, sodium, titanium and sometimes sulfur are also present to a lesser degree.

Flyash used as mineral admixture are classified as either class C or class F based on its chemical composition. American Society for Testing and Materials (ASTM) specification C618 suggested the chemical composition of class C and class F flyash. Class C ashes are generally obtained from sub-bituminous coals and consist primarily of calcium alumino-sulfate glass as well as quartz, tricalcium aluminates and free lime (CaO). Class C ashes contain more than 20%CaO. Class F ashes are typically derived from bituminous and anthracite coal and consist primarily of an alumino-silicate glass, with quartz, mullite and magnetite also present. Class F has less than 10% CaO.

Fig.. 3 show the development of the unconfined compressive strength in relation to curing time for Soil respectively. The soil properties and chemical analysis of flyash that use in Fig..3are given in table 1 and 2.

Table1-Atterberg limitsand soil classification of soil [14]

SOIL SAMPLES	ATTERBERG LIMITS			AASHTO CLASSIFICATION	UNIFIED SOIL CLASSIFICATION	
	PL	LL	PI		GROUP SYMBOL	GROUP NAME
Soil I	20	38	18	A-6	CL	Lean Clay

Table2-Chemical analysis of Kardia's fly ash [14]

Oxide	Percentage
	Fly ash I
SiO_2	19.9
Fe_2O_3	5.72
MgO	3.65
CaO	48.97
Na_2O	0.6
K_2O	0.45
Al_2O_3	9.26
SO_3	7.25
Loss of ignition	3.01
Free Cao	18.31

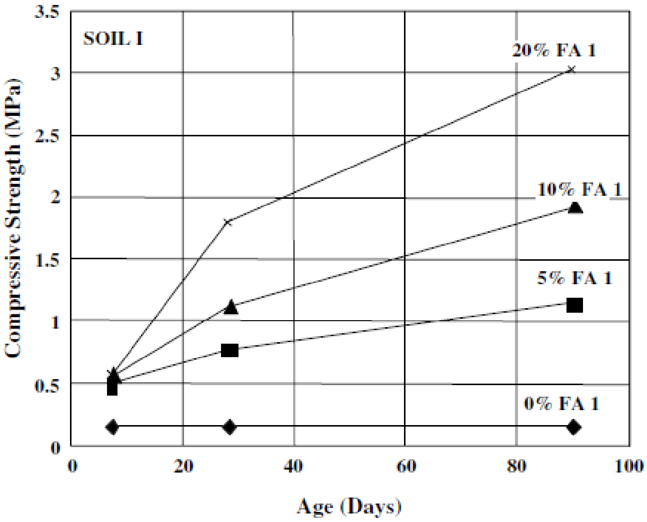

Fig. 3.Effect of fly ash addition on uniaxial compressive strength soil [14]

The use of high percentages of fly ash is, in certain cases, more effective than the combination of FA and cement but the problems associated with the use of large quantities of fly ash would need to be addressed.

4 Review of Soil Stabilization Using Waste Stone Powder

The other stabilizing material is Waste Stone Powder (WSP). The Waste stone powders are derived from waste slab marble as sludge. Waste stone powder cause great amount of environmental pollution that By reusing and recycling of these waste materials as an additive in the geotechnical properties of soils have great contribution to the economy and to the environment by minimizing polluting effects coming from stone quarries and stone plants. Recycled stone powder used in research was produced in slab stone processing and plant.

The unconfined compressive strength tests were conducted on clayey soil; clayey soil + lime mixes; clayey soil + lime + waste stone powder mixture. All the samples were prepared by static compaction plastic tube mold at their respective optimum moisture contents and maximum dry densities. The test was conducted under a constant strain rate of 1.5mm/min. For each test loading was continued until 3 (or) more readings are decreasing or constant. The properties and characteristics of lime treated clayey soils vary significantly, depending on the types of soil and amount and type of additives, and curing conditions including time and moisture. In the study, the samples of clayey soil and additive mixes were cured for 7 and 28days for un-soaked samples. All the tests were carried out in accordance to ASTM D2166 standard.

The results of the unconfined compressive strength tests performed in study for the natural and mixed states of the clay samples are given in figures 4,5.

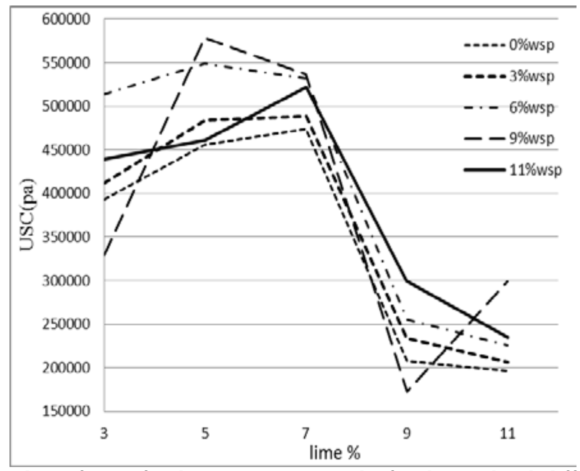

Fig. 4: Values of unconfined compressive strength of Soil treated with different amounts of lime and waste stone powder after 7 days curing and unsoaked [2]

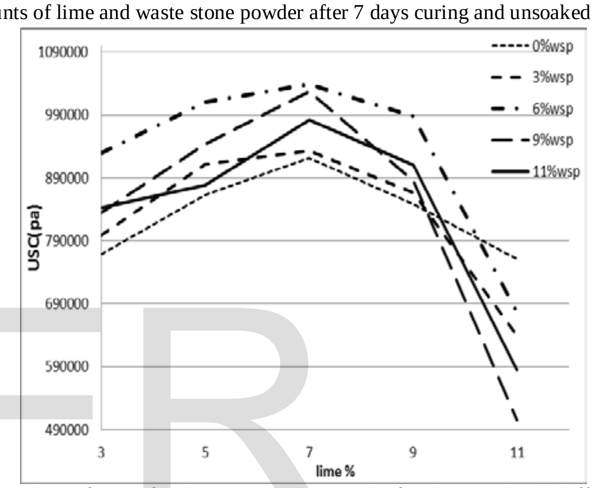

Fig. 5: Values of unconfined compressive strength of Soil, treated with different amounts of lime and waste stone powder after 28 days curing and unsoaked [2]

The figures show that at the different curing times, the addition of waste stone powder and lime caused an increase in the value of UCS up to 6% waste stone powder content and 7% lime content, thereafter, the value decreased.

5 Review of Marine Clay Stabilization Using Cement and Lime

Most of the Niger Delta, Nigeria consists of extremely soft marine clays (Peat) posing numerous problems for foundation engineers. Peat is a highly fibrous organic soil consisting mainly of vegetative matter in various states of decomposition (Wong et al 2006; 2008). Adesunloye (1987) perhaps was one of the earliest to report on the deltaic marine clays as part of his studies on the problem soils of Nigeria. According to him, the deltaic marine present as dark gray, dark brown to black material with characteristic foul odour.

In the unconfined test, no cell pressure was applied. The cylindrical samples were prepared at the optimum water content and dry unit weight obtained from the standard compaction test, and sheared to failure in the unconfined compression apparatus at an axial strain of 0.5 to 2% per minute; from where the maximum resistance to loading was determined.

ISSN 2229-5518

The stress-strain curves for lime treated marine clay and for cement treated marine clay are shown in fig 6.

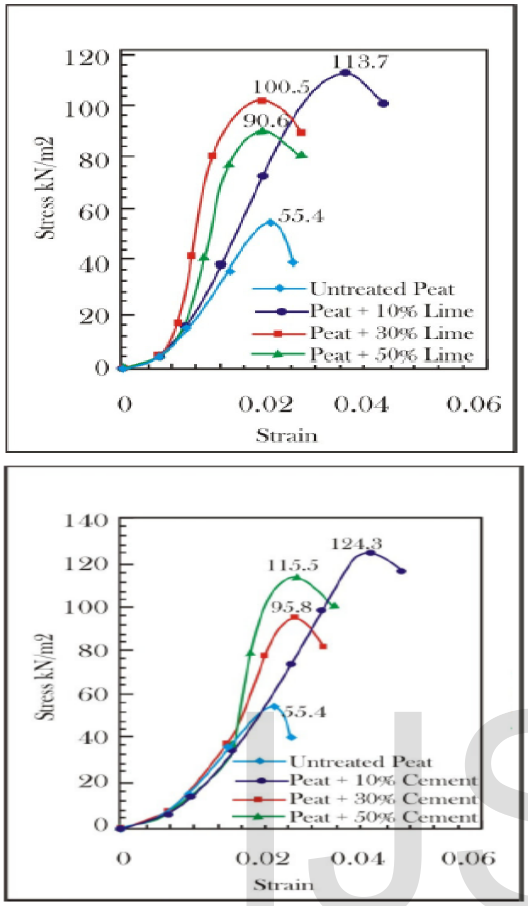

Figure 6: stress-strain curves for peat soil treated with lime and cement [8]

6 Review of Soil Stabilization using pyroclastic dust

The pyroclastic rock dust was sourced from quarry sites located at Ezza and Abakaliki area of southeastern Nigeria. The rock dust is an industrial by-product of quarries exploiting the light to dark grey lapilli, tufts and lapillistones of basaltic composition (Hoque, 1984). The rocks consist of a compact chaotic mixture of unsorted angular to sub-angular lithic fragments (shale, limestone, mudstone and siltstone) and amygdaloidal scoria and pumice set in a highly altered basaltic groundmass. (Obiora, 1994). The primary mineralogy comprises of pyroxene (augite?) that has been mostly replaced by chlorite and calcic plagioclase crystallized and altered to albite, carbonate and epiolite. Iron, apatite and titanium oxides are necessary accessory minerals. The rock matrix is made up of altered, petrified glass, plagioclase, chlorite and secondary carbonate.

The results of unconfined compressive strength (UCS) tests on the clay soil at varying percentages of pyroclastic rock dust are shown graphically in Fig. 7 from which it is evident that the strength of the clay soil increased with increase in pyroclastic rock dust content. Other workers using lime additive have shown similar result.

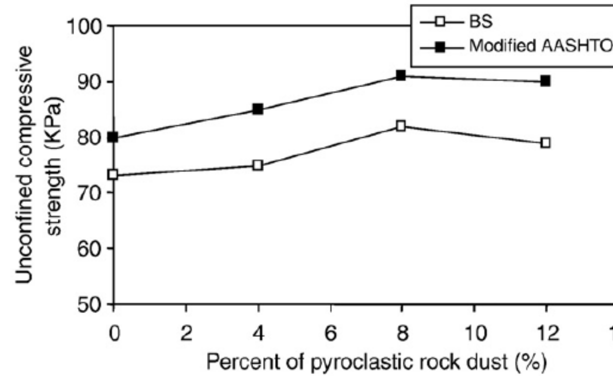

Fig. 7. Variation of shear strength (kPa) with varying percentages of pyroclastic rock dust [7]

7 Conclusion

The results of this study have shown that beneficial effects are obtained by the addition of cement/ lime and waste materials to soil. Therefore, On the basis of literature survey carried out following concluding remarks are made:

1. Fly ash can be used for variety of civil engineering applications like lower layers of road pavement, in the development of low permeability flowable fill, material, as a dike material, and as reclamation material.
2. Cement/ lime stabilized soil-waste mixtures can be used in a variety of civil engineering applications.
3. Although ordinary Portland cement seem to perform better than lime, both lime and cement significantly increase the unconfined compressive strength of the soil.
4. Rice husk ash an agricultural waste can be effectively used for stabilization of soils using cement or lime as additive.
5. The treatment of the samples with lime and WSP content changed the optimal moisture and maximum dry density values of the samples.
6. The optimal moisture content increased with increasing lime and WSP content for all the samples. Also the maximum dry density decreased with increasing lime and the maximum dry density increased with increasing WSP content.
7. The contribution of fiber in increasing strength is enhanced as the cycles of freeze–thaw increase.
8. The unconfined compressive strength of treated soil specimen with lime and waste stone powder was affected mostly by the amount of lime and waste stone powder mixed in soil mixtures. The unconfined compressive strength increased in association with increasing lime and waste stone powder content.
9. Pyroclastic rock dust can be said to be a good stabilizer of expansive clay soil. The trend of results obtained with it is similar to those obtained when lime is used as a soil stabilizer.

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