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Improvement of Geotechnical Properties of Lateritic Soil using Quarry Dust and Lime

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***Abstract**: Most of the rural roads are not covered by a wearing layer and sub-base is the topmost layer, hence it should be strong enough to take the load of the vehicles and not wear off due to bad weather conditions. Soil is the basic foundation of all civil engineering systems. Soil must withstand all loads without failure. In some areas, soil may be soft that cannot withstand all types of loads. Soil stabilization is required in such situations. There are different soil stabilization methods are available in the literatures. But the chemical composition of the soil is adversely affected by some approaches such as chemical stabilization. The quarry dust and lime were mixed with locally available lateritic soil to examine the improvement in the geotechnical properties in developing better subgrades for rural roads. This study presents the influence of lime, in the range of 0-5% with crusher dust blended lateritic soil. However, 4% lime addition can be observed as lime fixation point which can provide substantial increase in the workability of the soils and improved strength. Thus the properties of lateritic soil can be improved and hence locally available soil can be used as subgrade in rural road construction.*

***Keywords**: Soil stabilization, Lime, Subgrade, Lateritic soil, crusher dust.*

I. INTRODUCTION

The life and durability of the road depends on soil subgrade strength and traffic density. The soil in the subgrade is not consistent throughout the road alignment. By selecting industrial bi-products and locally available soils for the construction of subgrade and subbase course, the cost of road construction in such land can be significantly reduced. If the strength of locally available soil is not sufficient to withstand the wheel loads, soil stabilization methods are implemented to improve the soil properties [1]. The stabilizers like natural fibers can also be used with soil to minimize settlement and enhance the strength characteristics [2], [3]. The objective of mixing the admixtures with the soil is to improve strength, stiffness, give volume stability, modify permeability and minimize erodibility [4]. Soil stabilisation is the modification of any one or more of the soil characteristics so as to improve the needed performance by either proportioning or adding a chemical admixture or stabilizer. A variety of subgrade materials from expansive clay to granular materials can be treated with soil stabilization. This research discusses the enhancement of subgrade soil properties through the use of local materials. The additives like quarry dust and lime are used to test the improvement of subgrade soil properties. The subgrade strength of soil is important parameter for the design of pavements. Weaker subgrades require thicker layers, while stronger subgrades require thinner layers of pavement. California Bearing Ratio test (CBR) is usually used as a tool to measure strength of the subgrade soil. It is possible to improve the CBR value of subgrade soil and construction cost can be minimised to certain extent. This study comprises of the evaluation of lime as a binder to the crusher dust stabilized lateritic soil to be used as subgrade for road construction. The key importance of this study is to improve quality of stone dust stabilized soil by adding lime as a binding material in 1%, 2%, 3%, 4% and 5% proportions and to determine the optimum quantity of binder (lime) to get the desired strength.

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II. EXPERIMENTAL INVESTIGATION

A. Lateritic soil

Lateritic soil is a cheap, environmental friendly and abundantly available building material in the coastal region. Lateritic soil is formed due to tropical and subtropical weathering. Lateritic soil is rich in iron oxide and aluminum hydroxides and low in silica content [5]. The lateritic soil colour can vary from red, brown or black depending on the concentration of iron oxides. The reddish colour of lateritic soil is due to the existence of iron compounds in soil composition.

B. Admixtures

During crushing operations, stone dust is generated. It represents 20–25% of the output of each crusher system. In India, approximately 200 million tons of crusher by-products are produced annually [6]. Quarry dust is a very low cost replacement for sand which satisfies the need behind the alternative product. It even includes the risk of processing the crusher dust as it causes pollution of the atmosphere. The quarry dust imparts higher shear strength and it turns out to be a more advantageous geotechnical material [7].

C. Lime

Lime has been used for roads since ancient days as a soil stabilizer. Hydrated lime, also known as slacked lime, is the most widely used soil stabilizer. Lime is also used for soil stabilization along with other admixtures such as fly ash, cement, bitumen.

D. METHODOLOGY

The lateritic soil is blended with quarry dust in the proportion of 70% and 30% respectively as it was found optimum from the previous study [8]. The lateritic soil-stone dust, in the present investigation, is mixed with pulverized hydrated lime in various proportions, i.e. 0%, 1%, 2%, 3%, 4% and 5% by dry weight of oven dried soil mix. The samples are tested for Unconfined Compressive Strength (UCS) and California Bearing Ratio (CBR) of the soil with Maximum Dry Density (MDD) and Optimum Moisture Content (OMC). Proper care was taken to maintain the homogeneity of the mix. Various experiments have been carried out as per IS specification on soil - stone dust mix to study the correlation of the UCS, CBR, OMC and MDD.

III. RESULTS AND DISCUSSIONS

A. Geotechnical characteristics of lateritic soil

The geotechnical characteristics of lateritic soil are mentioned in Table 1. Gradation analysis of lateritic soil conducted as per IS: 2720 (part 4)-1985 is also specified in Fig. 1.

Table- I: Geotechnical characteristics of soil

Properties	Lateritic soil
Specific Gravity	2.9
Liquid Limit (%)	35.6
Plastic Limit (%)	23.2
Plasticity Index (%)	12.4
OMC (%)	11.4
MDD (kN/m^3)	21.4

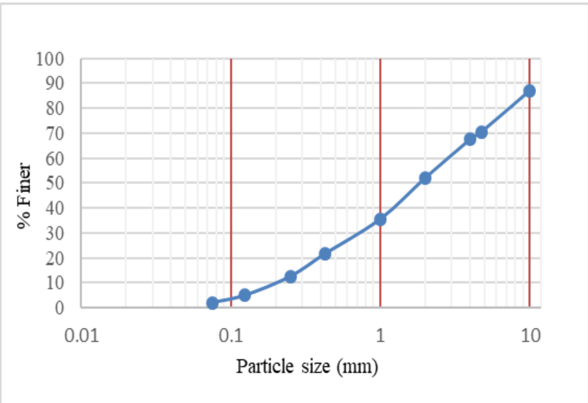

Fig. 1.Gradation of lateritic soil.

B. Geotechnical properties of quarry dust and mix

Grain size analysis of crusher dust and soil mixed with different proportions of lime conducted as per IS: 2720 (part 4)-1985 in this study is specified in Fig. 2 and Fig. 3. The value of specific gravity determined for the quarry dust is found to be 2.67.

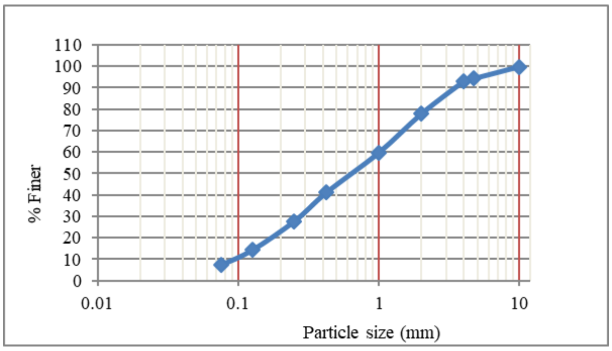

Fig. 2. Gradation of quarry dust.

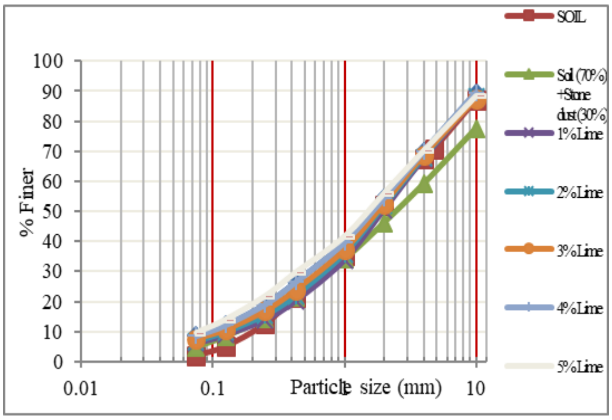

Fig. 3. Gradation of various mix.

C. Compaction test

The compaction test is carried out vide [IS: 2720 (Part 8) – 2002]. The dry density versus water content for different proportions are shown in Fig. 4. The values of MDD and OMC are noted and the MDD versus OMC for different proportions of lime are shown in Fig. 5 and Fig. 6.

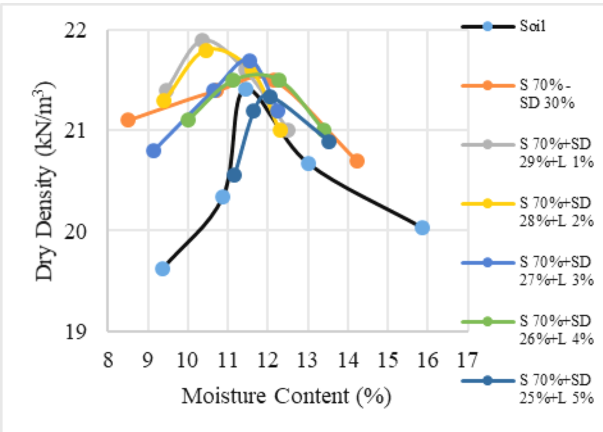

Fig. 4.Dry density verses moisture content.

The peak points of dry density and corresponding moisture content are noted from Fig. 4.

According to Fig. 5., the MDD of the various blended sample is declining with increase in the lime proportion.

The value of MDD of soil-quarry dust blend was 21.9 kN/m^3 and then shows the downward trend with increase in lime proportion reaching 21.34 kN/m^3.

The reduction in MDD can be due to soil replacement by lime in the mix having comparatively less specific gravity than that of soil. The higher values of pH condition in stabilized soil has modified the distribution of surface charges in clay soil particles, leading to increased repulsion between particle layers can be another cause of MDD reduction [9].

It is evident from Fig. 6, that the OMC increases from 10.36% at 1% lime addition to 12.05% at 5% lime addition. The lime being finer, the void ratio in the treated sample also increases which results in increase of optimum moisture content. The fines absorb more water as the surface area increases.

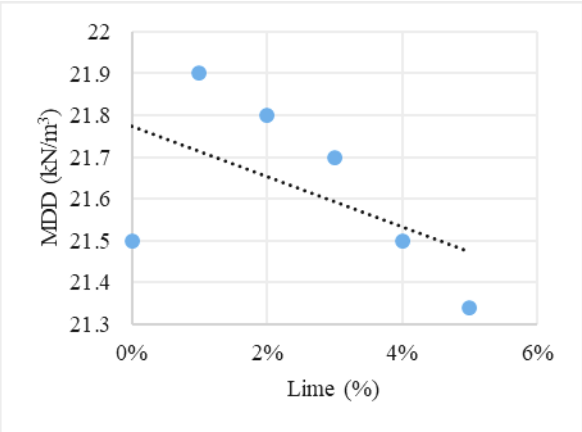

Fig. 5.MDD versus Lime.

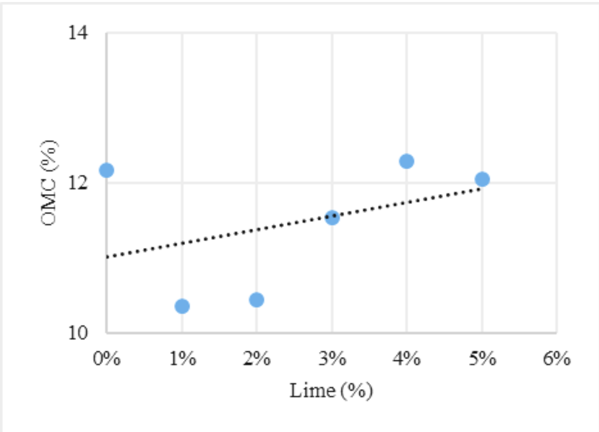

Fig. 6.OMC versus lime.

D. Consistency Limit Test

The oven dried lateritic soil-granite dust mix, blended with lime was tested for consistency limits. Soil samples weighing about 120 grams passing in 425 microns IS sieve was taken and carefully mixed with water to determine the consistency limits such as liquid limit (LL) and plastic limit (PL) as per IS [IS: 2720 (Part 5)-1985]. The changes in LL, PL and plasticity index (PI) with different proportion of lime are as shown in Fig. 7.

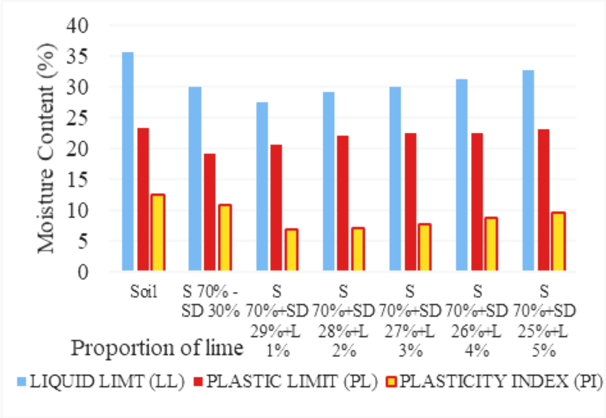

Fig. 7.Variation of consistency limits

It can be noted that the liquid limit of the soil initially decreased in combination with quarry dust and further decreased with addition of lime from 35.6% to 27.4%. Further addition of lime shows slight increase in the liquid limit. Generally, the liquid limit shows increasing trend with higher proportion of lime. Calcium Silicate Hydrate (CSH) composite is shaped in an alkaline environment with a pH value above 12, consisting of solid hydration products and water that is physically retained or adsorbed on the surface of the hydrates, increases the liquid limit of soil [10]. The plastic limit of soil stone dust blend increases from 19.03% to 23.05% with increase in the proportion of lime. The plasticity index of the soil initially decreases and then slightly shows the increasing trend. Overall the plasticity index of soil declined from 12.4% to 9.55% upon adding 5% of lime. This may be due to the exchange of cations amongst clay particles and lime causing contraction of diffuse double layer and also further by the pozzolanic reaction.

E. Unconfined Compressive Strength (UCS) test

The lateritic soil- stone dust mix blended with various percentage of lime were prepared using a standard mould with internal diameter of 38mm and 76 mm in height. The UCS of soil specimens were tested for 0%, 1%, 2%, 3%, 4% and 5% of addition of lime at 7 days curing period. The results are shown in Fig. 8.

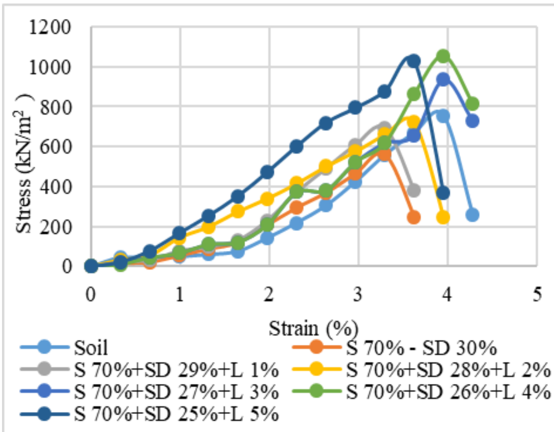

Fig. 8. Stress versus Strain

The Fig. 8. shows the relationship of axial stress and strain after 1 week of curing period.

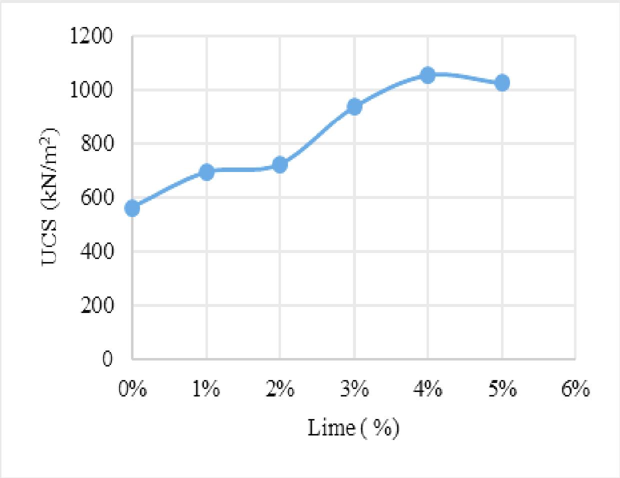

Fig. 9.UCS versus Lime

Thus the maximum value of stress is observed after one week of curing period for various treated samples. Fig. 9 shows the increment of UCS values against increasing proportion of lime for treated soils. The soil-quarry dust mix treated with 4% lime failed at higher value of UCS compared to other proportions of addition of lime. The values of UCS for blended soil increases from 563.69 kN/m^2 to 1,055.13 kN/m^2 for the soil blend mixed with 4% lime addition then slightly reduces to 1026.33 kN/m^2. The increase in strength may be due to a declination in the soil's plastic properties and, at a later stage, pozzolanic reactions of calcium ions with the alumina and silica of clay minerals. This leads to increasing value of pH of the molding water due to the calcium hydroxide dissociation. The calcium ions also bind with the soil's reactive silica or alumina to form insoluble silicates or calcium aluminates, or both harden to stabilize the soil while curing. This cycle has been going on for a few months. Thus strength of lime-stabilized soils increases [11].

F. California Bearing Ratio (CBR) test

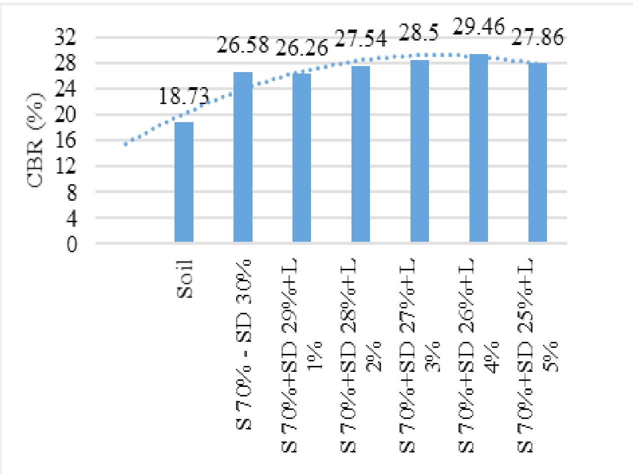

Fig. 10. Variation of soaked CBR with treated soil

The CBR test is performed after curing the treated samples for 7 days as per IS 2720 (part 16), 1987. The samples are saturated in water for 96 hours after curing period of 7 days. It can be observed from Fig. 10, the CBR values shows increasing trend for the treated soil. The value of CBR increases from 18.73 % to 26.58% with crusher dust blend. Further increment of lime proportion improves the CBR value of 26.26% to 29.46% with 4% of lime addition. The rise in soaked CBR is expected due to the incremental development of cementatious compounds such as calcium silicate hydrates (CSH), calcium aluminate hydrates (C A H) and calcium aluminum silicate hydrates (C A S H) associated with lime hydration and pozzolanic reactions. The increase in CBR value may be attributed to the increase in shear strength parameter (frction angle Φ) by blending the soil with crusher dust [7].

It can be observed that the blending of quarry dust enhances shear strength of the soil which might be due to improvement in gradation of the soil (S 70%+SD 30%). The addition of small percentage of lime also acts as a binder and reduces the plasticity of soil making it more friable and workable. The lime improves the strength by flocculation and agglomeration and further changing the gradtion of the soil will help in improvement of immediate strength. By introducing lime to a clay soil, it must first satisfy the soil's affinity for lime, that is, ions are attracted by clay minerals and are not completely used in pozzolanic reactions until such time as this affinity is satisfied. The lime content, which is fixed in the soil without available for other reactions, is called lime fixation. The lime fixation point is the point where, due to the addition of lime, there are no further modifications in the plastic limit. However, an optimum quantity of lime is needed for achieving maximum improvement on targeted properties of soil. The lime fixation point can be observed at soil-crusher dust blend mixed with 4% lime in UCS and CBR test as UCS values (Fig. 9) and CBR values (Fig. 10) shows decreaing trend after 4% addition of lime. The values of UCS and CBR are tabulated in Table II.

G. Suitability of soil as subgrade according to MORTH specification

The dry density of soil with the various proportions to be used in subgrade is more than the required dry density of soil as per MORTH specification of 17.5 kN/m^3. The LL and PI of the treated soil also meets requirement of MORTH specifications. MORTH recommends lime stabilization for soils having plasticity index more than 8. The CBR value of the optimum soil blend mixed with 4% lime also meets the requirement of MORTH specification and also having higher strength compared to other samples. The well graded sample of 4% lime addition (S70%+SD30%+L4%) giving higher value of CBR and UCS meeting requirements of MORTH can be considered as optimum mix. Thus the locally available lateritic soil can therefore be used in the construction of road subgrade.

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Table- II: Table showing UCS and CBR values of various samples

Samples	Soil	S 70% - SD 30%	S 70%+SD 29%+L 1%	S 70%+SD 28%+L 2%	S 70%+SD 27%+L 3%	S 70%+SD 26%+L 4%	S 70%+SD 25%+L 5%
UCS (kN/m^2)	753.6	563.69	693.78	723.83	936.693	1055.13	1026.33
CBR (%)	18.73	26.58	26.26	27.54	28.5	29.46	27.86

IV. CONCLUSION

A set of experiments performed to examine the effectiveness of quarry dust and lime for improving locally available lateritic soil. The following conclusions can be derived:

- The optimum mix proportion of soil giving higher strength of UCS of 1,055.13 kN/m^2 and CBR value of 29.46% is found to be soil blended with quarry dust at a proportion of 70% and 30% with a lime addition of 4%.
- The locally available lateritic soil can be improved and made suitable as subgrade for the construction of rural roads and highway construction as the geotechnical properties like particle gradation, liquid limit, plastic limit, plasticity index, density and strength were improved. CBR value of optimum mix is found to be two times higher than required value as per specifications of MORTH, Rural Roads Manual (IRC SP20).
- The environmental pollution due to disposal of quarry dust is controlled by utilizing it as an admixture in improving the geotechnical properties of lateritic soil.

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