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Potentials of Commonly Used Lime and Agricultural Waste in Stabilization of Sub-Grade Soil

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***Abstract**: Present study deals with the correlation between structural and mechanical characterization of sub-grade soils to increase the strength of soil for road. Clays are generally poor materials for foundations due to large lateral pressure and low resilient modulus. This investigation were carried out with waste products(Agricultural waste) like Rice Husk Ash (RHA) along with various percentages of locally available lime. X-ray fluorescence (XRF), California Bearing Ratio test (C.B.R), Standard Proctor Test, Unconfined Compression Test were done on these samples to characterize the structural and mechanical properties as significant increase in strength properties were observed in the soil samples upon mixing with RHA and lime. It was observed that soaking strength is around 16.8 for the Sample C-3 (Soil+9% RHA). Increase of strength may be due to the reduction of mica in the soil sample. Increase of the silica in the soil sample finally increase the strength and stability. The maximum soaking strength was observed 24.82 for the Sample C-7 (Soil + 9 % RHA + 8 % Lime). It is obvious because the wt.% mica phase become minimum for this composition. XRF results also reveals that silica and calcium contents are maximum for this composition. So microstructural results revealed that the mica phase may play very important role for maintaining the strength and stability of the soil.*

***Keywords** : X-ray fluorescence (XRF), Structural and Mechanical Characterization About four key words or phrases in alphabetical order, separated by commas.*

I. INTRODUCTION

Clays exhibit generally undesirable engineering properties. Generally, it has low shear strength and tends to lose shear strength upon further addition of water or any other physical disturbances. It can be plastic and compressible depending upon wetting and drying.

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Some types expand and shrink greatly upon wetting and drying – a very undesirable feature. Cohesive soils have a tendency to creep over time when it is under repeated load, especially when the shear stress is proceeding towards its shear strength, making the soil prone to sliding. These incidents can ultimately lead to lead to develop a large lateral pressures and low resilient modulus. Under this situation, clay is generally considered as inferior materials for foundations. It is being estimated that cost of damage to the structures and roads caused due to poor soil condition is around billions of dollars , according to the American Society of Civil Engineers in USA [1] and many more billions of dollars worldwide. Present study considers subgrade soil to increase strength of the soil for road construction. In this regard various percentages of agricultural waste materials like Rice Husk Ash individually mixed with soil and also in combination with different percentage of Hydrated Lime to study the improvement of weak sub-grade material. The chemical composition of the soil and other investigated samples were characterized by X-ray fluorescence (XRF). Mechanical strength of the subgrade soil and other batches were tested by standard compaction test. The physic- mechanical properties of the sub-grade soil and other samples were determined to study the structural evolution in the soil with addition of rice husk and lime.

II. RELATED WORK

This study presents the review of literature relevant to the present topic of research. Some papers have been studied here, which focuses on current issue, are described as follows: Subrahmanyam Et al. [2], studied the consequences of Lime-RHA mix through various experimental work on the properties of inorganic black clay and suggested that the Lime-RHA mix can be used significantly to increase the properties of inorganic black clay soil. This investigation concludes that: 1) the plasticity of inorganic black clay is improved significantly when mixed with various percentages of Lime and RHA admixtures. 2) the optimum moisture content (OMC) was increased and maximum dry density (MDD) was decreased. 3) The unconfined compressive strength was observed to be better. Chassan Chmeisse [3] focuses on the improvement of soil by using RHA and Granulated Blast furnace Slag (GBFS). Both the materials were found to have aluminous and siliceous and aluminous materials, which has the tendency to react with the cement or lime, and also having economic potential to replace some of the lime or cement presently used as an additive in the stabilization of soil.

In order to cultivate the effectiveness of GBFS and RHA as soil stabilizers, various soil parameters, including plasticity index and linear shrinkage, Untrained shear strength, CBR, unconfined compressive strength were measured followed by various microstructural analysis test. A repeated dynamic load test was also conducted in this investigation.

It is found that alone RHA cannot modify the soil up to a suitable level, however significant results can be obtained when it is applied in combination with cement or lime. It is shown that Lime-RHA and Cement-RHA additives increase the unconfined RHA along with cement or lime can significantly improve the compaction and shear characteristics of soil. Behavior of soil under the action of repeated dynamic loading were also found good along with the improved workability and volume stability of soil.

There has been a rapid increase in the construction sector especially in the roads in recent times. In view of that demand for proper sub-grade material is under rapid growth. But due to lack of lands in the nearby area for excavation of proper fill materials in order to prepare the sub-grade, T.K. Roy Et al. [4] shows use of various generated waste could be an alternative option for sub-grade, which not only can solve the depositional problem but also enhance the properties of sub-grade soil to a great extent. In this regard experiments were done to improve the properties of alluvial soil by adding RHA, pond ash along with cement. Results revealed that the index properties along with the soaked CBR value achieved a significant improvement.

III. METHODOLOGY AND EXPERIMENTS

The soil that has been used in these experiments is a standard Kolkata soil which contains Silt (68%), Clay (27%) and Sand (5%) and Specific Gravity of this soil is 2.65.

Elemental analysis of the sub-grade soil and other samples **(Table 1)** were estimated from X-ray fluorescence (XRF) spectrum analysis. XRF spectrums were recorded in AXIOS XRF (PANalytical) [5] for elemental analysis.

Compaction [6], Unconfined Compression [7, 8] and California Bearing Ratio (CBR) [8, 9] tests were performed on the sub-grade soil and other batch compositions to study the strength of the sub-grade soil.

Table 1: Mix Proportion Of Soil Samples

Name of Sample Combinations	Mix Proportion		
	Soil (%)	Lime (%)	RHA (%)
C-1	100	0	0
C-2	97	0	3
C-3	91	0	9
C-4	95	2	3
C-5	89	2	9
C-6	89	8	3
C-7	83	8	9

Compaction test has been performed on the samples by standard IS-2720 (Part VII) method to determine the relationship between moisture content and dry density of soil. Maximum dry density (MDD) **(Table 4)** and optimum moisture content (OMC) **(Table 4)** of the soil is determined by standard proctor compaction.

Unconfined compression test has been performed on the samples by the Standard IS-2720 (Part X) method for determining the unconfined compressive strength of clayey soil, remoulded or compacted, using controlled rate of strain. Stress-strain behavior and ultimate compressive strength (**Table 4)** are to be determined for the soil sample

The California Bearing Ratio (CBR) test is done at a certain moisture content (generally at OMC) and at a specific density. Also the absorption of moisture after a 4 day-soak is also measured. The expansion or swelling is measured during this soaking period using a strain gauge. The need of soil sub-grade stabilization and also the required overall pavement thickness above the soil subgrade can be determined from the CBR test data (**Table 4)**.

IV. RESULTS AND DISCUSSION

4.1 Structural

Structural characterization of sub-grade soil and batches (**Table 1)** were performed by XRF. Chemical compositions and elemental compositions of the investigated samples were estimated by XRF results (**Table 2)**.

From XRF results it is revealed that the origin soil contains silica. However it can be clearly seen that addition of RHA only increases the silica content in the soil. Addition of RHA increases the amount of silica in soil, thereby increase the strength and stability of soil sample. In addition to this the XRF result also reveals that the lime which we are using is available in the local market, is not pure calcite. Actually, this lime contains high percentage of silica which is ultimately adding more silica into the soil making it more stable. Moreover the Calcium content gets increased by the addition of Lime which also plays an important role in making the soil more stable.

If we compare the compaction and other soil properties with these results, it can be clearly seen that related compaction and other properties are becoming better while we add Lime and RHA in soil.

From Table 4, it was also observed that soaking strength is around 24.82 for the soil+9 % RHA+8 % lime. From XRF results (Table 2) it was also observed that silica and calcium contents are maximum for this composition.

Table 2: Semi-Quantitative elemental Analysis of the investigated samples from XRF spectrums

Name of Compound	Sample Name							
	Soil 100%	Lime	Soil + 3% RHA	Soil + 9% RHA	Soil + 3% RHA+ 2% Lime	Soil + 3% RHA+ 8% Lime	Soil + 9% RHA+ 2% Lime	Soil + 9% RHA+ 8% Lime
SiO_2	59.113	38.271	59.187	59.528	59.193	58.549	58.819	59.261
Al_2O_3	21.358	-	20.596	18.496	20.519	19.534	19.515	19.230
Fe_2O_3	9.136	0.189	9.450	10.276	9.181	8.710	9.020	8.236
CaO	1.601	57.857	1.794	2.103	2.478	5.039	3.107	5.139
K_2O	3.582	0.065	3.499	3.710	3.490	3.279	3.415	3.281
MgO	2.960	0.643	2.923	2.698	2.628	2.609	2.616	2.542
TiO_2	1.047	0.026	1.011	1.092	1.037	0.985	1.001	0.936
Na_2O	0.705	0.076	0.696	0.694	0.730	0.737	0.804	0.734
P_2O_5	0.107	-	0.136	0.190	0.153	0.119	0.148	0.441
SO_2	0.295	2.873	0.605	1.084	0.492	0.347	1.449	0.100
MnO	0.095	-	0.105	0.128	0.099	0.093	0.105	0.100

4.2 Mechanical Property

4.2.1 Proctor Test Results

From **Table 3** it is shown that Maximum Dry Density (MDD) of the origin soil is 1.63. But when Rice Husk Ash (RHA) is added the MDD is decreased (**Sample C-2** & **C-3**). When 2% and 8% lime is added to the soil respectively along with the 3% RHA **(Sample C-4** & **C-6**) the value of MDD decreases. The result follows the same when 2% and 8% lime is added to the soil respectively along with the 9% RHA (**Sample C-5** & **C-7**).

Table 4: MDD, OMC, UCS & C.B.R.

Name of Sample Combinations	MDD	OMC	UCS (kN/m^2) At 0 Days	C.B.R. at OMC	
				Unsoaked	Soaked
C-1	1.63	15.92	6.43	4.25	3.5
C-2	1.552	21.32	9.13	10.2	12.65
C-3	1.44	24.2	4.79	14.3	16.8
C-4	1.475	21.54	10.71	12.3	14.2
C-5	1.36	30.88	17.09	18.15	14.92
C-6	1.436	26.8	19.4	20	22.4
C-7	1.28	31.03	28.54	23.65	24.82

From **Table 3** it is shown that Optimum Moisture Content (OMC) of the origin soil is 15.92. But when Rice Husk Ash (RHA) is added the OMC is increased (**Sample C-2** & **C-3**). When 2% and 8% lime is added to the soil respectively along with the 3% RHA (**Sample C-4** & **C-6**) the value of OMC increases. The result follows the same when 2% and 8% lime is added to the soil respectively along with the 9% RHA (**Sample C-5** & **C-7**).

4.2.2 Unconfined Compessive Strength Test

From **Table 3** it is shown that Unconfined Compressive Strength (UCS) of the origin soil is 6.43 kN/m^2. When 3% Rice Husk Ash (RHA) is added the value of UCS is increased (**Sample C-2)**. But upon increasing amount of RHA (**Sample C-3**) it has found that the value of UCS is decreased. But when 2% and 8% lime is added to the soil respectively along with the 3% RHA (**Sample C-4** & **C-6**) the value of UCS increases. The result follows the same when 2% and 8% lime is added to the soil respectively along with the 9% RHA (**Sample C-5** & **C-7**).

4.2.3 California Bearing Ratio (CBR) Test

From Table 4 it is found that upon adding 3% and 9% RHA along with the origin soil increases both the soaked and unsoaked CBR value at OMC (**Sample C-2** & **C-3**) when compared to the origin soil (**Sample C-1**).When 2% and 8% lime is added along with the both 3% and 9% RHA to the soil, both the soaked and unsoaked CBR value at OMC increase (**Sample C-4**, **C-5, C-6, C-7**).

V. CONCLUSION

The present study shows significant strength characteristics in Soil, Rice Husk Ash and Lime combinations. XRF Analysis also confirms that. But for more detailed prediction, XRF Analysis should be done on more combinations.
Experiments performed revealed that agricultural waste materials like rice husk ash has high potential as it can be used in bulk quantity in the road construction sector, which will not only can solve the depositional problem but also enhance the properties of sub-grade soil to a great extent. This ultimately can reduce the overall construction cost as well as solve the pollution issues arising from such waste.

Test results confirmed the presence of high percentage of siliceous contents present in lime and RHA, which is actually the key factor for stabilizing the soil. XRF Analysis has been done to study the microstructure and elemental composition of Soil and some Soil-Lime-RHA mixes to predict the strength characteristics. The compaction and other properties of soil also confirm this ideology.

The paper highlights the effect of alternative materials such as Rice Husk Ash, Lime etc, which are cheap and easily available, in stabilizing the low strength soil in order to minimize the overall cost of construction as well as the depositional problems of waste materials.

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