Structural Correlation With Mechanical Properties Of Sub-Grade Soil Mixed With Rice Husk Ash And Lime

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Abstract : Present study considers structural characterization of sub-grade soil to increase the strength of soil for road. The present investigation has been carried out with agricultural waste materials like Rice Husk Ash individually mixed with soil and also in combination with different percentage of Hydrated Lime. Structural and mechanical characterization of the investigated samples was performed by X-Ray Diffraction (XRD), X-Ray Fluorescence (XRF), Standard Proctor Test, Unconfined Compression Test, California Bearing Ratio (CBR) Test. It was observed that increase of strength may be due to the reduction of mica in the soil sample. Increase of the silica in the soil sample finally increases the strength and stability. Microstructural study revealed that the mica phase may play very important role for maintaining the strength and stability of the soil.

Keywords: X-ray diffraction (XRD), X-ray fluorescence (XRF), Structural and Mechanical Characterization

I. INTRODUCTION

Clays exhibit generally undesirable engineering properties. Generally, clay has low shear strengths and to lose shear strength further upon wetting or other physical disturbances. It can be plastic and compressible depending upon wetting and drying. Some types expand and shrink greatly upon wetting and drying – a very undesirable feature. Cohesive soils can creep over time under constant load, especially when the shear stress is approaching its shear strength, making them prone to sliding. These lead to develop large lateral pressures and low resilient modulus. For these reasons, clays are generally poor materials for foundations. The annual cost of damage because of poor rood condition is estimated as $91 billion a year in 2013, 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. The present investigation has been carried out with agricultural waste materials like Raw Rice Husk and Rice Husk Ash individually mixed with soil and also in combination with different percentage of Hydrated Lime [2] with several mix proportions to study the improvement of weak sub-grade material. Rice Husk Ash was mixed in different percentages with soil which was previously stabilized with different percentages of lime. The chemical composition of the sail and other investigated samples were characterized by X-ray fluorescence (XRF). Crystallographic phases present in the sub-grade soil and other investigated samples were identified by XRD analysis. Mechanical strength of the subgrade soil and other batches were tested by compaction and California Bearing Ratio (CBR) 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:

In paper" Use of Rice Husk Ash for Soil stabilization",[3] Subrahmanyam Et al., conducted experimental work to study the effect of Lime-RHA mixtures on the properties of an inorganic black clay nd proposed RHA in combination with Lime can be used for stabilization of clays. The investigation concluded that: 1) the plasticity index of clay is significantly reduced by the addition of Lime and RHA admixtures. 2) the maximum dry density was decreased and optimum moisture content was increased. 3) The unconfined compressive strength of the clay was increased when the clay was mixed with admixture of Lime and RHA.

Chassan Chmeisse [4] focuses on the stabilization of soil by using Granulated Blast furnace Slag (GBFS) in paper " Soil Stabilization Using Some Pozzolanic Industrial and Agricultural Products",. Both the Material were found to have siliceous and aluminous materials, and react with the lime or cement, having economic potential to replace some of the lime or cement presently used as an additive in the stabilization of soil.

To determine the effectiveness of RHA and GBFS as stabilizers, general geotechnical soil parameter, including unconfined compressive strength, undrained shear strength, CBR, plasticity index and the linear shrinkage were measured. X-Ray Diffraction (XRD) analysis, Scanning Electron Microscopy (SEM) and a repeated dynamic load test were also conducted in this investigation.
It is revealed that RHA is not alone suitable for modifying soil properties, however beneficial results are obtained when it is used in combination with lime or cement. It is shown that Lime-RHA and Cement-RHA additives increase the unconfined compressive strength, CBR and undrained shear strength 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.

In paper "A Study on The Effect of Cement on Alluvial Soil Strengthened with Pond and Rice Husk Ash for Construction of Road Subgrade",[5]T.K. Roy Et al. shows that in the recent times the demand for subgrade materials has been increased due to increased constructional activities in the road sector and due to paucity of available nearby lands to allow excavate fill materials for making sub-grade. In this situation a means to overcome this problem is to utilize the different alternative generated waste materials, which cause not only environmental hazards and also the depositional problems. Using this viewpoint, a study was undertaken to examine the improvement in the properties of alluvial soil when mixed with large quantity of pond ash, RHA and small quantity of cement. Experimental results indicated improvements in index properties and significant improvement in the soaked CBR value of soil when mixed with pond ash and RHA. However further experiment with addition of small amount of cement can improve the soaked CBR value to a great extent.

V. S. Shrivastava shows in paper "X-Ray Diffraction and Mineralogical Study of Soil: A Review",[6] that the surface layer of soil consisting of the mixture of mineral and organic matter reflects the nature and properties of the soil. Weathering the minerals of the earth crust originally derived most of the substances including plant nutrients. Among various substances, clay is an important soil constituent that controls its properties and also influences its management and productivity. In addition to commercial applications of clay minerals, it has great potential to fix pollutants such as heavy metals, organics and plays an important role in cleansing the biosphere. Despite the fact that excess clay induces unfavorable property and required more energy for tillage operation, clay immensely improves soil fertility. In this respect, it is important to carry out quantitative and qualitative analysis of clay minerals in soil. X-Ray Diffraction has shown as the best tool for identification and qualification of minerals present in soil.

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 were estimated from X-ray fluorescence (XRF) spectrum analysis. XRF spectrums were recorded in AXIOS XRF (PANalytical) for elemental analysis. Crystal phase evolution in the sub-grade soil and the other batches **(Table 1)** were determined by XRD.

The X-ray diffraction pattern of the samples were recorded in X'pert Pro MPD diffractometer (PANalytical) using X'Celerator operating at 40kV and 30 mA using CuK$_\alpha$ radiation. The XRD data were recorded with step size 0.05° (2Θ) and step time 75sec from 10° to 90° for these samples. Weight percentages of the crystalline phases nad values of unit cell parameters were estimated for the samples from X-ray diffraction line profile analysis using Rietveld method [7] by X'Pert High Score plus software (PANalytical) [8]. Compaction [9], Unconfined Compression [10, 11] and California Bearing Ratio (CBR) [11, 12] 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 for the determination of the relation between the water content and the dry density of soils using light compaction. The maximum dry densities and optimum moisture content of the soil is determined by standard proctor compaction. Standard proctor compaction tests were done to determine the Maximum Dry Density (MDD) and the Optimum Moisture Content (OMC) **(Table 4)** in each case.

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. These specimens are of maximum dry unit weight and optimum moisture content state, prepared by static compaction. To ensure that effective mixing between the soil lime and RHA the process is staged. Initially all of the soil and half of the water and fibers are mixed, after which the proportions of water and fiber are gradually increased up to optimal water content and the prescribed fiber percentage. The mix is to be compacted in proctor mould with desired water content and density. Then specimens are to be extracted from the mould for carrying out unconfined compressive strength test (**Table 4)**. Stress-strain behavior and ultimate compressive strength 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 were performed by XRD and XRF (**Table 1)**. Chemical compositions of the investigated samples were estimated by XRD (**Table 2).** Elemental compositions are shown in the XRF results (**Table 3)**.

Table 2: Wt.% of phases as obtained by Rietveld Analysis (XRD Analysis

Sample Marks	Phases identified from XRD	wt. %
Soil 100%	Quartz Mica Clinochlore	43.3 47.8 8.9
Soil+ 3% RHA	Quartz Mica Clinochlore Cristobalite	43.7 38.5 8.6 9.2
Soil + 9%RHA	Quartz Mica Clinochlore Cristobalite	33.5 39.9 15.4 11.2
Soil+ 3% RHA+ 2% Lime	Quartz Mica Clinochlore Cristobalite Gismondine	47.4 35.2 13.6 3.7 8.1
Soil+ 3% RHA+ 8% Lime	Quartz Mica Clinochlore Cristobalite Gismondine	50.6 31.2 11.7 1.0 1.4
Soil+ 9% RHA+ 2% Lime	Quartz Mica Clinochlore Cristobalite Gismondine	39.2 33.7 13.5 5 8.7
Soil+ 9% RHA+ 8% Lime	Quartz Mica Clinochlore Cristobalite Gismondine	45 29.3 12.8 3.5 9.3

Table 3: Semi-Quantitative elemental Analysis of the investigated samples from XRF spectrums

Compound Name	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

Phase evolution in the sub-grade soil and other batches were determined from XRD. XRD data were recorded with step size 0.05^0 (2Θ) and step time 75 sec from 10^0 to 90^0 for these samples. Weight percentages of the crystalline phases nad values of unit cell parameters were estimated for the samples from X-ray diffraction line profile analysis using Rietveld method(Ref1, Ref2} by X'Pert High Score plus software (PANalytical) (Ref3}. XRD patterns (**Fig 1**) of the soil sample shows that the starting soil sample contains crystalline quartz, mica and clinochlore. The main constituent present in the RHA is Silica. Addition of RHA increases the amount of Silica in soil, thereby increase the strength and stability of soil sample.

After addition of rice husk (RHA) with the soil gives extra Cristobalite phase with the existing phases (**Fig 2**). **Fig. 3** shows that the rice husks contain only cristolobalite phase. 3 % RHA and 9 % RHA were added with the soil sample for the above mentioned purpose. After addition of rice husk with the soil gives extra Cristobalite phase (SiO_2) with the existing phases (**Fig 2**).

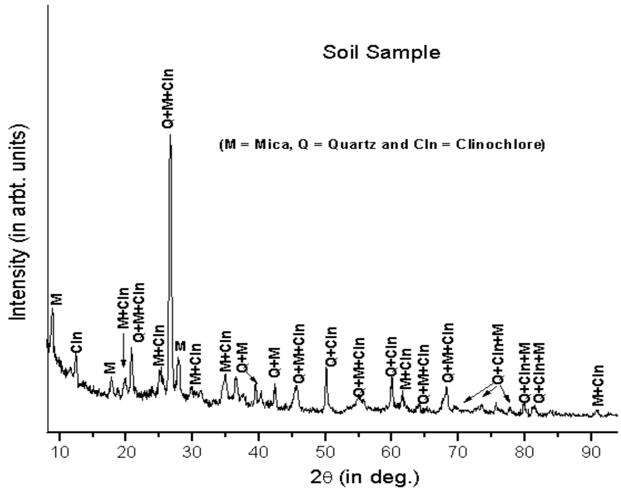

Fig. 1 XRD pattern of the Soil sample

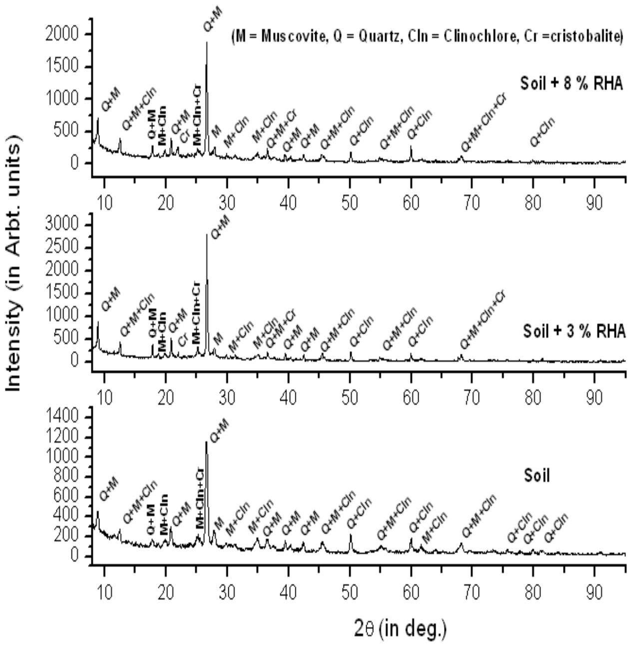

Fig. 2 XRD pattern of pure soil sample and soil samples mixed with Rice Husk (RHA)

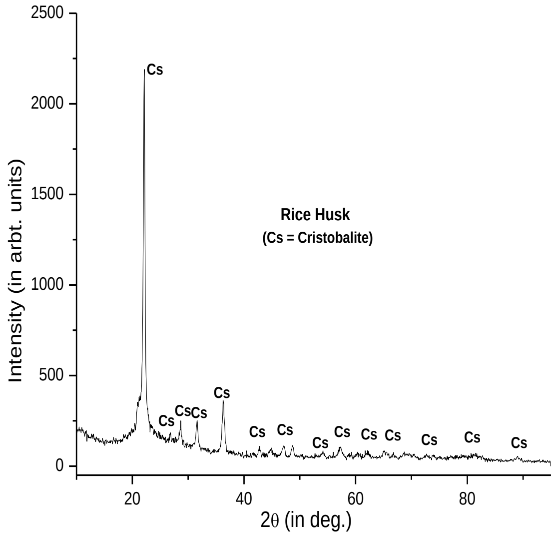

Fig. 3 XRD pattern of the Rice Husk sample

XRD pattern (**Fig.4**) of the used Lime shows that used lime contains Calcite (Calcium Carbonate), Silica (Quartz), Calcium Hydroxide and Sulphur dioxide (SO_2).

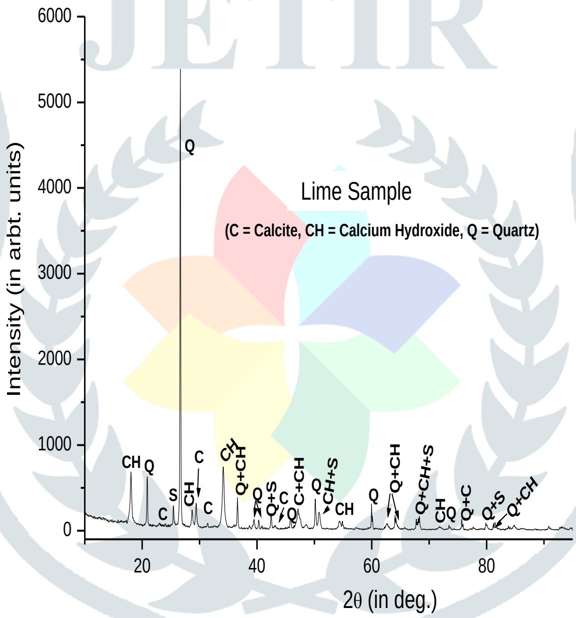

Fig. 4 XRD pattern of the lime sample

From **Table 2**, it was observed that wt. % of cristobalite phase increase with addition of rice husk ash while as wt. % of mica decreases with that. From **Table 4**, it was also observed that soaking strength is around 16.8 for the soil+9 % RHA. Increase of strength may be due to the reduction of Mica in the soil sample (soil+9 % RHA). Increase of silica in the soil sample finally increases the strength and stability of soil sample. XRF results (**Table 3**) also corroborates with this results.

The lime which we are using is available in the local market, is not a pure one. **Fig 4**, shows that the lime which is used for increasing the stability and the strength of the soil is not pure calcite. Actually, this lime contains silica as major phase which was also observed from XRF results (**Table 3**). Hence the addition of lime with the soil actually increases the total silica content in the sample.

From **Table 4**, it was also observed that soaking strength is around 24.82 for the soil+9 % RHA+8 % lime. This is the maximum strength observed for this composition. It is obvious because the wt. % mica phase become minimum for this composition. From XRF results (**Table 3**) it was also observed that silica and calcium contents are maximum for this composition.

4.2 Mechanical Property

4.2.1Table 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

4.2.1 Proctor Test Results

From **Table 4** 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**).

From **Table 4** 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 4** 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**). After addition of lime, another extra phase Gismondine (**Fig.5**) appeared with the existing phases.

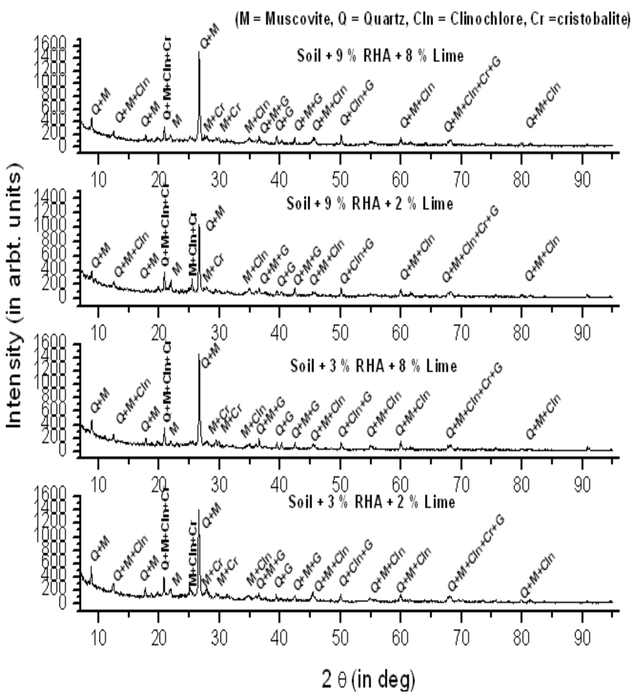

Fig. 5 XRD pattern of pure soil sample and soil samples mixed with RHA and lime

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.

XRD/XRF Analysis also confirms that. But for more detailed prediction, XRD/XRF Analysis should be done on more combinations.

Experimental study performed in the laboratory have shown that waste materials like Rice husk and Rice Husk Ash have high potential to be used in bulk quantity in road construction work along with lime. This will not only save construction cost but will also reduce the accumulation hazard and environmental pollution arising from such wastes.
The high percentage of siliceous materials present in Rice Husk Ash proves its usefulness as a potential ground stabilizing material. The effect of curing of stabilized soil on the results of Unconfined Compressive Strength tests was also studied.

The paper highlights the effect of stabilization of low strength cohesive soil with admixture of different materials like Rice Husk Ash, Lime etc, which are cheap and easily available.

XRD/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.

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