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Soil Subgrade Stabilization by Using Lime Rice Husk

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***Abstract*: Soil is crucial material for road construction in sub grade and sub base region. The property of soil changes when get contact with water and if the strength of soil is low, high swelling tendency or low shear strength than soil stabilization is required at subgrade. In market there are numerous stabilizers available like lime, cement, fly ash, granulated slag etc. Subgrade of the pavement is foundation and its stability gives long life to the pavement. In this paper we will use fly ash, rice husk, ground granulated blast furnace slag as stabilizer. Major and important property which we want to improve volume stability, strength, compressibility, stability, durability. This study is to improve the locally available weak soil with stabilizers. The test performs such as Modified proctor test to and CBR test to check whether adding admixture improves the soil, as higher the CBR it helps to reduce the crust thickness and helps in increasing the bearing capacity of the soil. Modified proctor test conducted to determine maximum dry density of soil sample. After several soil sample test result which gives overall depth reduction in soil subgrade.**

***Keywords*: Lime, rice husk.**

1. Introduction

India is the developing county with limited resources. To provide a complete network of road system, particularly in providing connectivity to remote villages. The cost of road construction and materials is increasing year by year which result road construction speed become slow. There is a need to construct low cost road method by utilizing local materials and adopting stabilizing techniques in different layers of pavements. By the use of controlled compaction, proportion and/or addition of suitable stabilizers and additives Stabilization of soil can be done. Soil Stabilizers used in subgrade with physical, physiochemical and chemical method to ensure that the stabilized soil serves its intended purpose as the homogeneous pavement component material.

The objective of soil stabilizing pavement constructions are,

- It is economical in initial pavement construction cost of lower layer such as subgrade and sub base course.
- To stabilized in-situ soil for sustain under applied loads without serious deformation and retain soil strength and stability at the same time.
- General techniques for improving the properties of natural materials are modification, compaction, stabilization, drainage, vibro compaction, precompression, soil reinforcement which includes soil nailing and use of geotextiles.

In some area locally available soil is found to be not suitable for a sub grade, base material for the construction material of important pavement.

- After testing proctor test, liquid limit test of a suitable soil from nearby and other borrow areas that have acceptable soil properties, transport the borrowed soil from the pits to the construction sites, compact the different layers and construct the sub grade of specified 500mm thickness.
- By removing air, water voids we gain the desired value of dry density and unit weight of subgrade of soil. So, this technique is useful for unsuitable soil found under pavement area.

2. Literature Review

(Koteswara Rao D 2011)5 Rice husk when mixed with lime and gypsum it gains potential to stabilize. It reduces the cost of road construction in rural areas and also reduces the environmental waste like rice husk ash. Rice husk when mixed with lime (5%) it increased the CBR value. To reduce the effect of swelling and shrinkage of expansive soil. Rice husk gives significantly result.

(M. Harikumar et.al., 2016) [1] had studied that the use of natural additives like rice husk ash & lime for stabilizing soil are economical. When RHA, lime added there is slight increase in optimum moisture content and Maximum dry density decreases. RHA and lime addition gradual increase in liquid limit and plastic limit of soil. Several soil samples tested with RHA, lime and by conducting these laboratory test optimum content of RHA was determined. Several results are compared in laboratory test after finding strength parameter like maximum dry density, optimum moisture content, unconfined compressive strength. So instead of hauling soil from long distance, it was decided to use the locally available plastic clay stabilized using Flyash. Flyash is freely available in locality of a thermal power plant.

(P. N. Babaso H. Sharanagouda 2017) [2] rice husk contains like carbon, hydrogen, silicon, oxygen, silica. Bulk density of rice husk is 96-100 kg per metre cube. Rice husk cheaper fuel then coal. Rice husk having binding ability, which reduces the formation of crack in soil. It is seen that the local soil was highly

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plastic so the flyash can be used upto 25% after which maximum dry density was increased 1.25 times the original.

(M Alhassan 2012) [8] The maximum dry density decreases due to lower specific gravity (2.25) of RHA. Whereas the specific gravity of soil is 2.69 which have to stabilized. RHA act as a filler in soil voids. As the increase in RHA content also increase in PMC and unsoaked CBR.

The main science was to use lime or cement with rice husk and to change it to take more load from foundations. BC soil was obtained from Bangalore in Karnataka and rice husk obtained from industry and were dry-mixed. The strength of specimen increased by 18% at 7 and 14 days of curing, at 38% for 28 days.

(Aparna Roy 2014) [4], By using rice husk cost of stabilization may be minimized and this agricultural waste will be disposed. So that environmental hazards get down. Small percentage of cement and rice husk the soil get stabilized by adding them gradually. Several observation are taken after changing percentage of rice husk and cement which gives good performance of maximum dry density and optimum moisture content. The MDD is decreased while the OMC increased with increased in RHA content. By increasing 10% of RHA and 6% of cement content the maximum improvement in strength and these percentage are also applicable to practical purpose.

(Ankit Singh Negi, 2013) [3] For highly active soil lime is used which takes less time for quick stablization of soil. Lime improves various property of soil such as shrinkage, carrying capacity of soil, plasticity index, increase in CBR value and increase in compression resistance with time. Lime is good stabilizing material for cohesive soil. Low weight material is used for better compaction of cohesive soil by filling voids between them.

(A. Hossain, M khandaker 2011) [9] studied the cost of soil stabilization is high due to over dependency on the utilisation of industrial additives such as cement, lime etc. So, by keeping soil stabilization economical the used of agricultural based product should be done. These agricultural based product also reduce environmental hazardous. In soil modification addition of a modifier (cement, lime etc.). Which causes change in index properties, increase in strength, change durability. RHA stabilized the soil slowly when mixed with lime and gypsum.

(Sharma and Sivapuliah, 2015) [6] for old usual method of soil stabilization is to remove the soft soil and replace it with stronger materials. Due to most economical method has driven the researcher to look for alternative method and one of these methods is process of soil stabilization. The primary benefits of using these additives for soil stabilization are cost saving. Slag is cheaper then cement then cement and their availability over across the country. For cohesive soil use of rice husk gives us better result in property of soil.

(B. Suneel kumar & T. V Preethi 2014) [7], Studied that due to increased constructional activities in road sector the demands for subgrade material have increased. To fulfils the demand of subgrade material use of different alternatives waste material gen rate. These alternate waste materials do not cause environmental hazardous and depositional problem. By several investigation has been done after which agriculture waste material like rice husk ash which improve the subgrade properties. A chemical reaction in stabilization process is started when rice husk ash mixed with other cementious materials such as lime and cement.

A. *Summary of Literature*

The practical work has been done in field of soil stabilization, and mainly it depend on necessity of on field modification of soil stabilization like CBR, MDD, OMC, UCS and Atterberg limits. The fundamentals of soil stabilization with respect to lime and GGBS is studied. Subgrade of pavement is improved due to soil stabilization, and economy in construction is analysed and if possible reduced with help of lower cost of admixture, or lowering the crust thickness. Further in this project we are going to study the effects of soil stabilization with ricehusk, fly ash and GGBS and its effect on MDD, CBR, Crust thickness and would check if overall cost of 1km road using stabilized soil has positive or negative effect on the economy of the project.

3. Materials

A. *Soil*

The soil is obtained from taramandal area in Gorakhpur. There soil is mildly expansive due to some clay content in it. The soil is sieved through 4.75mm sieve followed by 2.36mm, 1.18mm, .600mm, .425mm, .075mm, finally .002mm and retained on pan) weighed and air dried. Once the soil is naturally air dried, it is tested for natural moisture content in a muffle furnace. The various geotechnical properties of the soil are listed below.

B. *Lime*

When soil is added with lime then exchange of cation takes place which increase plastic limit and reduce plasticity index and finally increase the stability of soil. If the clay soil contains gravel then lime act as a binding material for clay gravel. Lime soil Stabilization is treated in warm atmosphere, it is not suitable for cold area.

Table 1
Properties of lime

Chemical Formula	$Ca(OH)_2$
Molar Mass	74.093 g/mol
Appearance	White Powder
Odour	Odourless
Density	2.211 g/cm^3
Melting Point	580^{O}C
Solubility	Soluble in acids and glycerol Insoluble in alcohol
Solubility in water	1.89 g/L (0^{O}C) 1.73 g/L (20^{O}C) 0.66 g/L (100^{O}C)
Refractive Index	1.574
Magnetic Susceptibility	-22*10^{-6} cm^3/g

C. *Rice Husk*

Rice husk Ash was grinded in XOM-20 vertical planetary ball mill made by tianchuang powder. After grinding rice husk Ash, the sample was immediately filled in a sealed bag and stored. It can be seen that the RHA particles after grinding are very small and most of them are less then 10micro meter. The specific surface area and particles size analysis of RHA was tested by using laser size analyzer. The specific surface area is about 5910cm^2/g.

The pozzolonic reaction between RHA & lime generates hardening and strength development. A phenomenon found that when RHA-lime is tested, the fine particles of expansive soil are reduced and the coarse particles are correspondingly increased. Sometimes particles of RHA lime become larger the specific surface area of mixture is lowered; at the same time, medium particle size D50 is improved. Big amount of silicate mineral is generated when soil is cured for a certain period and the distribution of soil particles is difficult to measure by laser particle size analyzer.

4. Methodology

A. Soil - Lime Stabilization

Soil Lime works in better ways as a binder and also as modifier for gaining plasticity of soil. Lime can be used in powdered fine-grained soil. The main principle shows result with soil lime stabilizer is puzzolonic action. The puzzolonic reaction takes place mainly due to addition of hydrated lime with moist soil and is defined as hydrated lime (Ca(OH) + Water + Soil (SiO_2, Al_2O_3 and others). Cementious material with stabilized with silicate hydrates and calcium aluminate hydrates. The effect due to the addition of lime are improvement in workability by increasing OMC wrt soil without lime, increase in all type of strength related properties by decreasing plasticity index, swell reduction. With suitable addition of granular blast furnace slag, it can be added to the gravel, sand and silt.

B. Mineral Activation

Rice milling generates a raw by-product know as husk. This surrounds the paddy grain. During milling of paddy about 76% of weight is received as rice, broken in rice and bran. Rest 24% of the weight of paddy is received as husk. This husk is used as fuel in the rice mills to generate steam for the boiling process and other activity. This husk contains about 74% organic volatile matter and the remaining 26% of the weight of this husk is converted into ash during the firing process, known as Rice husk (RHA). This RHA in turn contains around 86%-91% amorphous silica. So far, every 1000 kg of paddy milled, about 222 kg (22%) of husk is produced, and when this husk is burnt in the boilers, about 55Kg (25%) of RHA is generated. India is a big rice producing country and the husk generated during milling is mostly used as a fuel in the boilers for processing paddy, producing energy through direct combustion and or by gasification. About 22 million tons of RHA is produced annually. This RHA is great environmental threat causing damage to the land and the surrounding area in which it is dumped. Lots of ways are being thoughts for disposing it by making commercial use of RHA. For this study RHA is obtained from the modern rice mill, and it is having 67.8 % SiO2 content. The specific gravity of the RHA is 2.04.

C. Test Performed

1) Modified Proctor Test (IS 2720 Part 8- 1983, Reaffirmed May 2015)

Modified proctor test is used to determine the compaction of different sample soil and change in properties of soil with the change in water content. It gives us a relationship between water Content and dried density of z a given soil sample. Compaction is mechanical process in which a unsaturated soil reduced the volume of voids filled with air, while the volume of solids & water content remains the same.

The results from compaction of soil is to increase shear strength, decrease compressibility, reduce permeability, & to control swelling & shrinkage of soil. The degree of compaction of soil is measured in terms of its dry density. In this test the maximum dry density of soil occurs at optimum moisture content (OMC).

2) California Bearing Ratio Test

CBR test in highway engineering was developed by California state highway department for obtaining the strength of subgrade soil, thickness and other pavement materials for the designs and construction of flexible pavements. The CBR test results have been directly related with flexible pavement thickness requirements for highway and airfields. Being empirical test method, CBR test result cannot be related accurately with any fundamental property of soil or pavement material to be tested in laboratory. CBR method is conducted for cohesive soil and applicable to maximum size of particle 19mm.

CBR test evaluate the resistance to penetration of a soil or

Table 2
Sample description and test results for MPT and CBR

Sample No.	Sample Mix Description (by weight)	Maximum Dry Density g/cc	CBR Value %
1	Soil + 0% Rice husk+ 0% Lime	1.67	5.89
2	Soil + 2% Rice husk+ 0.% Lime	1.66	5.91
3	Soil + 4% Rice husk + 0.% Lime	1.69	5.75
4	Soil + 6% Rice husk + 0.% Lime	1.71	6.33
5	Soil + 8% Rice husk + 0% Lime	1.70	6.44
6	Soil + 0% Rice husk+ 0.5% Lime	1.72	7.50
7	Soil + 1% Rice husk + 0.5% Lime	1.74	7.85
8	Soil + 2% Rice husk + 0.5% Lime	1.75	7.96
9	Soil + 4% Rice husk + 0.5% Lime	1.80	8.18
10	Soil + 6% Rice husk + 0.5% Lime	1.77	8.24
11	Soil + 8% Rice husk+0.75% Lime	1.83	8.43
12	Soil + 1% Rice husk + 1.0% Lime	1.86	9.62
13	Soil + 8% Rice husk + 1.0% Lime	1.92	10.13
14	Soil + 9% Rice husk + 1.0% Lime	1.88	10.06
15	Soil + 10% Rice husk + 1.0% Lime	1.83	9.70

flexible pavement material (particle size, aggregate) of standard plunger under controlled test condition. The test also conducted on both undisturbed and remoulded soil specimens. Lab test procedure should be strictly adhered if high degree of reproducibility is required.

The main principle of CBR test in highway engineering is by causing a cylindrical plunger of 50mm diameter to penetrate into the soil sample or pavement component material at a rate of 1.25mm per minute under control condition. The required load for 2.5mm and 5mm penetration of plunger under controlled condition in soil or pavement material to be tested is noted. This CBR value of the material tested is also expressed as a percentage of standard load value in a same material. The standard normal load value has been established based on a large number of test standard sample crushed stone aggregates at penetration value of 2.5 and 5mm. These standard normal load value given below maybe directly used to calculate the CBR value of the test sample material. The penetration points for CBR test were 0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10.0, 12.5 mm.

5. Rate and Crust Thickness Analysis

In this study there is a change in CBR of soil by adding rice husk and Lime in to sample soil of sub grade due to cohesion properties in both the material when properly mixed and in contact with moisture. By adding only rice husk to the soil, there was only slight modification to the CBR and maximum dry density. It is seen that Rice husk is mainly neutral compound and does not react unless an activator is added, in this case it is lime. The reaction between soil and rice husk has taken place very less, also the specific gravity of rice husk is higher than soil, so there is an increase in MDD. MDD increased from 1.67g/cc in case of Sample 1 (Soil 100%) to 1.71g/cc when 3% rice husk is added.

Table 3

Traffic	1130Cvd (An assumed road)
Standard Axle (Ns)	[(365 * (1+r) n – 1/r) * D * F *A]
Traffic	Ns / 10^6
Design Period (n)	15 years for SH, NH
Growth Rate (r)	5%
Lane Distribution Factor (D)	0.75
Vehicle Damage Factor (F)	3.5
A	1130 CVD
Standard Axles (Ns)	[({365x (1+0.05)15– 1}/0.05)x0.75x3.5x1130] = 23169378.75 CVD
Design Traffic	Ns / 10^6 = 23.16 MSA

The value of CBR also significantly increases from 5.89in case of sample 1 to 6.44% in case of sample 5 (4% rice husk). But when lime is not added than continuous increase in CBR does not take place. Lime act as an activator and when added in the mix there is gradual increase in MDD and CBR. Also, the specific gravity and other property of the soil has slight increase. The most increase in CBR and MDD takes place in case of sample 13 (Soil +8% RHA+ 1% Lime) when CBR increases upto 10.13%, and MDD increases upto 1.92g/cc.

A. Crust Thickness

Calculation of Crust Thickness: All the calculations are done as per the guidelines of IRC: 37 – 2018.

B. Rates

- Item Rates are calculated as per Data Book of Roads and Bridges, MORTH.

Table 4
Crust thickness

S.No.	**Admixture**	**CBR**	**Sub grade thickness in mm (Earth Work)**		**Crust Thickness**			
				Total crust in mm	**GSB in mm**	**WMM in mm**	**DBM in mm**	**BC in mm**
1	No Admixture	5.88	500	670	270	250	110	40
2	Soil +8% RHA+ 1% Lime (Sample 13)	10.13	500	570	200	250	80	40
3	Reduction in Crust Thickness	-	-	100	70	-	30	-

Table 5
Rate analysis for preparation of sub grade using admixtures by mechanical means

S.No.	**Description**	**Unit**	**Quantity**	**Rate**	**Amount**
1	**Labour**				
	Mate	day	0.360	351.00	126.36
	Skilled mazdoor for alignment and geometrics	day	1.000	351.00	351.00
	Mazdoor for spraying lime	day	8.000	338.00	2704.00
2	**Machinery**				
	Tractor with ripper and rotavator attachments @ 60 cum per hour for ripping and 25 cum per hour for mixing	hour	12.000	486.00	5832.00
	Motor Grader 110 HP @ 50 cum per hour	hour	6.000	2858.25	17149.50
	Vibratory roller 8 - 10 tonne capacity	hour	6.00x0.65*	1838.90	7171.71
	Water tanker 6 KL capacity	hour	12.000	28.86	346.32
3	**Material**				
	Lime at site	tonne	115.2	8500	979200
	Slag at Site	tonne	921.6	1500	1382400
	Cost of water	KL	50.0	150.00	7500.00
4	**Overhead Charges (1+2+3) @ 10%**				2385631.39
5	**Contractor's Profit (1+2+3+4) @10%**				477126.27
6	**Cost of 6000 m^3**				5248389.05
7	**Rate per m^3 (1+2+3+4+5)/6000**				874.3

Table 6
Bill of Quantity for Sub grade with No Admixtures for 1km road of 12m (2.5 + 7.0+ 2.5)

S.No.	Description	Quantity (m^3)	Rate (Rs.)	Amount (Rs.)
1	Earth Work for Sub grade Preparation	1000*12*0.50 = 6000	280	1,68,0000
2	GSB	1000*7.3*0.27 = 1971	3687	72,67,077
3	WMM	1000*7*0.25 = 1750	4124	72,17,000
4	DBM	1000*7*0.11 = 770	8805	67,79,850
5	BC	1000*7*.04 = 280	9664	27,05,920
	Total	-	-	2,56,498,57

Table 7
Bill of Quantity for Sub grade with Admixtures for a 1km road of 12m (2.5 + 7.0+ 2.5)

S.No.	Description	Quantity (m^3)	Rate (Rs.)	Amount (Rs.)
1	Earth Work for Sub grade Preparation	1000*12*0.50 = 6000	874.3	5248389.05
2	GSB	1000*7.3*0.20 = 1460	3687	53,83,020
3	WMM	1000*7*0.25 = 1750	4124	72,17,700
4	DBM	1000*7*0.08 = 560	8805	49,30,800
5	BC	1000*7*.04 = 280	9664	27,05,920
	Total	-	-	2,54,858,29.1

Table 8
Net Saving due to stabilization

Cost of Road without Admixture (Rs.)	Cost of Road with Admixture (Rs.)	Change Amount	in	Net Savings (Rs.)	Net Savings %
2,5649847	2,5485829	165018		165018	0.631%

- Admixture Rates are taken from Local Vendors and are Market Rates.
- Admixtures are added to top 500mm of the sub grade as per IRC 37 2018 and the procedures are taken in accordance with Specification for Roads and Bridges Work IRC – MORTH.

C. Quantity, Cost of Admixture and Net Savings

Cost of Admixtures:

For Sample 13, The maximum CBR and MDD was observed.

Density of Stabilized Soil = 1.92g/cc (Modified Proctor Test Sample 13)

MDD = 1.92g/cc = 1920 kg/m^3

For 1 m^3 soil,

Weight of Stabilized Soil = 1920kg for 1m^3 mix.

Quantity of Admixture Added in soil = 8% RHA + 1% Lime.

Weight of 8% RHA = 1920*8/100 = 153.6 kg in 1m^3 of sample.

Weight of RHA in 6000 m^3 = 921600 kg or 921.6 tonnes.

Cost of RHA= Rs 1.5 per kg or Rs 1500 per tonne.

Weight of 1% Lime in 1m^3 Sample = 1920*1/100= 19.20kg

Weight of Lime in 6000 m^3 = 1,15,200 kg or 115.2 tonnes.

Cost of Lime = Rs 85 per kg or Rs 8500 per tonne.

Net Savings = Cost of Road without Admixture - Cost of Road With admixtures

= 2,5649847-2,5485829=165018

Net Savings % = (Net Saving/Cost of Road without Admixtures) * 100 = (164018/2,5649847) * 100 = 0.631%

It is found in the results that maximum CBR was found to be 10.13% at Sample 13 (Soil + 8% rice husk +1% Lime). At the particular CBR, the Crust thickness was calculated as 570 mm. If no stabilization was done, then the crust thickness was found to be 670mm. Therefore, by doing stabilization we are saving 100mm of crust.

Based on that per km cost saving was Rs 164018 which was the difference between Cost of the Pavement without admixture and Cost of the pavement with admixtures. Based on this savings we find out that we have a net saving % of 0.631%.

6. Conclusion

From the research paper on stabilization of expansive soil using Lime activated ground granulated blast furnace slag following conclusion can be drawn.

- Lime and rice husk can work together as an admixture in stabilization of soil, it is due to the fact that although slag is neutral, slag contains about 35-45% CaO in it, and when lime and water are added to it, due to exothermic reaction between lime and water, the overall alkalinity of the mixture increases, therefore it helps slag to activate which in turn additionally helps in increasing strength of soil.
- Stabilization of expansive soil improves the geotechnical properties of the expansive soil like Maximum dry density, reducing swelling Optimum moisture content of the soil and index properties of the soil etc.
- The maximum dry density of original soil was found to be 1.67 g/cc, whereas sample 13 (Soil + 8% rice husk+ 1% Lime) was found to be 1.92 g/cc, which indicates strength of soil has increased due to admixture and compaction.
- Due to a decrease of 100 mm in crust thickness (70mm in GSB and 30mm in DBM), significant reduction in cost has taken place. The Net saving amount is found to be Rs 1,65018.00.
- The Net Saving % is found to be 0.631%.
- The schedule rates have been taken from Data Book of Standard Highway MORTH, and the design of flexible pavement is done as per IRC 37: 2018.
- It is found that both in case of CBR and MPT, when in soil only rice husk is added, negligible increase in density and CBR value is observed from Sample 1 to Sample 5. But when lime is added, the values show a

significant increase.

- The effect of stabilization on mechanical properties (shear strength, splitting tensile strength, stiffness, compressive strength), hydraulic conductivity, consolidation properties of expansive soil have not been studied in this paper because it creates wide scope of this research.
- Condition of stabilized and un stabilized soil subjected to cyclic loading is hardly covered in the paper. Also, these tests are performed in the lab, and if performed in the field results may show variations because natural strata have been destroyed.

7. Future Scope and Discussions

Based on the present analysis, it is felt that future work should be pursued in the following area:

- Evaluation could be done with other additives like geo synthetics, crumb rubber, and waste materials like PET bottles, fly ash and debris.
- Analysis should be carried out for the types of activators for Ground granulated blast furnace slag like calcium hydroxide, gypsum, ordinary Portland cement, sodium hydroxide, sodium carbonate and sodium sulphate etc.
- Analysis should be carried out with locally available soil which will be more useful for natural purpose and non-hazardous to environment.
- Mixture of admixture used for stabilization should be carried out better result and cost effective.
- Findings of this analysis should be carried out and tested in field for actual result. While we have only involved lab work, these tests should also be carried out in field. Generally, a difference in result which is observed since in lab and we can control the environment condition such as temperature.
- Environmental situation should also be considered in analysis of the findings for further actual results like the results obtained on soil will be different in monsoon, summer, winter.

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