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Soil Stabilization by Using Lime Rice Husk

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***Abstract*: Soil is important material for road construction in sub grade and sub base region. The property of soil changes when get contact with water and if the soil strength is low, high swelling tendency or low shear strength then soil stabilization is required at subgrade. In market there are various stabilizers available like lime, cement, flyash, granulated slag etc. Foundation of any pavement is subgrade and it's stability gives long life to the pavement. In this paper we will use rice husk, lime as stabilizer. The important property which we want to improve in soil is volume stability, strength, compressibility, stability, durability. This study is to improve the locally available weak soil with soil stabilizers. The test performs such as Modified proctor test and CBR test is to check whether adding admixture improves the soil. Higher the CBR value helps to reduce the crust thickness and also helps in increasing the bearing capacity of the soil. Modified proctor test are conducted to determine maximum dry density of soil sample. Results after testing several soil samples gives reduction in overall depth of soil subgrade.**

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

1. Introduction

India is the developing county with limited resources for infrastructure. To provide a complete network of road system, particularly in providing connectivity to remote villages use of economical raw material is required. The cost of road construction and materials is increasing year by year which result speed of road construction become slow. For construction of low-cost road, we use the method of 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 gives homogeneous properties to overall length of pavement.

The objective of soil stabilizing pavement constructions are:

- It is economical in initial stage of pavement construction for the cost of lower layer such as sub grade and sub base course.
- To stabilized in-situ soil for sustain under applied loads without serious deformation and retain soil strength, homogenity and stability at the same time.

General techniques for improving the properties of natural soil are modification, compaction, stabilization, drainage, vibrocompaction, 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 in the pavement.

After testing proctor test, liquid limit test of a suitable soil from nearby and other borrow areas 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 sub grade of soil. So, this technique is useful for unsuitable soil found under pavement area.

2. Literature Review

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

(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.

(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

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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.

(Koteswara Rao D 2011) [5] Rice husk when mixed with lime and gypsum it gain 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.

(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 generate. 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.

(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.

(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.

A. *Summary of Literature*

The practical work has been done in field of soil stabilization, and mainly it depends on necessity of field modification for soil stabilization like CBR, MDD, OMC, UCS and Atterberg limits. The fundamentals of soil stabilization with respect to lime and rice husk is studied. Subgrade of pavement is improved due to soil stabilization, and economy in construction is analyzed and if possible reduced with help of lower cost of admixture, or lowering the crust thickness. Further in this project we proceed to study the effects of soil stabilization with rice husk, 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. The 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) weighted and oven dried. Once the soil is oven 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 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 conducted 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 husks are the protective coverings of rice grains which are separated from the grains during milling process. Rice husk is a widely available waste material in all rice producing countries, and contains about 30%–50% of organic carbon. In the process of a typical milling process, the husks are removed from the raw grain to reveal whole brown rice which upon further milling to remove the bran layer will yield white rice.

The objective of main materials employed for composting were fresh rice husks (< 2 mm long), which were obtained from local available farmers. Properties of the rice husks were analyzed in the laboratory, and the results were as follows:

9.5% moisture content, 48.1% total carbon, and 0.78% total nitrogen.

4. Methodology

A. Soil - Lime Stabilization

Soil Lime works for long life as a binder and also as modifier for gaining plasticity of soil. Lime should 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 known as hydrated lime (Ca(OH) + Water + Soil (SiO2, Al2O3 and others). Cementious material are stabilized with silicate hydrates and calcium aluminate hydrates. The effect due to the addition of lime are gradual improvement in workability by increasing OMC w.r.t soil without lime, increase in all type of strength related properties by decreasing plasticity index, swell reduction.

B. Mineral Activation

Rice milling generates a raw by-product known as husk. During milling of paddy about 76% of weight is received as rice, broken in rice and bran and rest 24% of the weight of paddy is received as husk. This husk is used as fuel in the rice mills to produce steam for the boiling process and other activity. 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. 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. RHA is great environmental threat which causing damage to the land beneath and the surrounding area in which it is dumped. 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 analyze the compaction of different types of soil and modify the properties of soil with the change in moisture content. It also gives us a relationship between Moisture Content and dried density. Compaction is densification (by mechanical means) of unsaturated soil by the reduction in the volume of voids filled with air and water, while the volume of solids & water content remains the same.

The major aim of compaction of unsaturated soil is to increase shear strength, reduce compressibility, reduce permeability, & to control shrinkage & swelling of soil. The degree of compaction of soil is determine in terms of its dry density. Generally maximum dry density of soil occurs at optimum moisture content (OMC).

2) California Bearing Ratio Test

CBR test was developed by California state highway department for evaluating the strength of subgrade soil and other pavement materials for the designs and construction of flexible pavements. The CBR results have been correlated 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.

CBR method is also standardized by Bureau of Indian Standards (BIS).

CBR test denotes a measure of resistance to penetration of a soil or flexible pavement material 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 basic principle of CBR test 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. The load required for 2.5mm and 5mm penetration of plunger in soil or pavement material to be tested is recorded. The CBR value of the material tested is expressed as a percentage of standard load value in a material. The standard load value has been established based on a large number of test standard crushed stone aggregates at penetration value of 2.5 and 5mm.

5. Rate and Crust Thickness Analysis

From the study there is an improvement in CBR of soil due to adding rice husk and Lime in to selected soil of sub grade due to cementicious properties in both the admixtures when properly mixed and in contact with moisture. By only adding rice husk to the soil, there was only slight improvement to the CBR and MDD. It is due to the fact that rice husk is fairly neutral compound and does not react unless an activator is added, in this case it is lime. Slight reaction between soil and rice husk has taken place, and the specific gravity of rice husk is lesser than soil, so there is an increase in MDD. MDD increased from 1.67g/cc in case of Sample 1 (Soil 100%) to

Table 2

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

1.92g/cc when 2% rice husk is added.

CBR value also increases from 5.88 in case of sample 1 to 6.44% in case of sample 5 (4% GGBS. But when activator is not added then significant increase in CBR does not take place.

When lime is added to the mix, then lime acts as a cementitious compound and also act as an activator which helps in significant gain in MDD and CBR. Also, the specific gravity of the soil has slight increase.

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.

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 = 2% RH+ 1% Lime

Weight of 8% RHA = 1920*2/100 = 38.40 kg in 1m^3 of sample.

Weight of Rice Husk in 6000 m^3 = 2,30,400 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 10.5 per kg or Rs 10500 per tonne

Net Savings = Cost of Road without Admixture - Cost of Road With admixtures = 2,46,89,847-2,34,13,276 = 12,76,571

Net Savings % = (Net Saving/Cost of Road without Admixtures)*100 = (12,76,571 / 2,46,89,847)*100 = 5.17%

It is found in the results that maximum CBR was found to be 10.13% at Sample 13 (Soil + 2% rice husk +1% Lime). At the particular CBR, the Crust thickness was calculated as 570 mm.

Table 3
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 +2% Rice husk + 1% Lime (Sample 13)	10.13	500	570	200	250	80	40
3	Reduction in Crust Thickness	-	-	100	70	-	30	-

Table 4
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	10500	1209600
	Rice husk at Site	tonne	230.4	6000	1382400
	Cost of water	KL	72.0	250.00	18000.00
4	**Overhead Charges (1+2+3) @ 10%**				264368.85
5	**Contractor's Profit (1+2+3+4) @10%**				267766.95
6	**Cost of 6000 m^3**				3175836.75
7	**Rate per m^3 (1+2+3+4+5)/6000**				529.30

Rate of Sub grade Preparation with admixtures = Rs 529.30 /m^3

Table 5
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	120	7,20,000
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	-	-	2,46,89,847

Table 6
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	529.3	3,17,5836.73
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	-	-	2,34,13,276

Table 7
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 %
2,46,89,847	2,34,13,276	12,76,571		12,76,571	5.17%

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 12,76,571 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 5.17%.

6. Conclusion

From the research paper on stabilization of expansive soil using Lime and rice husk 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 1,65,018.00. 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 furture 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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