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Feasibility Study of Improving Properties of Black Cotton Soil Using Industrial Wastes

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Abstract - Expansive nature of black cotton soil generates lot many problems in pavement construction. It drastically affects the performance and life of the pavement. Thus for good performance and long life of road it is important to improve the properties of black cotton soil. This study deals with improving the properties of black cotton soil through addition of locally available industrial wastes as Foundry Sand, Rice Husk Ash and Bagasse Ash. Laboratory tests were conducted on various proportions of mixes of black cotton soil and industrial wastes 0% to 60% at the interval of 10%. The soaked CBR value untreated soil is 2.08%. The soaked CBR value of mix soil: rice husk ash in the proportion of 60:40 is 10.04% which is increased by 79.28% in comparison with untreated soil. Stabilized pavement by using industrial wastes saved 21.91% cost as comparison with conventional flexible pavement.

Keywords - Black cotton soil, Foundry sand, Rice Husk ash, Bagasse ash, CBR value.

1. INTRODUCTION

Black cotton soil causes many problems to road constructed on it. About 20% of the soil found in India is expansive in nature. Roads on black cotton soils are known for bad condition. In rainy season black cotton soil absorbs water heavily which results into swelling and softening of soil. In addition to this it also loses its strength and becomes easily compressible. Black cotton soil has tendency to heave during wet condition. In summer season reduction in water content it shrinks and produces cracks. Thus as a result of this roads on black cotton soil suffer from early failures in pavement with heavy traffic excessive unevenness, ruts, waves and corrugations are formed.

It is proposed to study causes of roads failure on black cotton soil. Typical behavior of these soils under different climatic conditions has made the construction and maintenance of road not only expensive but also difficult. The failure occurs after every monsoon season, resulting in heavy cost of maintenance demand every year. The black cotton soils are very poor and undependable subgrade material. Hence the main problem is to treat the subgrade soil itself such that the undesirable characteristics are modified by stabilization. Stabilization is the process of improving the engineering properties of soil and making it more stable. Now a days there is problem to utilization of industrial waste because thousands of tones wastes are generated from industry. The usage of industrial waste in stabilization of soil becomes economical and it is easily available.

There is a need to focus on improving properties of black cotton soils using cost effective materials like treating with industrial wastes those having cementitious properties. In this study, industrial wastes like rice husk ash (RHA), Foundry sand (FS) and Bagasse ash (BA) are used to improve geotechnical properties of a soil.

1.1 Research Design

The problems related to road construction on black cotton soil is minimized in this work, the flow of work as follows

Sample collection- The sample of black cotton soil was collected from Bavachi, Dist- Sangli, Maharashtra. Various laboratory tests carried out on soil to determine the properties of black cotton soil

Tests after addition of wastes- Three wastes are used in this work foundry sand, rice husk ash and bagasse ash to improve the properties of black cotton soil at 0 to 60% proportions independently. These wastes are easily available in local area.

Optimum amount of stabilizer- Various test are carried out on mixes soil and industrial wastes. From the Soaked CBR tests optimum amount of stabilizer required is obtained

Cost analysis- Cost analysis of conventional flexible road and stabilized road is done for 1km road length

1.2 Objective of study

- To study the properties of black cotton soil consistency limits, shear strength parameters and CBR value
- To study the changes in properties of black cotton soil by adding stabilizers.
- To find out optimum amount of stabilizer required for stabilization of black cotton soil.
- Cost analysis

2. PREVIOUS RESEARCH WORK

A.Sreerama Rao, G. Sridevi (2011) reported that lime stabilized granulated blast furnace slag is suitable for sub-base layer. CBR test was conducted on the soil. The shear strength of the soil increases due to addition of lime. Any material to use it as a road sub-base should posses minimum soaked CBR of 20%

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Dr. Praveen Kumar, Dr. G D Ransinchung R. N. & Aditya Kumar Anupam (2012) studied the waste materials as an alternative to conventional materials in rural road. They reported that admixing of rice husk ash improves the CBR of the soil. Blast furnace slag improves the properties of soil.

E. A. Meshida, G. L. Oyekan, A. O. Ogundalu (2013) carried laboratory investigation on the influence of steel mill dust on characteristics of tropical black cotton soil. The addition of steel mill dust increased the Maximum Dry Density (MDD) of tropical black cotton soil about 28%. This is considered satisfactory to excellent.

Moses, G and Osinubi, K. J. studied the influence of compactive efforts on black cotton soil treated with up to 8% ordinary Portland cement (OPC) admixed with up to 8% bagasse ash(BA). Finally they got an optimal mix of 8% OPC and 4% bagasse ash (BA) for treatment of black cotton soil for uses as a sub-base material.

3. MATERIAL USED

3.1 Soil

The soil use for this study is collected from Bavachi, Maharashtra. This soil has black-grey color. The index properties such as liquid limit, plastic limit, plasticity index and other important soil properties as per AASHTO and soil classification systems are presented in Table 1.

Table 1 Physical properties of soil

Properties	Values	Literature Review	Remark
Liquid Limit (%)	66.67	40-85	Very High
Plastic Limit (%)	38.89	23-48	High
Plasticity Index (%)	27.78	14-43	_
Specific Gravity	2.47	2.63	_
Maximum Dry Density (gm/cc)	1.58	1.21-1.82	Standard Proctor
Optimum Moisture Content (%)	21.79	11.2-27	
CBR Value	2.08	1.54-4	Less, 5% is good

The partical size distribution graph of black cotton soil shows that the soil is poorly graded because uniform size particles are present in soil.

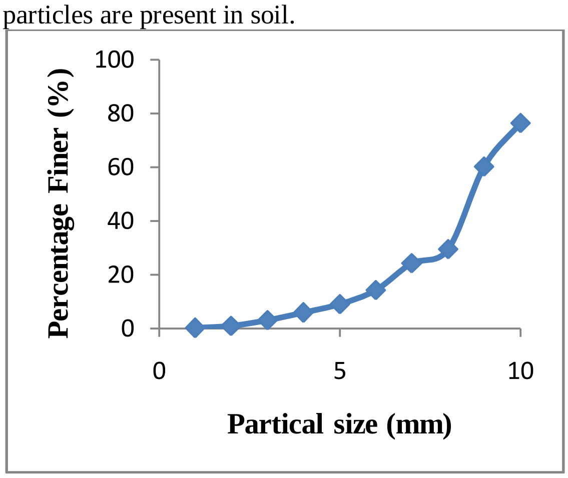

Fig.1. Grain size distribution of soil

3.2 Foundry sand

Foundry sand is byproduct of ferrous and non-ferrous metal casting process. Foundry sand has uniform grain size per source and high structural integrity.The Foundry sand used in this work was obtained from Siddhivinayak founders and engineering works, Gokul shirgaon MIDC, Kolhapur, Maharashtra. The properties of foundry sand are in table below.

Table 2 Properties of foundry sand

S.No.	Physical parameters	value
1	Colour	Black
2	Specific gravity	2.55
3	Liquid limit (%)	
4	Plastic limit (%)	Non plastic
5	Plasticity index	-
6	Dry density	1.77 gm/cc
7	Optimum (%)moisture content	9.5

3.3 Rice husk ash

Rice husk is an agricultural waste obtained from rice milling. The rice husk ash used in this work was obtained from Maharashtra rice mill Koparde haveli, satara district, Maharashtra. Rice husk ash was burned at 400^o to 500^o temperature. The properties of rice husk ash are as below.

Table 3 Properties of rice husk ash

Sr. No.	Physical parameters	value
1	Colour	Black
2	Specific gravity	2.05
3	Liquid limit	Non -plastic
4	Plastic limit	Non- plastic
6	Dry density	1.04 gm/cc

3.4 Bagasse ash

Bagasse ash is by-product of sugar manufacturing. When juice is extracted from the cane sugar. The bagasse ash was collected from “Rajarambapu sahakari sakhar Karkhana, Rajaramnagar sakharale. Tal – Walwa, Dist – Sangli. The Fig. shows the bagasse sample.

Table 4 Properties of bagasse ash

Sr. No.	Physical parameters	value
1	Colour	Black
2	Specific gravity	1.307
3	Liquid limit	Non -plastic
4	Plasticity index	-
5	Dry density	1.17 gm/cc

3.5 Wastes combination

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	Soil	FS (%)	RHA (%)	BA (%)
1	100	0	0	0
2	90, 80, 70, 60,50,40	10, 20, 30, 40,50,60	0	0
3	90, 80, 70, 60,50,40	0	10, 20, 30, 40,50,60	0
4	90, 80, 70, 60,50,40	0	0	10, 20, 30, 40,50,60

Table 5 wastes combination with soil

4. Laboratory Investigation and Interpretation Of Results

The influence of FS, RHA and BA on the geotechnical properties of black cotton soil of were investigated by conducting various laboratory tests viz. consistency limits, standard proctor and California bearing ratio (CBR) test.

4.1 Liquid Limit (LL) and Plastic Limit (PL) : IS: 2720 (Part V) 1985

The value of liquid limit for various proportions of black cotton soil and FS, RHA, BA are given in table. The value of liquid limit is decreased after addition of wastes with respect to untreated soil. In case of addition of 40 % foundry sand liquid limit value is greatly decreased at 33.82%. The liquid limit values of soil after addition of various percentages of wastes are listed in Table 6.

Table 6 Liquid limit value after addition of wastes

% waste	Liquid limit (%)		
	Foundry sand	Rice husk ash	Bagasse ash
0	66.67	66.67	66.67
10	59.1	61.25	62.5
20	53.25	54.83	52.08
30	46.92	50	49.2
40	44.12	47.72	50.84
50	50.95	44.39	53.18
60	54.14	48.81	48.2

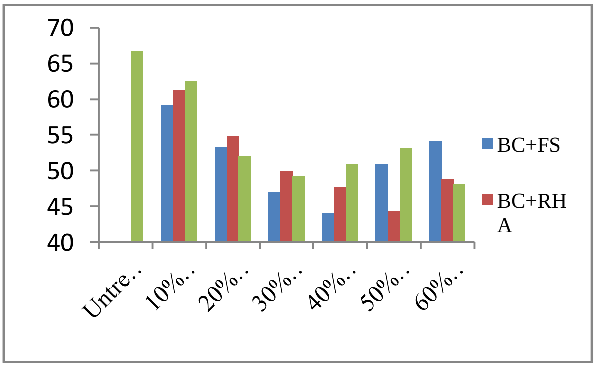

Fig. 5 effect of wastes on liquid limit of soil

4.2 Plasticity Index

Plasticity index is the numerical difference between the liquid limit and plastic limit of soil. After addition foundry sand plasticity index value increases for 10% then decreases up to 40% and again increase after 40%. In case of addition of rice husk ash and bagasse ash the plasticity index value increases for 10% addition then decreases up to 50% addition and after 50% it again increases. The values of plasticity index are given in Table 7.

Table 7 plasticity index after addition of wastes

% waste	Liquid limit (%)		
	Foundry sand	Rice husk ash	Bagasse ash
0	27.28	27.28	27.28
10	28.52	29.09	29.64
20	25.67	27.47	29.09
30	27.12	23.7	28.42
40	19.74	23.72	20.71
50	28.45	19.37	15.5
60	31.3	24.76	19.96

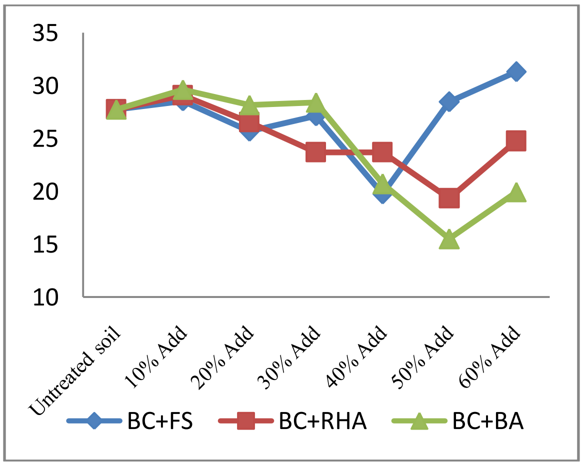

Fig. 6 effect of wastes on plasticity index of soil

4.3 Standard Proctor Test: IS: 2720 (Part VII) 1980

This method covers the determination of the relationship between moisture content and the density of soil compacted in a mould of a given size with 2.6kg rammer dropped from a height of 310 mm. This test is required to assess the amount of compaction and water content required on the field.

Table 8 Maximum dry density after addition of wastes

% waste	Liquid limit (%)		
	Foundry sand	Rice husk ash	Bagasse ash
0	1.58	1.58	1.58
10	1.608	1.42	1.513
20	1.628	1.36	1.51
30	1.643	1.22	1.355
40	1.651	1.24	1.382
50	1.628	1.256	1.389
60	1.59	1.261	1.41

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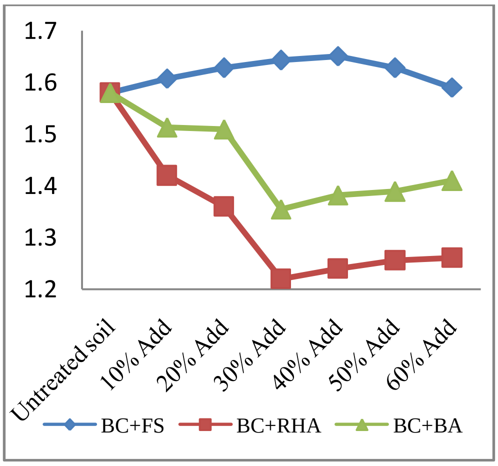

Fig. 7 effect of wastes on MDD of soil

Graph shows that after addition of foundry sand Maximum Dry Density increase up to 40% then decreased. In case of other two wastes the values of Maximum Dry Density decrease up to 30% and then increased.

4.4 California Bearing Ratio Test

The soaked CBR value of black cotton soil after addition of all three wastes increases up to 40% addition and after it decreased. The maximum soaked CBR value 10.04% is obtained at 40% addition of rice husk ash. CBR test is most important test because as per IRC the pavement thickness is depends upon CBR value of soil. Hence from Soaked CBR test result 40% optimum value of adding industrial wastes is obtained.

Table 9 CBR values after addition of wastes

% waste	Liquid limit (%)		
	Foundry sand	Rice husk ash	Bagasse ash
0	2.08	2.08	2.08
10	3.67	4.83	3.67
20	6.25	6.91	5.65
30	8.4	9.58	8.22
40	8.92	10.04	8.76
50	8.12	9.59	8.01
60	6.98	8.48	7.52

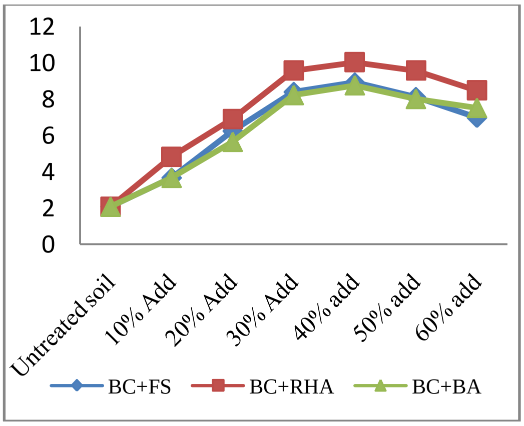

Fig. 8 effect of wastes on CBR of soil

All results obtained from the tests shows the changes in properties of black cotton soil after addition of various percentages of industrial wastes. The gradation of soil is changes after addition of wastes due to which gap between soil particles is reduced. The soil particles comes closer to each other and compact effectively due to which dry density and CBR values of soil increases result into stability of soil increases. Industrial wastes are non-plastic in nature hence the as the percentage of wastes add into the soil water absorption of soil reduced. The soil shows good drainage property.

5. Design of Pavement Thickness

The construction of road by treating subgrade soil with foundry sand, rice husk ash and bagasse is suitable in locally area. This is illustrated with design of road as per IRC: 37 – 2001. The data considered for design of single lane pavement is given below:

i. Initial traffic in the year of completion of construction = A = 200 CV/day
ii. Growth rate per annum = r = 5.5 = 0.05
iii. Design life = n = 10 years
iv. Vehicle damage factor = F = 2.5
v. Single lane road = D = 100% = 1
vi. CBR of subgrade = 2.08%

For the subgrade soil treated with foundry sand, the CBR value is increased to 8.92% from 2.08% for proportion of 60:40. For the above data and CBR 8.92%, the pavement thickness obtained is 450mm. Therefore, the reduction in pavement thickness is 210 mm. For different wastes are as given in Table 8

Table 10 Design of pavement thickness

Wastes	CV/day	msa	CBR %	Thickness (mm)	Reduced thickness mm
Untreated BC Soil	200	2.2	2.08	660	-
Foundry sand	200	2.2	2.08%	450	210
Rice husk ash	200	2.2	2.08%	380	280
Bagasse ash	200	2.2	2.08%	470	190

6. Cost Analysis

The cost analysis for construction of flexible pavement by conventional method and construction of stabilized pavement is given in Table

Table 11 Cost analysis for conventional and stabilized road

Pro portion	Soaked CBR %	Cost of construction Rs
100:00	2.56 (Conventional flexible pavement)	11, 01, 400/-
60:40	10.04 (Stabilized pavement)	8, 60, 500/-

[**NOTE**: The cost analysis is done according to Maharashtra PWD DSR (For Pune region) 2012-13]

7. Conclusion

In the present study performance of three industrial wastes foundry sand, rice husk ash and bagasse ash in road construction on black cotton soil are studied through laboratory investigation. The various tests like Liquid limit, standard proctor and CBR test were conducted. The following conclusions have been made from these test results.

1. The liquid limit values of black cotton soil decreased after addition of waste material. It has been seen that maximum decrement by 33.82% after addition of 40% foundry sand. Reduction in liquid limit improves the drainage property of soil.
2. The value of maximum dry density is increased continuously after addition of foundry sand. Maximum increased by 4.30% at 40% addition of foundry sand. Improvement in maximum dry density helps us to provide stable working platform mainly in rainy season.
3. The CBR value of black cotton soil increased after addition of all three waste material separately but for addition of 40% rice husk ash it increased maximum (10.04%) as compared to untreated soil (2.08%). Good CBR value increases the stability of soil.
4. As per IRC 37:2001 Pavement thickness for flexible pavement by conventional method of 2.08% CBR value is 660 mm and for rice husk ash stabilized road of 10.04% CBR value is 380mm. Stabilization saves the natural material.
5. Pavement thickness for stabilized road is reduced by 280mm and cost saving is 21.91% with respect to flexible pavement of 1km road length. It is economical to construction as well as maintenance of road.
6. The utilization industrial wastes are economical for local area and it is environmental friendly.

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