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COST EFFECTIVENESS OF FLEXIBLE PAVEMENT ON STABILISED EXPANSIVE SOILS

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ABSTRACT: Black cotton soil also known as expansive soil poses a lot of problems to structures resting over it. Flexible pavements with expansive soil subgrade have shown very poor performance due to differential settlement and cracking. The present study deals with the cost effectiveness of flexible pavement on stabilized expansive soil. The subgrade course was stabilized with lime and California Bearing Ratio (CBR) test was performed for different proportions of lime content. The thickness of various layers of pavement was then calculated in accordance with IRC: 37 [1]. Cost analysis was then made for pavements with both unstabilized and stabilized subgrade course based on Public Works Department (PWD) of Delhi. It was observed that when expansive soil was stabilized with 5% lime content, the drop in cost of flexible pavement was maximum.

Keywords: Expansive Soil, Lime, Cost Analysis, Subgrade, Pavement, California Bearing Ratio

1. INTRODUCTION

Transportation plays an important role in influencing the infrastructural development of a country. The ever-growing demand on India's roadways over the past few years, decreasing budget funds, and the requirement to provide an efficient, safe and cost effective road transport system has led to a need for providing cheaper road constructions in India. Problems associated with pavement construction further become far more critical, particularly in regions where the subgrade consists of expansive soils. Pavement structural response is very sensitive to the characteristics of the subgrade, which provides a firm support for such pavement structures. In India these soils cover about 800000 Sq. Km. area which is more than 20% of its surface area and extends over the states of Andhra Pradesh, Telangana, MP, some regions of UP and Rajasthan, interiors of Gujarat and some southern locations of India [2]. Pavement construction in regions showing existence of expansive soil has consistently shown poor performance. With variation of moisture in different seasons, subgrade has shown volumetric changes which has often resulted in heaving during rainy seasons and shrinkage during dry seasons. Hence, to overcome these problems it is necessary to provide a cost effective stabilization solution for such road networks.

The addition of lime to expansive soil provides an abundance of calcium ions and magnesium ions. These ions tend to displace other common cations such as sodium Na+ and potassium K+, in a process known as cation exchange. Calcium ions replace sodium and potassium ions which significantly reduces the plasticity index of the clay. A reduction in plasticity is usually accompanied by reduced potential for swelling. The addition of lime increases the soil pH, which also increases the cation exchange capacity.

2. EXPERIMENTAL PROGRAM

2.1 Materials Used

2.1.1 Black Cotton Soil

The soil used in the testing was black cotton soil was collected from Dobinagar, Nagpur. Physical and Engineering properties of black cotton soil used for testing are given in Table 1.

2.1.2 Lime

Lime was collected from the retail market of Azadpur, Delhi. Chemical composition and index properties of lime are shown Table 2 and Table 3 respectively.

2.2 Preparation and Testing of Specimen

The test specimens were prepared with different proportions of lime content. The percentages of lime addition were 2, 3, 4, 5, and 6 with the expansive soil. After finding physical and engineering properties of the soil, compaction test and CBR test were performed for each sample of soil mixed with different contents of lime.

Table 1 Physical Properties of the Soil

Property	Result
Specific Gravity	2.41
Liquid Limit	48%
Sand	11.8%
Silt	58.2%
Clay	30%
Plastic Limit	25.3%
Plasticity Index	22.7%
OMC	19%
Maximum Dry Density	1.56
CBR	1.9

Table 2 Chemical composition of lime (Sarkar et. al. [3])

Properties	Test value (%)
Minimum Array (Acidimetric)	95.00
Maximum Limits of Impurities	
Chloride (Cl)	0.10
Sulphate (SO_4)	0.50
Iron (Fe)	0.10
Lead (Pb)	0.02
Loss on Ignition	10.0

Table 3 Index properties of quicklime and hydrated lime (Sarkar et. al [3])

Properties	Quicklime	Water	Hydrated lime
Molecular weight	56	18	78
Specific gravity	3.3	1	2.2
Relative weight	1	0.32	1.32
Relative volume	1	-	1.99

2.2.1 Compaction Test

The tests were performed as per Indian Standard [IS 2720 Part VIII]. Maximum dry density (MDD) and optimum moisture content (OMC) were calculated for each test sample.

2.2.2 California Bearing Ratio Test

Soaked CBR tests were conducted on black cotton soil and soil mixed with admixtures as per Indian Standards. Sample was prepared in cylindrical mould and compacted in five layers. Then the compacted sample along with mould was submerged in water for 72 hours. After removing from water, the CBR test was performed under a constant strain rate of 1.25 mm/min.

3. RESULTS AND DISCUSSIONS

3.1 Compaction Test

It was observed that with increase in lime content (upto 5%), the maximum dry density increases. But further increase of lime content decreases this value. This due to the quick reaction of lime with the soil which brings changes in base exchange aggregation and flocculation. It leads to an increase in void ratio of the mix causing a decrease in the MDD of the mix. Summary of compaction test at different lime content is shown in Fig. 1. Fig.2 shows the variation of maximum dry density with lime content. The values of MDD were 15.6 kN/m^3, 16.2kN/m^3, 16.3 kN/m^3, 16.4 kN/m^3, 16.4 kN/m^3 and 16.0 kN/m^3, when lime was mixed with soil in the percentage of 0, 2, 3, 4, 5 and 6, respectively.

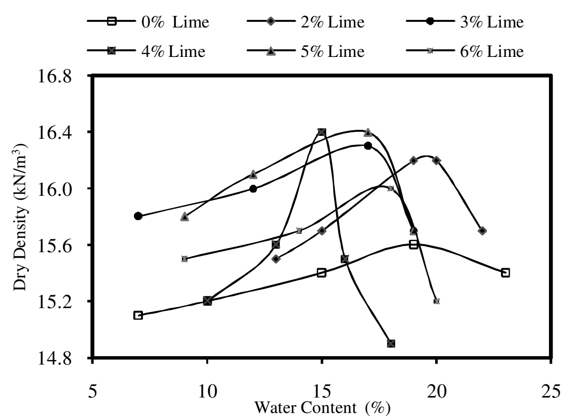

Fig.1 Summary of Compaction Test at Different Lime Content

3.2 California Bearing Ratio

Fig. 3 show the variation of CBR values obtained from the CBR tests conducted with both unstabilized and lime stabilized soil. The CBR values were 1.8%, 3.6%, 6.1%, 7.3%, 8.9% and 8.4% when lime was mixed with soil in the percentage of 0, 2, 3, 4, 5 and 6, respectively. It was observed that the values of CBR were increased upto 5% lime content and decreases thereafter. The

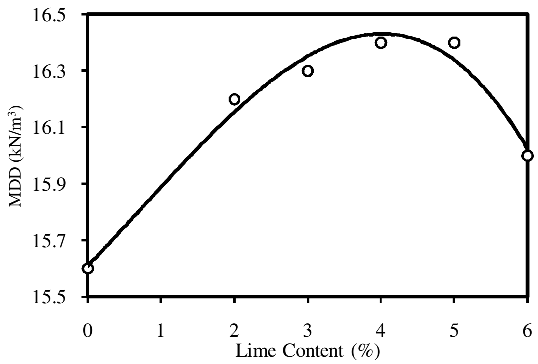

Fig. 2 Variation of maximum dry density with lime content

maximum value of CBR was obtained at 5% lime content. The behaviour of lime shows that strength should increase up to a certain limit of addition of lime and decreases thereafter [3]. The CBR value increases upto 5% addition of lime content is due to the fact that silica particles of soil are used up to this value and addition of more lime actually becomes counterproductive thereafter.

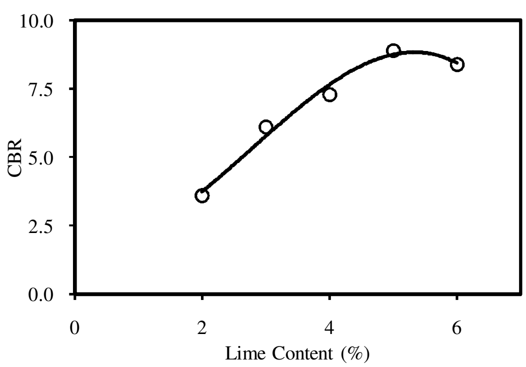

Fig. 3 Variation of CBR with lime content

3.3 Analysis of costs of pavement section

In the present study, the pavement is designed for a single subgrade soil. The various layers are considered as follows:

- Subgrade (SG)
- Subbase (SB)
- Water Bound Macadam (WBM)
- Dense Bituminous Macadam (DBM)
- Bituminous Concrete (BC)

The design data was assumed as per as per IRC: 37 [1] and it is as below:

Initial traffic in the year of completion of construction	=100msa
Design Life	=10 years

Fig. 4 shows the pavement section as per IRC: 37 [1] for subgrade which was made up of black cotton soil (CBR = 1.9%). Similarly Fig. 5 shows the pavement section as per IRC: 37 [1] for subgrade which was made up of black cotton soil mixed with 5% lime (CBR = 8.9%).

Table 4 shows the cost analysis of the subgrade course. Table 5 shows the construction cost of different layers including subgrade layer made of black cotton soil. Similarly Table 6 shows the construction cost of different layers including subgrade layer made of black cotton soil mixed with lime (5%). Based on the analysis, it is observed that the cost of saving is 32.5% if subgrade is made up of lime (5%) stabilized black cotton soil.

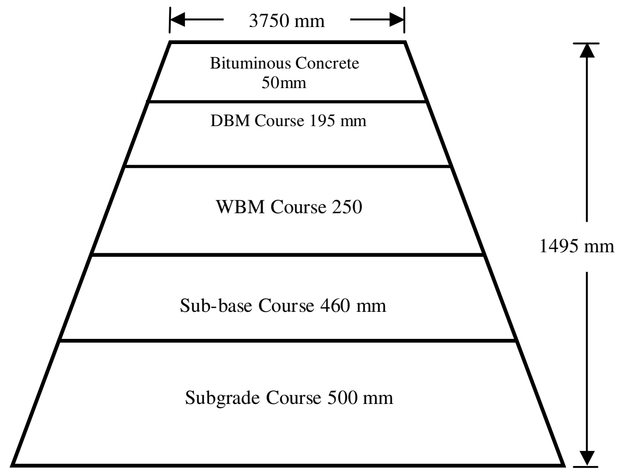

Fig. 4 Pavement section showing thickness of various layers for unstabilized black cotton soil

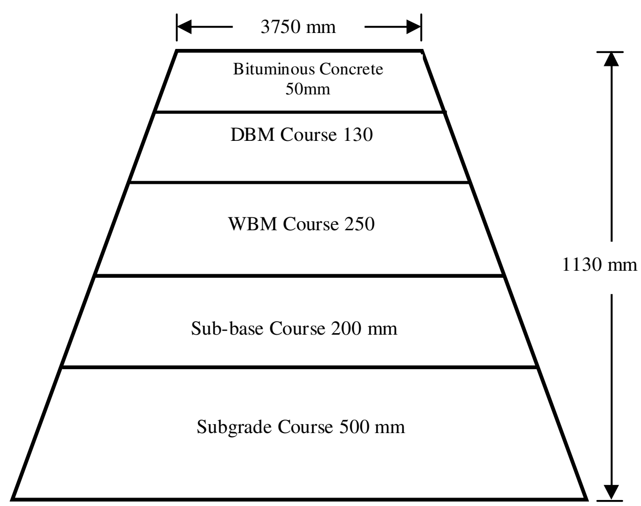

Fig. 5 Pavement Section showing thickness of various layers for stabilized black cotton soil

4. CONCLUSIONS

The following conclusions are drawn based on results presented from the present study.

1) It was observed that with increase in lime content (upto 5%), the maximum dry density increases. But further increase of lime content decreases the value.
2) Similarly, the maximum CBR value (= 8.9%) was obtained when 5% lime was mixed with soil.
3) 32.5% drop in cost was observed in pavement section having 5% lime stabilized subgrade course when compared with pavement with unstabilized subgrade course.

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Table 4 Cost analysis of subgrade course [4]

Taking Output: 100 m^3						
(a)	Labour Component					
	Sl. No.	Item	Unit	Quantity	Rate (Rs.)	Amount (Rs.)
	1	Mate	Day	0.04	360.49	14.42
	2	Labour (Unskilled)	Day	1.50	238.07	357.11
	Total					371.53
	Total per m^3					3.72
(b)	Machinery					
	Sl. No.	Item	Unit	Quantity	Rate (Rs.)	Amount (Rs.)
	1	Grader	Hr	2.00	1800.00	3600.00
	2	Dozer	Hr	0.50	1200.00	600.00
	3	Water Tanker	Hr	5.00	350.00	1750.00
	4	Vibratory Compactor	Hr	1.25	760.00	950.00
	5	Dumper	Hr	1.25	1400.00	1750.00
	6	Excavator	Hr	1.00	1700.00	1700.00
	7	Soil Spreading Unit	Hr	0.36	2250.00	810.00
	Total					11160.00
	Total per m^3					111.60

Table 5 Construction costs of different layers including subgrade layer made of black cotton soil

Sl. No.	Pavement Component	Top width (m)	Bottom width (m)	Height (m)	Volume (m^3)	Rate per m^3 (Rs.) [4]	Cost (Rs.)	Total Cost (Rs.) (1+2+3+4+5)
1	Bituminous Course	3.75	3.95	0.050	192.5	6402.75	12,32,529	110,16,150
2	DBM Course	3.95	4.73	0.195	846.3	5429.45	45,94,944	
3	WBM Course	4.73	5.73	0.250	1307.5	1371.14	17,92,766	
4	Sub-base Course	5.73	7.57	0.460	3059.0	953.81	29,17,705	
5	Subgrade	7.57	9.57	0.500	4285.0	111.60	4,78,206	

Table 6 Construction costs of different layers including subgrade layer made of black cotton soil mixed with lime (5%)

Sl. No.	Pavement Component	Top width (m)	Bottom width (m)	Height (m)	Volume (m^3)	Rate per m^3 (Rs.) [4]	Cost (Rs.)	Total Cost (Rs.) (1+2+3+4+5)	Saving in cost (%)
1	Bituminous Course	3.75	3.95	0.050	192.5	6402.75	12,32,529	74,35,233	32.5
2	DBM Course	3.95	4.47	0.130	547.3	5429.45	29,71,538		
3	WBM Course	4.47	5.47	0.250	1242.5	1371.14	17,03,641		
4	Sub-base Course	5.47	6.27	0.200	1174.0	953.81	11,19,773		
5	Subgrade	6.27	8.27	0.500	3635.0				
	a) Soil (95%)					111.6	4,05,666		
	b) Lime (5%)					7.00*	2,086		

*The rate of lime was taken per kg