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Experimental Study on Stabilization of Black Cotton Soil Subgrade using Bagasse Ash and Egg Shell Powder for the Design of Flexible Pavement

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Abstract : This study evaluates the potential of Bagasse Ash (BA) and Egg Shell Powder (ESP) to stabilize soft and expansive soil. The physical properties of clay, BA and ESP have been studied by conducting Specific gravity, wet sieve analysis, Liquid Limit (w_L) and Plastic Limit (w_P) tests. The soil has been classified as Clay of Medium Compressibility (CI). Light Compaction Test (LCT) has been carried out to determine the Optimum Moisture Content (OMC) of virgin soil. Then, for the purpose of determining the strength of virgin and stabilized soil, California Bearing Ratio (CBR) tests have been conducted. Optimum proportion of BA and ESP are to be replaced to stabilize the soil is determined by varying the proportions from 5% to 25% by weight of soil and addition of 3% of ESP then CBR tests are conducted. The design of flexible pavement for the CBR value and the estimation of savings in cost are carried out. The results of the experimental research show that soil replaced by 25% BA and addition of 3% of ESP can effectively be used as a soil stabilizer for subgrade as not only the CBR value has increased but also the expansive nature of clay is reduced. This leads to reduction in overall cost.
Keywords : Bagasse Ash(BA),Egg Shell Powder(ESP), California Bearing Ratio, Light Compaction Test, Optimum Moisture Content.

1.0 Introduction

Soil stabilization is a general term of any physical, chemical, biological or combined method of changing a natural soil to meet engineering purposes. Improvements include increasing the weight bearing capabilities and performances of *in-situ subsoil* , sands, and other wastes materials in order to strengthen road surfaces. The prime objective of soil stabilization is to improve the *California bearing ratio* of the in-situ soils by 4 to 6 times. The other prime objective of soil stabilization is to improve on-site materials to create a solid and strong sub-base and base courses. Originally, soil stabilization was done by utilizing the “rammed earth” technique and lime. Soil is the basic construction material. It supports the substructure of any substructure and is the subgrade which supports the sub base and base in the pavement. The existing soil at a particular location may not be suitable for the construction due to poor bearing capacity and high compressibility or even sometimes excessive swelling in case of expansive soil. So it is also necessary to determine the strength characteristics of the subgrade for the design of pavements. The properties of soil can be improved by stabilization it with admixtures. The cost of introducing renewable technologies and chemical admixtures has also increased in recent years. These opened gate for the researchers to find natural admixtures such as fly ash, sugarcane bagasse ash, ESP etc. Locally available soil is treated with sugarcane BA and ESP in different percentages up to CBR value increases. The CBR tests were done in un soaked condition [1]. Since the national society of professional engineers (NSPE) has explored some of the newer types of soil stabilization technology, specifically looking for “effective and green” alternatives. Among many literatures, lime and lime sludge have been used as additives with BA to improve unconfined compressive strength, plastic index, optimum moisture content and CBR value of that soil. In some other research papers lime, quarry dust, have been used as additive with ESP. Moreover, in some other researches BA has been used as partial replacement of cement and ESP has been used as a partial replacement of industrial lime. But in this research, black cotton soil has been replaced with varying percentage of BA and added with 3% of ESP to improve the subgrade CBR value and to find out optimum percentage of BA and ESP which has not been done so far.

2.0 Experimental Analysis

2.1 Materials

Soil is collected from Athipalayam is taken as subgrade material .BA is collected from sugarcane industry which is located in Udumalpet, Tamilnadu is used for stabilization of Expansive soil .The ESP is collected from kurumbapalayam, which is later powdered also used for the stabilization of black cotton soil.

2.2 Methods Used & Results Discussed

Classification tests

The results of classification tests conducted on the Virgin soil and BA plus ESP used in the present study are given in table 1 and 2 respectively.

Table 1 Physical Properties of virgin soil

Soil Properties	Description
Liquid limit, w_L	42.05%
Plastic limit, w_P	28%
Plasticity index, I_P	14.05
IS classification	CI
Specific gravity	2.17
Type of soil	Clay of medium compressibility

Table 2 Physical Properties of BA

Properties	Description
Liquid limit	Non-plastic
Plastic limit	
Specific gravity	2.0

Chemical composition and properties given as percentage of total weight of BA used in this study obtained from the manufacturer are shown in table3.

Table 3 Chemical Properties of BA

Constituents	(%)
Silica	66.23
Iron	3.09
Calcium	2.81
Magnesium	1.54
Sodium	0.26
Potassium	6.44
Loss of ignition	16.36
Alumina	1.90
Titanium	0.07
Manganese	0.60

Light Compaction Tests

The objective of Light Compaction Test is to determine the Optimum Moisture Content (OMC) which results in Maximum Dry Density (MDD) so that it could be used for compaction of the pavement material in the CBR mould. The results of the tests are given in table 4.

Table 4 Results of Light Compaction Tests

Material	**OMC (%)**	**MDD (g/cc)**
Virgin soil	20	1.5664
Virgin soil replaced by 5% BA+3% ESP	16.8	1.5578
Virgin soil replaced by 10% BA+3% ESP	16.25	1.566
Virgin soil replaced by 15% BA+3% ESP	16	1.5772
Virgin soil replaced by 20% BA+3% ESP	15	1.638
Virgin soil replaced by 25% BA+3% ESP	15.35	1.616

The results of the Light Compaction Test for Virgin soil and various BA added ESPmixtures are shown in Fig.1.It can be observed that the maximum dry density decreases with increase in % of BA with constant percentage of ESP. This is because specific gravity of BA is relatively lower than that of virgin soil. The increase in OMC is obviously due to the addition of BA which is finer relative to virgin soil. Addition of finer particles increases the overall specific surface area and these results in higher OMC. It must also be noted that MDD always decreases with the increase in OMC.

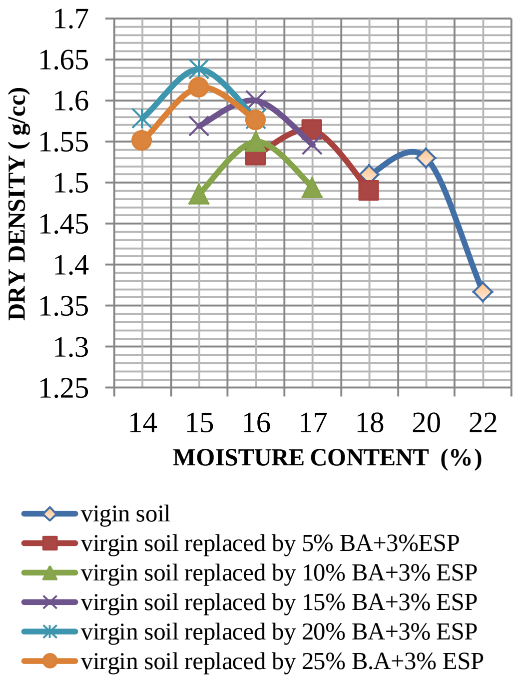

Fig.1Light Compaction curves for various mixes

2.3 California Bearing Ratio Test

The CBR test is a penetration test for the evaluation of strength of pavement material. Here, CBR tests have been conducted for every mixes. For the design of flexible pavement as per IRC:37-2001, [7] the CBR values of various components of the pavement are used. The results of the CBR tests are presented in table 5.

Table 5 Results of CBR Tests

Material	CBR
Virgin soil	0.58%
Virgin soil replaced by 5% BA and 3% of ESP	5.30%
Virgin soil replaced by 10% BA and 3% of ESP	6.13%
Virgin soil replaced by 15% BA and 3% of ESP	8.80%
Virgin soil replaced by 20% BA and 3% of ESP	11.026%
Virgin soil replaced by 25% BA + 3% of ESP	12.23%

From table,it can be observed that there is a significant improvement in the CBR value with the replacement of BA and addition of ESP to virgin soil[4]. It is noted that when virgin soil replaced with 25% BA and addition of 3% ESP produces maximum CBR value.

3.0 Design of Flexible Pavement

3.1 Pavement Design for virgin subgrade

The first step in pavement design is to estimate the cumulative number of standard axles to be catered for the design, which is calculated as follows:

$$N = \frac{365[(1+r)^{n}-1]}{r} \times A \times D \times F$$

Where,

N = cumulative number of standard axles to be catered for the design in terms of msa
A = Initial traffic in the year of completion of construction in terms of number of commercial vehicles per day (CV/day)
D = Lane distribution factor (As per clause 3.3.5 of IRC37:2001, taken as 1.0 for single lane road)
F = Vehicle damage factor (As per clause 83.3.4.4 of IRC37:2001, assumed as 1.5)
n = Design life in years (As per clause 4.3.2 of IRC37:2001, assumed as 15 years)
r = Annual growth rate of commercial vehicles (As per clause 3.3.6.1 of IRC37:2001, assumed as 7.5%)

The initial traffic in the year of completion of construction can be calculated as,

$A = P\ (1+r)^{x}$

Where,

P = number of commercial vehicles as per last count (assumed as 120)
x = number of years between last count and yearof completion of construction (assumed as 2years).
Substituting the respective values,
A = 173.34 and
N = 3msa.

As per IRC: 37-2001, when highly expansive soil is present as a subgrade material, buffer layer having thickness ranging from 0.6 m to 1.0 m needs to be provided. When the CBR of subgrade is < 2%, pavement structure corresponding to CBR of 2% has to be provided. In addition to this a capping layer of thickness 150 mm whose CBR is not less than 10% should be introduced between subgrade and sub base. Since the subgrade is not only week (CBR=1.3%) but also expansive, a 600mm thick buffer layer whose CBR ≥ 10% is introduced between subgrade and sub base to counteract both the weakness and expansive nature of the subgrade.

From plate 1 of IRC37:2001, for the CBR value of 2%, the total pavement thickness is 1350mm.The recommended pavement structure is given in Fig.2

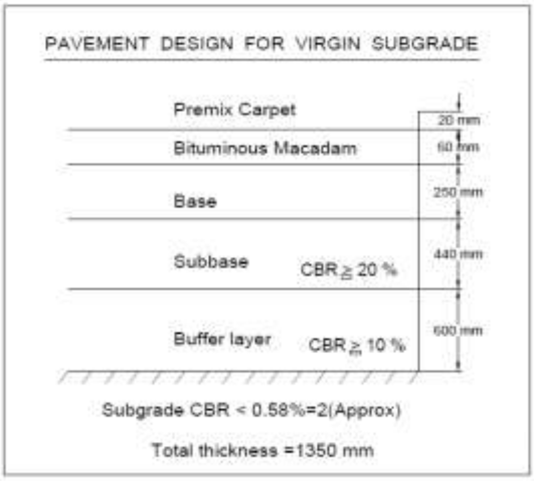

Fig.2Pavement Structure for virgin subgrade.

3.2 Pavement Design for the stabilized subgrade

When the virgin soil is replaced by 25% of BA and addition of 3% of ESP, the soil not only becomes stronger (CBR=12.23%) but also less expansive (turns to CL from CI). For this stabilized subgrade neither capping layer nor buffer layer is necessary[5].

From plate 1 of IRC37:2001, for the CBR value of 12.23 %, total thickness of the pavement is 450mm.The recommended structure of the pavement is given in Fig. 3

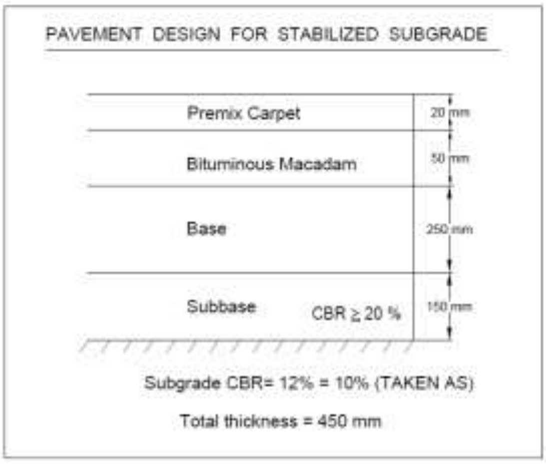

Fig 3 Pavement Structure for stabilized subgrade

4.0 Cost Estimation

4.1 Pavement for virgin subgrade

The quantity of various materials and cost of pavement per unit area of pavement structure for virgin subgrade are given in tables 6 and 7 respectively.

Table 6 Calculation of quantities for virgin subgrade

Items of works	No	L (m)	W (m)	D (m)	Qty (m^3)
Compaction of subgrade	1	1	1	0.5	0.5
Buffer layer	1	1	1	0.6	0.6
Sub base	1	1	1	0.44	0.44
Base	1	1	1	0250	0.25
BM	1	1	1	0.06	0.06
PC	1	1	1	-	1m^2

Table 7 Abstract of cost for virgin subgrade

Items of works	Qty	Unit	Rate per unit	Amount
			Rs	Rs
Compaction of subgrade	0.5	m^3	260	130
Buffer layer	0.6	m^3	650	390
Sub base	0.44	m^3	1280	563.2
Base	0.250	m^3	2360	590
BM	0.060	m^3	12870	495
PC	1	m^2	65	65
Total Cost / m^2 area = Rs 2510.40				

4.2 Pavement for stabilized subgrade (Subgrade treated with BA & ESP)

The quantity of various materials and cost of pavement per unit area for pavement structure, when the subgrade is stabilized with 25% BA and 3% of ESP by weight of virgin soil are given in tables 8 and 9 respectively.

Table 8 Calculation of quantities for stabilized subgrade

Items of works	No	L (m)	W (m)	D (m)	Qty (m^3)
Compaction of subgrade	1	1	1	0.5	0.5
Sub base	1	1	1	0.150	0.150
Base	1	1	1	0.250	0.250
BM	1	1	1	0.050	0.050
PC	1	1	1	-	1m^2

The MDD of mix with 25%BA= 1.6g/cc= 1.6t/ m^3
Volume of the mix per m^2 area of pavement = 0.5 m^3
Therefore, Mass of mix = 1.6 x 0.5 = 0.8t = 800kg
Mass of BA= 800x0.25=200 Kg
Mass of ESP= 800x0.03= 24 Kg

Table 9 Abstract of cost for stabilized subgrade

Items of works	**Qty**	**Unit**	**Rate Per unit**	**Amount**
			Rs	**Rs**
Compaction of subgrade	0.5	m^3	260	130
BA	200	Kg	1.50	300
Sub base	0.150	m^3	1280	192
Base	0.250	m^3	2360	590
BM	0.050	m^3	12870	643.5
PC	1	m^2	65	65
Total Cost / m^2 area = Rs 1920.50				

Total cost of pavement per unit area for pavement structure for stabilized subgrade is Rs.1920.50/-. Comparison shows a cost reduction of 23.4%, when the expansive and weak subgrade is stabilized with BA&ESP [7]. However, the reduction in cost is valid only for the example taken.

5.0 Conclusion

From the test results and cost estimation, the following inference has been made: The results of classification tests performed on the natural soil show that it is **clay with medium compressibility (CI)** BA replacing the soil by 5, 10, 15, 20 and 25 % and ESP addition for about 3% are found to increase the CBR value. Soil replaced by 25 % BA with 3 % addition of ESP produces the optimum result and further increase in additives leads to decrease in workability. With the liquid limit and the plasticity index of soil replaced with 25% BA and added 3% of ESP, the soil is found to be stabilized to **clay with low compressibility(CL).** Thickness of the pavement of stabilized soil is found to lesser than the thickness of the pavement of virgin soil.Comparison shows a cost reduction of 23.4%, when the expansive and weak subgrade is stabilized with BA&ESP.

6.0 References

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