Economic Appraisal of Lime and Sugarcane Waste Utilization in Road Construction

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Abstract. Clayey soil having Illite mineral, which expands or shrinks when it is in contact with moisture. Many cracks occurs on the structure which founded on this type of soil. The clayey soil passes low strength and excessive volume change. Many engineers face lot of problems in the engineering field. Therefore, we improve soil properties by some these methods mechanical, chemical, thermal and other mean. In this research work soil strength is evaluated after treatment with bagasse ash and lime. In this work, the different mix proportions of lime and bagasse ash were tested on compaction test, strength properties and CBR values of soil characteristics. The soil was stabilized with lime and bagasse ash in different proportions with 3%, 5%, 7%, 9% of lime and 10%, 15%, 20%, 25% of BA. All stabilized sample was cured on 7 days for determine index properties, compaction test results and CBR results. These various test results shows that with addition of bagasse ash and combination of lime, MDD decrease by 11% with increase the percentage of lime(7%) and BA(9%). However, OMC(16% to 19%) and CBR (2.5% to 14%) increases with increases the percentages of lime (7%) and BA (9%). The best results show on the effect of applying 7% lime as in combination with 20% bagasse ash on the geotechnical soil properties for 7 days cured soil samples. Therefore, this work shows the results that lime combination with bagasse ash can improve the properties of clayey soil with high plasticity and soaked CBR value. From these observations, it have been found that these wastes could be utilize in strength the soil sub-grade of a flexible pavement design and reduce the thickness of pavement layer with combination of lime and bagasse ash making it economical.

Keywords: Baggase ash, lime; Clayey soil, Pavement

1 Introduction

Soil stabilisation is use to decrease the permeability and compressibility of soil mass in earth structures and to increase its shear strength. Soil stabilisation is increase the bearing capacity of soil foundation. It is use for city and suburban streets to make them more noise absorbing. The industrially manufactured soil improving additives (like lime) have kept the cost of construction of stabilized road is financially high.

Many researches attempt to stabilize the clayey soil with use of cementious materials and industries waste as a combination: we focused here some works based on use of bagasse ash, which used in combination with lime or other cementious materials. Little (2001) successfully worked on improving the poor and expensive clayey soil subgrade. For maximum development of strength and durability, proper compaction is necessary. Sabat (2005) improved the strength of soil subgrade with BA and lime sludge. The different percentage of lime sludge was used 0%, 8%, 10%, 15% or 20% and BA percentages 2%, 4%, 6%, 8% or 10%. The optimum value of CBR at 76:8:16. These industrial waste lime sludge and BA can be utilized for strengthens the soil subgrade of flexible pavement in expensive soil areas with saving in cost of cost of construction. Gandhi et al. (2012) investigated on stabilization of expensive soil using bagasse ash. In this research work he concluded that the results show that when the percentage of bagasse ash (0 to 10%) is increased in the soil subgrade, the plasticity of soil decrease from 30% to 25% and plasticity index also reduces from 42% to 27% at same percentages of BA. Free swell index and swelling pressure decrease as percentage of bagasse ash increases. These experimental results were shows that soil stabilization by applying waste product bagasse ash successfully improves the existing poor and expansive subgrade soil. Manimar (2012) represented the use of bagasse ash and SCBA to improve the properties of expansive soils. He concluded that by using 6% bagasse ash with addition of 9% SCBA. Sadeeq et. al (2015) test was conducted on the used oil, contaminated lateritic soil treated with bagasse ash. CBR values of soil samples increases with BA increased but reduce with the used oil contamination. So, contaminated soils should be avoided to use as construction material.

1.1 Soil Stablisation Material Used

Lime. Lime is produced by burning of lime stone in kilns. The quality obtained depends upon the parent material and the production process. Lime reacts chemically with available silica and alumina in soils. Addition of lime causes a high concentration of calcium ions in double layer. It causes decrease in the tendency of attraction of water. Lime creates a reduction in plasticity. Lime adjustment has been widely used swelling potential and swelling weights in soils.

Fig. 1. Lime

Table 1. Chemical Composition of Lime

Description	Abbreviation	Lime (%)
Silica	SiO_2	0
Iron	Fe_2O_3	0.08
Calcium	CaO	95.03
Magnesium	MgO	0.04
Sodium	Na_2O	0.05
Potassium	K2O	0.03
Loss of Ignition	_	4.33
Alumina	Al_2O_3	0.13
Sulphur Triox-ide	SO_3	0.02
Manganese	MnO	0.6
Phosphorus	P_2O_5	0

Lime addition gives better improvement in a short time in clayey soil properties by decreasing plasticity and increasing strength of soil.

Baggage Ash

Bagasse ash is extract from the burning of bagasse in sugar production industries. Bagasse is the fibrous matter that remains after sorghum stalks crushed to extract their juice. It is recently use as a bio fuel and in the manufacture of pulp and paper products and construction materials. This bagasse ash is burnt the resultant ash is bagasse ash. For each 10 tonnes of sugarcane crushed, a sugar factory produces nearly 3 tonnes of wet bagasse. For electricity production, it is stored under moist conditions, and the mild exothermic reaction. These properties make bagasse particularly problematic the subject of a large body of literature. With its normal reactivity, Bagasse ash powder will set in stockpiles, even without sorted out curing.as the cost of fuel oil, natural gas and electricity has increased bagasse has come to be regarded as a fuel rather than refuse in the sugar mills. The bagasse ash based cement costs much less, than the normal cement sometimes is half its cost. Therefore, bagasse ash based cement not only imparts pozzolanic properties but also is more economical than the ordinary cement Bagasse ash contains large amount of silica, which is the most important component of cement replacing materials. Despite this abundance and silica content, relatively little have been done to examine the potential of this material for soil stabilization.

The workplace exposure to dusts from the processing of bagasse ash could cause the lungs disease condition pulmonary fibrosis, more specifically referred to as bagasse ashes.

Table 2. Chemical Composition of Baggase Ash

Description	Abbreviation	Ash%
Silica	SiO_2	66.23
Iron	Fe_2O_3	3.09
Calcium	CaO	2.81
Magnesium	MgO	1.54
Sodium	Na_2O	0.26
Potassium	K_2O	6.44
Loss of ignition	_	16.36
Alumina	Al_2O_3	1.9
Titanium	TiO_2	0.07

Fig. 2. Baggase Ash

Clayey Soil Used

Clayey Soil is a residual soil, which have been formed from basalt or trap and contain the clay mineral illite that causes excessive swelling and shrinkage characteristics of the soil. The swelling behavior of the soil will depend largely on the clay minerals that are present in those type soils and proportions of which they are present. There is a reduction in the water content, and these soils shrinks and cracks are form on surface of earth. These cracks formed at great depth into the ground surface of soil. Generally, these cracks are up to 20 to 25 mm wide.

Importance of Clayey Soil as the sub-grade soil is given below:
1. The soil remains in enhances the shear resistance of clayey soil in this way making its auxiliary capacity.
2. Promote uniform settlement.
3. Construction time can be utilised when ash remains soil methods are utilize.
4. The consideration of slag empowers the property of the utilization of poor quality soils to be utilized, as basic segments keep in respective, a preformation during CBR Tests have been arranged.

5. This removal and replacement technique both can be costly and time consuming. Where aggregates are large amount, the use of these non-renewable resources is viewed as non-sustainable, particularly distances are significant.

2 Experimental Research

2.1 Soil Sampling

The soil is clay of intermediate compressibility (CI). This soil was made expansive or highly clayey by adding bentonite slurry powder to it. By 15% adding bentonite, the clay soil started becoming expansive and exhibited same index properties as shown by expansive soil. Soil was collected for laboratory test and after than dried in oven. It was sieved through 2.36 mm.

2.2 Properties of Material

Soil

Table 2. Properties of Clayey Soil

S. No	Properties	Quantity
1	Specific Gravity	2.56
2	Atterberg' Limit	
	a) Liquid limit (%)	43
	b) Plastic limit (%)	30
	c) Plasticity index (%)	13
3	IS classification	CI
4	Standard proctor test results:	
	a) OMC (%)	16
	b) MDD (kN/m^3)	16.6
5	Soaked CBR (%)	2.5

Baggase Ash

Source of Bagasse ash used in study from Budhewal Sugar Mill in Budhewal village.

Table 3. Properties of Bagasse Ash

S. No.	Property	Values
1	Colour	Black
2	Standard proctor test results a) OMC (%)	16.7

	b) MDD (kN/m^3)	15.2
3	Specific gravity	1.95

Properties of the Lime

Lime used in this work was purchased from the local market in Ludhiana.

Table 4. Properties of Lime

Sr. No.	Property	Values
1	Colour	White
2	Standard proctor test results a) OMC (%)	16.7
	b) MDD (kN/m^3)	15.8
3	Specific gravity	2.23

2.3 Sample Preparation

Treatment and testing of sample was prepared with the method described in AASHTO T87-86. Then, sieve analysis is performing to separate the dried soils into two groups. Then, soil and bagasse ash is mixed manually to get uniform mix ratio for each test. Pycnometer test (Specific gravity), Moisture Content, Atterberg's Limits Testing, Liquid Limit, Plasticity Index, Compaction, CBR. For conducting various tests soil, lime and bagasse ash were mixed together in different ratios.

3 Results and Discussions

To observe the effect of lime and Bagasse ash on the compaction behavior of soil, standard Proctor tests were carried out in the lab. The result were shown in Figure 3.

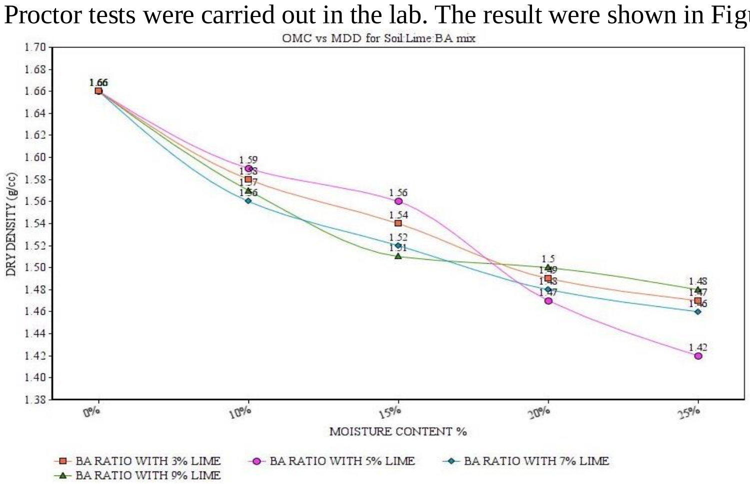

Fig. 3. OMC vs. MDD with Lime & BA variation

The reason of decrease in the maximum dry density is mainly due to the decrease in dry density of all treated soils is mainly due to low specific gravity value of bagasse ash (1.95) than that soil which replaced having specific gravity is(2.6). It may also be attributed to coating of the soil by the bagasse ash which result to large particles with larger voids and hence low density . Thus, there is less need for the soil to be dried to lower moisture content for compaction in the field.
The increase in the optimum moisture content was mainly due to the addition of lime and bagasse ash together increase the OMC compared to the both materials mix separately. The OMC increases with increases the BA because bagasse ash is finer than soil. The more fines the more surface area, so more water is required to provide well lubrication. The increase in OMC is due to pozzolanic reaction of silica and alumina in bagasse ash and soil with calcium of the lime to form calcium silicate hydrate (CSH) and calcium aluminates hydrate (CAH) which are the cementing agents. Additional water is also required for wetting the large surface area of the fine bagasse ash particles or is absorbed by the fine particles of the bagasse.

3.2 CBR Test for Soil Mix

The CBR soaked test of clayey soil sample was conducted on three soil specimens after compacting the specimen at OMC and MDD.

California Bearing Ratio Tests Results

CBR of virgin was calculated at OMC. The same tests were conducted after mixing lime as 3,5,7 and % of weight of soil. The samples were tested after 7 days curing and 4 days soaking. The CBR curves were shown in figure 4 (a) and its variation with lime was represented in figure 4(b). CBR tests were also carried out with variation of bagasse ash as 10,15,20, and 25% of soil weight keeping lime as 3, 5,7 and 9% lime. The variations of CBR were shown in figure 4(c).

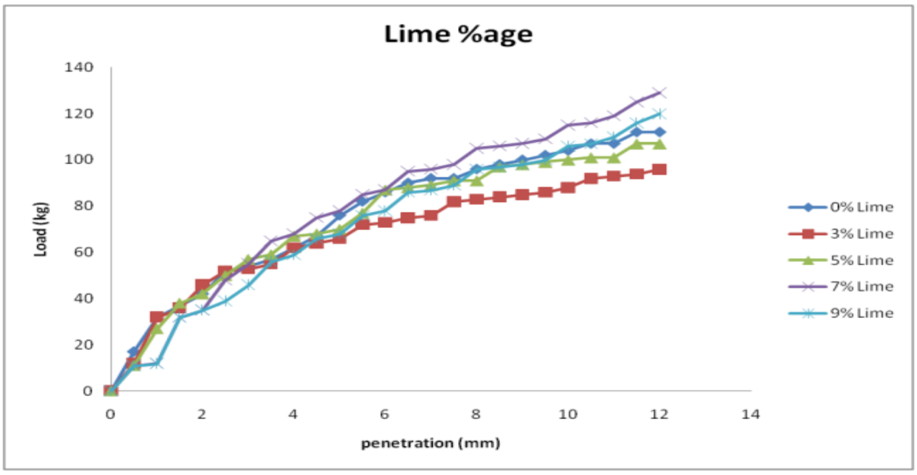

Fig. 4(a). CBR test values at different Lime %age (soaked cond.)

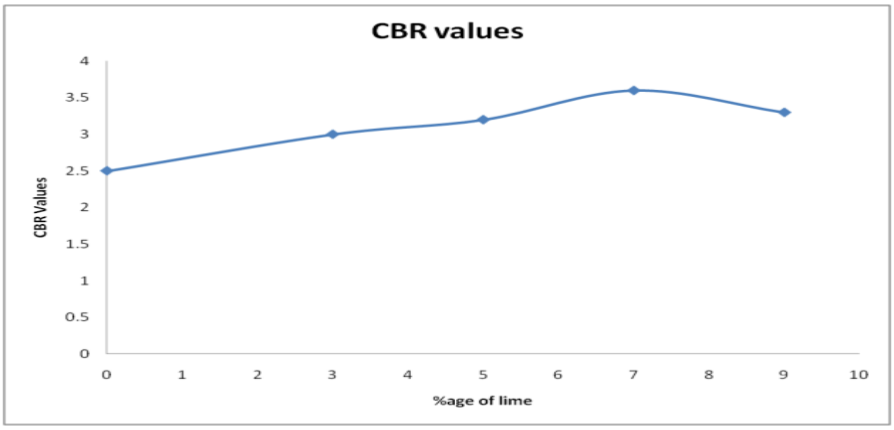

Fig 4(b): Variation of CBR at different Lime %age (soaked cond.)

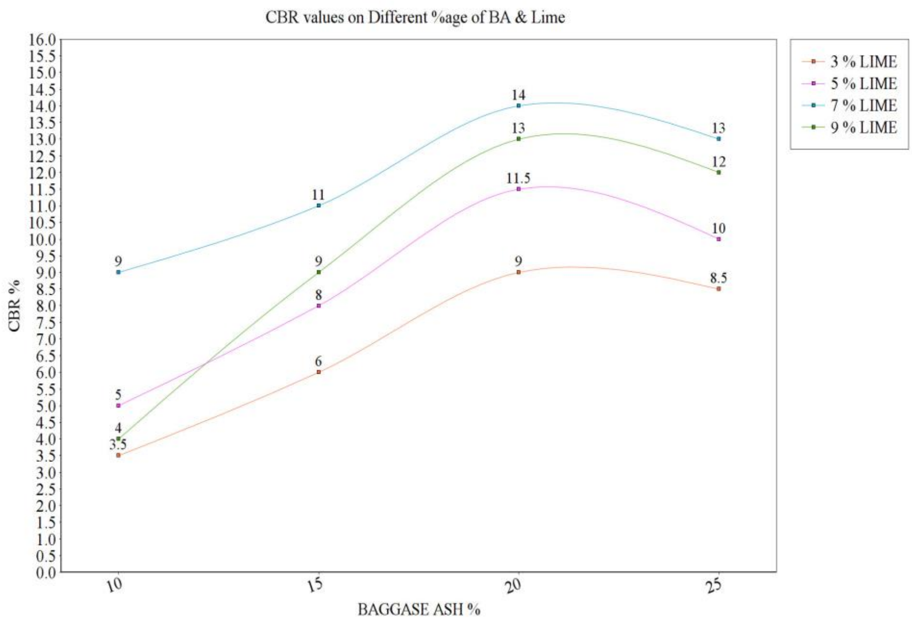

Fig. 4(c). CBR values on different %age of BA & Lime

The soaked CBR value of virgin soil is 2.5. These values are slightly increases 2.9, 3.2, 3.6, 3.3 with addition of lime at percentages 3%, 5%, 7% and 9%. After addition the both of combination of lime and bagasse ash the CBR increases more than single addition of lime. Firstly, this value of CBR increased to 11% and 14% on addition of 5% and 7% of lime on 15% and 20% of bagasse ash. Then value of CBR reduces are 13% at 25% of BA on lime 9%.

3.3 Calculation of Pavement Thicknesses

3.3.1 Granular Base and Granular Sub-base

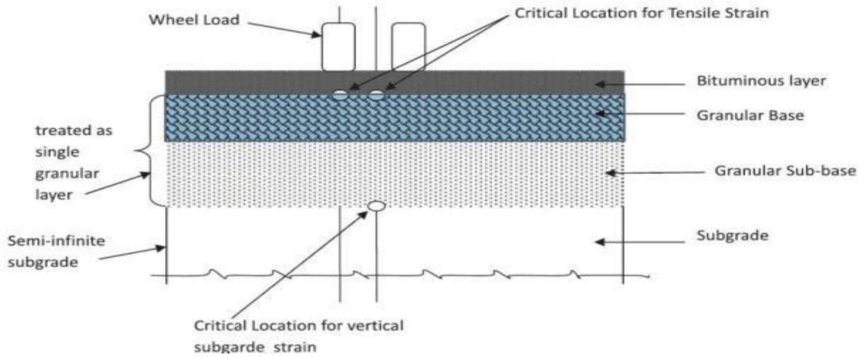

Fig. 5. Various Pavement Layers

The design traffic in terms of the cumulative number of standard axles to be carried during the design life of the road should be computed using the following equation:

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

<u>Case –1:</u> Sub-grade material was replaced by borrow material. In this case CBR = 8% was assumed.

<u>Case – 2</u>: Sub-grade was replaced by same soil mixed with 20% bagasse ash and 7% lime. In this case CBR = 14% was calculated by soaked CBR test.

Pavement composition interpolated as: (IRC37-2012 page 27 plate 3) Granular Sub base = 300 mm, Base course (WMM) = 250 mm, DBM =120 mm, BC =40 mm

Table 6. Design Layers

S. No	Description	Layers	Layers Thick-ness(mm)
1	100% Soil + 0% Lime + 0% Bagasse Ash	Granular Sub base	300
2		Base Coarse (WMM)	250
3		DBM	120
4		BC	40

1. Allowable Horizontal Tensile Strain in Bituminous Layer is 563.6 x $10^{-6}$for VG 40 mixes (Allowable value is 178 x $10^{-6}$from IRC: 37-2012).
2. II. Allowable Vertical Compressive Strain on Subgrade is 513.28 x 10–6 (Allowable value is 370 x 10–6 from IRC: 37-2012).

BC = 40 mm, DBM = 80 mm, WMM = 250 mm, GSB-330 mm. The computed strains from IITPAVE Software are

I. Horizontal Tensile Strain in Bituminous Layer is **422.8 $x10^{-6}$< 563.6 $x10^{-6}$**

II. Vertical Compressive Strain on Subgrade is **329.4 x 10–6 < 513.27 x 10–6**

Hence the Pavement Composition is Safe.

Table 7. Design Layers

S. No	Description	Layers	Layers Thickness(mm)
1	100% Soil + 0% Lime	Granular Sub base	250
2	+ 0% Bagasse Ash	Base Coarse (WMM)	200
3		DBM	100
4		BC	40

1. Allowable Horizontal Tensile Strain in Bituminous Layer is 527.9 x $10^{-6}$for VG 40 mixes (Allowable value is 178 x $10^{-6}$from IRC: 37-2012).
2. Allowable Vertical Compressive Strain on Subgrade is 513.28 x 10–6 (Allowable value is 370 x 10–6 from IRC: 37-2012).

BC = 40 mm, DBM = 80 mm, WMM = 250 mm, GSB-330 mm. The computed strains from IITPAVE Software are

I. Horizontal Tensile Strain in Bituminous Layer is **115.8 $x10^{-6}$< 527.9 $x10^{-6}$**

II. Vertical Compressive Strain on Subgrade is **355.4 x 10–6 < 513.28 x 10–6**

Hence the Pavement Composition is Safe.

Table 8. Conclusion Result of Flexible Pavement Thickness Design

Material	Descrip-tion	Layers	Layer Thick-ness(mm)	CBR%	Ef-fective CBR%	Conclu-sion
Virgin SOIL	100% Soil + 0% Lime + 0% Bagasse Ash	Granular Sub base, Base Coarse (WMM),DBM, BC	300+250 +120+40 =710	2.5(assumed 8%)	5%	The total thickness of flexible pavement gets reduced from 710 to 590adding LIME & BA mix with clayey soil was found at CBR 14%.
Soil+ Lime+ Bagasse Ash	73% Soil +7% Lime+20 % Ba-gasse Ash	Granular Sub base, Base Coarse (WMM), DBM, BC	200+250 +100+40 =590	14%	8%	
			Total 710-590 120mm			

4 Conclusions

Various experiments were carried out with a point of view to find a optimal dose of lime and Bagasse to decrease significant cost of flexible pavement. From the present study, following conclusions were drawn.

1. The OMC increases with increases of lime and bagasse ash mix. It increases from16% to 17% by adding 7% lime and 20 % bagasse ash and about 11% MDD was decreased by adding the same % of lime and bagasse ash.
2. CBR increases with increases of lime and bagasse ash mix. It increases from 2.5% to 14% by adding 7% lime and 20 % bagasse ash. Therefore the optimal dose of lime and bagasse ash 7% and 20% respectively.
3. The total thickness of pavement is reduced from 710 to 590 mm if 7% lime and 14% Bagasse ash was mixed in the soil. It may be concluded that adding lime and baggage ash in clayey soil for pavement is economically beneficial.

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