Soil Stabilization Using Bagasse Ash

Dharmesh Lal, M. Jeevan Kumar, K. Naresh Kumar, K. Sindhu and Ashok Kumar

Abstract Clay soils exhibit undesirable engineering properties like low shear strength, high compressibility and low permeability. The properties further deteriorate upon wetting or other physical disturbances. Hence, soil is stabilized before construction by soil stabilization techniques. Bagasse ash is a biodegradable waste material which can be effectively used as a stabilizer for soils after recycling or reprocessing. Bagasse ash has been found to improve the strength characteristics of soils. The main objective of this study is to investigate the use of bagasse ash in geotechnical applications to evaluate the effects of the waste powder on geotechnical characteristics of highly compressible clay soil deposits. The bagasse ash material is added to the soil in different proportions, i.e. 2, 4, 6 and 8%, to find the optimum percentage contributing to maximum strength development. The results obtained clearly indicate that the addition of the ash enhances the properties of the soil deposit.

Keywords Clay soils · Engineering properties · Bagasse ash · Stabilizer · Compressible clay · Optimum percentage

1 Introduction

Generally, clayey soil exhibits undesirable properties like low shear strength, low bearing capacity and high settlement. Clay soil is a mixture of several particles which are connected to each other. They rest on each other due to gravity and form grids based upon its properties. Each particle produces its own contact forces by the surrounding particle. These contact forces together hold all the individual particles at their place. The sudden water pressure leads to soil losing its cohesion. Once the soil loses its cohesive strength, it gets softened, weak and finally loses its solid properties. Due to these circumstances, it results in differential settlement, soil liquefaction and landslides. Also, black cotton soils encountered in many construction sites have poor engineering properties and become problematic because of their tendency to expand

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during wet season and shrink during dry season. These problems can be solved by improving the strength of the soil by the process called soil stabilization.

Soil stabilization is the process of enhancing the stability of soil by the use of suitable admixtures, stabilizers or mechanical means. For many years, engineers have used additives such as cement, lime and cement kiln dust to improve the physical properties of soil [1–9]. Field and laboratory performance tests have confirmed that the addition of such additives can enhance the stability and strength of such soils. However, the cost of introducing these additives has also increased in recent years. This has opened the door widely for the development and introduction of other kinds of soil additives such as plastics, bamboo and liquid enzyme soil stabilizers.

In this present study, an attempt has been made to improve the properties of clay soil by stabilization technique using bagasse ash. Laboratory investigations were carried out to know the effect of bagasse ash as a stabilizer when mixed in different proportions. Properties of soil obtained with and without adding the stabilizer were compared. Bagasse ash (Fig. 1) is a waste product obtained from the sugar supplying industries. Bagasse ash improved the basic properties and shear strength characteristics of clayey soils [9].

Extensive experimental investigations were carried out on soil stabilization using bagasse ash by [10]. It was observed that bagasse ash can significantly enhance the properties of the soil used in the construction of road pavement. The soil was mixed with varying percentages (0.0, 0.2, 0.4, 0.6, 0.8%, etc.) of bagasse ash, and the soaked CBR value was noted. The optimum dosage of bagasse ash was obtained at 0.6%. At optimum, an improvement of about 26% was obtained. Also, a reduction of CBR value was observed at 0.2% bagasse content as a result of dispersed structure.

The main aim of this study is to find out the benefits of bagasse ash in geotechnical utilization to check out the holdings of the bagasse ash on geotechnical characteristics of highly compressible clay soil deposits. The bagasse ash material is mixed with the soil in various proportions, i.e. 2, 4, 6 and 8%, to find the optimum percentage

Fig. 1 Bagasse ash

contributing to maximum strength development. Different tests such as Atterberg's limits, standard Proctor test and triaxial tests have been performed to find out the effect of bagasse ash on strength parameters of soil. Standard Proctor test results indicate that the optimum moisture content increases with increase in percentage of sugarcane bagasse ash and the maximum dry density decreases with increase in percentage of sugarcane bagasse ash. Also, an enhanced strength parameter values were obtained with the introduction of the ash. These results clearly show that sugarcane bagasse ash can be used as an effective stabilizer for reinforcing soil.

2 Materials and Methodology

2.1 Materials Used

Clay

Table 1 indicates the properties of black cotton soil used for the study.

Bagasse Ash

Bagasse ash (Fig. 1) is a waste product obtained from the sugar supplying industries. The composition of bagasse ash used for the study is enumerated in Table 2.

The triaxial tests were carried out by preparing the soil samples at maximum dry density condition with an aspect ratio of 2 (38 mm × 76 mm).

Table 1 Basic properties of black cotton soil

S. no.	Property	Value
1	Specific gravity	2.125
2	Liquid limit	59%
3	Plastic limit	37.95%
4	Plasticity index	21.05%
5	OMC	24.27%
6	MDD	14.60 kN/m^3
7	Cohesion	54.97 kPa
8	Angle of internal friction (degree)	10°
9	CBR	1.07%

Table 2 Composition of bagasse ash

Constituents	Percentage (%)
Silicon dioxide (SiO_2)	66
Aluminium oxide (Al_2O_3)	6
Ferric oxide (Fe_2O_3)	5
Calcium oxide (CaO)	2
Magnesium oxide (MgO)	2
Potassium oxide (K_2O)	6.5
Sodium oxide (Na_2O)	1
Phosphorous pentoxide (P_2O_5)	1
Sulphur trioxide (SO_3)	0.18
Cl_2	<0.1
Manganese oxide (MnO)	0.05
Titanium dioxide (TiO_2)	0.25
Loss of ignition (LOI)	10

3 Results and Discussion

Triaxial test is conducted for clay without adding any additives. The stress–strain curve obtained is shown in Fig. 2. Based on results, modified shear strength parameters, i.e. p and q values, are obtained and listed in Table 3.

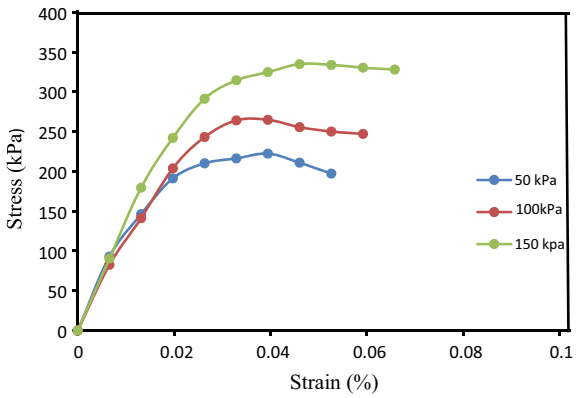

Fig. 2 Stress versus strain curve for plain soil

Table 3 Modified shear strength parameters

p	q
164.745	114.745
222.81	122.81
280	130

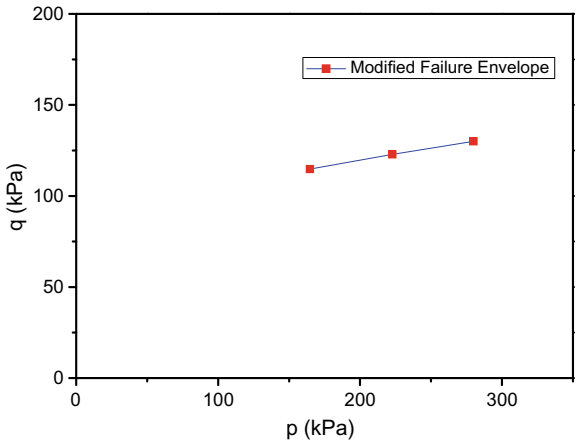

Fig. 3 Modified failure envelope

Figure 3 shows the plot between p and q which gives modified failure envelope, where p and q are given in Eq. (1)

$$p = \frac{\sigma_1 + \sigma_3}{2} \quad \text{and} \quad q = \frac{\sigma_1 - \sigma_3}{2} \tag{1}$$

- From the modified failure envelope, the intercept and the slope are found.
- By using these slope and intercept, the cohesion and the angle of internal friction are calculated.

For the normal soil, the shear parameters cohesion and angle of internal friction are found to be 54.97 kPa and 10°.

3.1 Strength Ratio

Strength ratio is the ratio of peak deviator stress of stabilized soil to the peak deviator stress of plain soil. The optimum percentage of plastic powder is obtained by plotting the graph between the % of bagasse ash and strength ratio. Table 4 shows the values of strength obtained for considered % of bagasse ash. Figure 4 shows the graph plotted between strength ratio and the % of bagasse ash.

Table 4 Strength ratio with respect to % of bagasse ash

% of bagasse ash	Strength ratio
2	1.11
4	2.86
6	3
8	1.44

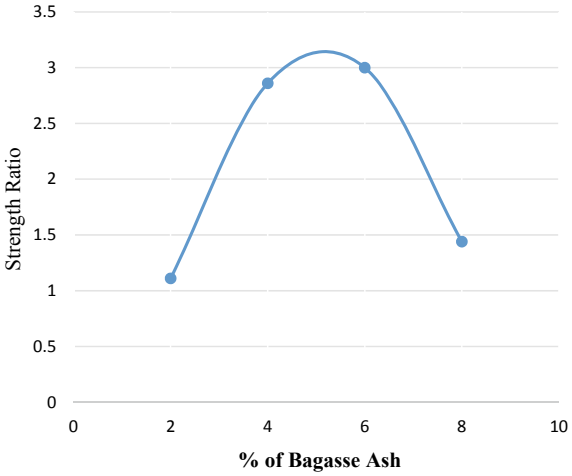

Fig. 4 Strength ratio versus % of bagasse ash

From the strength ratio graph, it is observed that optimum % of bagasse ash was 6%.

3.2 Triaxial Test Results for 6% Bagasse Ash

Triaxial test was conducted for pure clay with addition of 6% of bagasse ash as the optimum was obtained at this percentage. Based on the observations, the stress–strain curve was obtained (Fig. 5). The C and $\varnothing$ are found to be 164.46 kPa and 10.2° from the modified failure envelope (Fig. 6). The values of p and q are shown in Table 5.

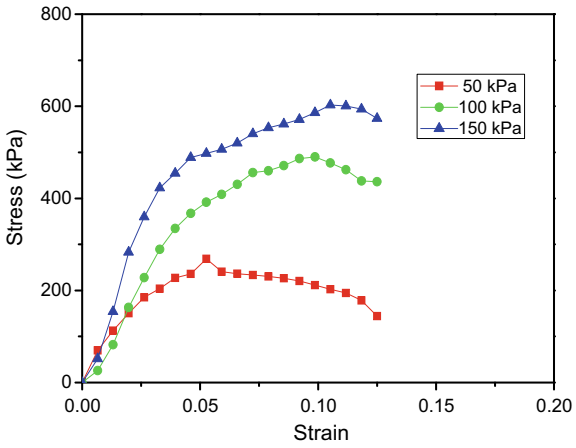

Fig. 5 Stress versus strain curve for 6% of bagasse ash

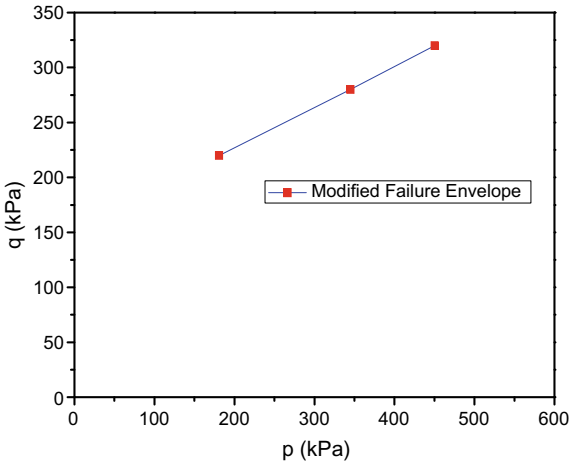

Fig. 6 Modified failure envelope

Table 5 p and q values

p	q
180.80	220
344.99	280
450.33	320

From the results, it is clearly understood that value of cohesion increases and thereby increasing the strength and stiffness characteristics of soil. Similar conclusions were drawn by [10]. This is mainly because of the pozzolanic properties possessed by the ash. As indicated by the composition of ash in Table 2, it consists of various amounts of silica and other relevant oxides which enhance the pozzolanic activity of the soil [10].

4 Conclusion

Based on the above tests conducted in the present study, the following conclusions were drawn.

1. The optimum percentage of the bagasse ash which gave maximum strength and stiffness improvement was found to be **6%**.
2. The C and ∅ values of the plain soil are 54.97 kPa and 10°, whereas the C and ∅ values of the reinforced soil were found to be 164.46 kPa and 10.2°.
3. Overall it can be concluded that reinforced soil can be considered as a good ground improvement technique, especially in engineering projects on weak soils.
4. The use of bagasse ash is a cost-effective and sustainable method of soil stabilization.

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