STUDY ON ENGINEERING PROPERTIES OF SOIL USING STONE DUST AND BAGASSE ASH

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Abstract - In the discipline of civil engineering, soil stabilization is the process of enhancing and improving the engineering qualities of soil so that it can support large loads without failing. The safe and efficient disposal of waste material without causing harm to society is a significant concern in a well-managed ecosystem. Utilizing solid waste products to stabilize soil has become more popular recently as a successful way to manage trash from many sectors. This paper reviews the usage of various solid waste items that have been applied to stabilize soft soils. However, there are numerous approaches and strategies for stabilizing this soil. This research offers a method for stabilizing soft soil using waste products. An investigation into the stabilizing potential of bagasse ash and sisal fiber for highly compressible clayey soil has been prompted by the rising expense of building traditional stabilizers and the necessity of inexpensively consuming industrial and agricultural wastes for value trade. There is a growing demand for sustainable construction, which is why recent research has concentrated on sustainable resource consumption trends. We can employ natural and biodegradable resources, as well as waste products, to obtain. This study was a large-scale laboratory experiment to explore the use of natural fibers, industrial waste, and agricultural waste to improve the engineering qualities of moderately compressible clay. The purpose of this study was to determine whether Stone Dust and Bagasse Ash were suitable for stabilizing clayey soil. The results of testing for consistency limits, maximum dry density, optimal moisture content, UCS, and (soaked) CBR were obtained using percentages of 10%, 15%, and 20% by weight of dry soil for Bagasse Ash and 6%, 8%, and 10% for Stone Dust. In this work, expansive soil was stabilized using Stone Dust and Bagasse Ash. Bagasse Ash was fixed at 15%, after that Stone Dust was changed to 3%, 6%, and 9%.

***Key Words*: Compaction test, CBR, UCS, Stone Dust, Bagasse Ash**

INTRODUCTION

Soil is the uppermost unconsolidated material of the earth present naturally in the universe. It is formed by the decomposition of rocks under the influence of naturally occurring conditions such as wind, rain, snow, heat, etc. It is abundantly available and is the cheapest construction material. It is a complex material because of its highly variable composition and characteristics. The characteristics of soil change according to topography and its location. For safer construction the properties of soil should match with the design requirements of an engineering structure. Geotechnical engineer plays an important role in this work for checking whether the requirements of the structure are fulfilled by the soil or not. Construction of engineering structures on poor soil involves a great risk. These soils show settlements, low shear strength and high compressibility.

Very often the available soil is not suitable for construction purposes.Strength, permeability and stability on slopes are the main aspects of soil that we have to deal with. For studying the engineering behaviour of soil, we have to deal with the stability of underground structures, retaining structures, foundations, slopes, earth dams and pavement construction.

2. Literature Review

SavithaA.L. et al. (2013) conducted compaction tests and UCS tests on Black Cotton soil using coarse and fine fly ash. They varied the percentage of flyash from 5% to 25% with increase of 5% at a time. Curing was done for 1,7,14,28 days. They reported that the strength obtained by fine Sugarcane Bagasse Ashwas 25% more than that of coarse fly ash.On increasing water contentupto 30%, the dry density decreases and if water content is increased further the dry density decreases gradually.The MDD was 1.35 g/cc for 5% Sugarcane Bagasse Ashmixed with 95% soil and lowest density was 0.6g/cc for 30% Sugarcane Bagasse Ashmixed with 70% soil.

Agrawal M.L. et al. (2013) performed compaction tests and CBR test on black cotton soil. They varied the percentage of fly ash from 10% to 50% with increase of 10% at a time. They investigated that the MDD increases with increment in Sugarcane Bagasse Ash up to 20% , and with more addition it decreases. The increase in CBR value and dry density is maximum for 30% Sugarcane Bagasse Ash mixture with black cotton soil. On increasing percentage of fly ash, there is decrease in the liquid limit of black cotton soil, resulting in reduced swelling of soil.

Ruprai B.S. et al (2013) conducted compaction test and California bearing ratio test on black cotton soil. They used varying percentages of Sugarcane Bagasse Ash i.e. 10, 20, 30, 40, 50% and observed the effect of Sugarcane Bagasse Ash on moisture –density relationship and CBR value of soil. They reported that as compared to other mixes the CBR value is higher for 20% fly ash. Moreover the dry density was also more at 20% Sugarcane Bagasse Ash content.

Kumar R. et al. (2014) studied the effect of sisal fibers on the UCS value of bentonite. He reported that there can be an increase in the UCS value of bentonite by adding lime, phosphogypsum and sisal fibers. The highest UCS value was obtained at 8% lime, 8% phosphogypsum and 1% sisal fibers. UCS value increased with increment in fiber from 0.5 to 2% fiber.

Abadi et al. (2014) conducted compaction test and California bearing ratio test on clay. He varied the percentage of flyash from 5% to 25% with increase of 5% at a time. He reported that the MDD of clay increased with increment in ash till 15%, then decreased to 1.53 at 20% ash. The OMC decreased until 15 %,then after that it started to increase. CBR value reduces slightly when soil ash mixture contains more than 15% ash.

S. S. Kandolkar et al., (2014) Stone dust is rock particles formed when huge rocks are broken into smaller sizes for use as construction material. Enormous amount of stone dust is generated as waste product at quarry sites all over India. Proper utilization of this waste is needed in a developing country like India. To check the suitability of this waste product in geotechnical engineering applications, a series of triaxial tests have been performed on stone dust without and with reinforcement. Reinforcements used were bamboo grid (BG) and steel grid (SG). Circular reinforcement grids of diameter 55 mm were used and placed in the triaxial specimen in four different arrangements as: one layer at center, two layers each at 1/3rd height, three layers each at 1/4th height, and two layers with one each at top and bottom of specimen.

Swarup J. et al., (2015) performed compaction tests and CBR tests on the black cotton soil. They used sisal fiber (0.25%, 0.5%, 0.75%, 1%, 2%, 3%), NaOH (3%, 6%, 9%, 12%, 15%) and flyash 20% by weight of dry soil. They concluded that optimum value of NaOH is 9%, 12N. Normal soil matrix gives the maximum CBR values at nearly 11% of fiber content but due to this stabilization technique,the maximum amount of CBR value can be attained at less amount of fiber content i.e. at 0.2%.

Sharanakumar et al., (2018) The sisal fiber was collected from Tokyo Engineering Corporation Private Limited, Coimbatore (Tamilnadu).Soil stabilization is done with the addition of sisal fiber with varying percentages of sisal fiber are 0.2%, 0.5%, 0.9% and 1.2% with varying lengths of sisal fiber are 3cm, 3.2cm and 3.4cm length at the interval of 0.2cm.For knowing the properties of soil laboratory tests are to be done. They are Atterberg's limits, Light compaction test, unconfined compressive strength test, Specific gravity test, California bearing ratio test, Moisture content test and Sieve analysis test.

S.M Kavitha et al., (2019) Geotechnical engineers face various problems while designing foundation because of clayey soil due to poor bearing capacity and excessive settlement. So, we rectify that with various engineering works but in this project we choose fibers for improving soil parameters, this method is cost-effective and eco-friendly one. The clay sample was collected from Devakottai, Tamil Nadu, and India. Sisal, polypropylene, and hybrid of these two fibers were used for soil stabilization. The sisal fiber was mixed 0 .1%, 0.2%, 0.3% and 0.4% by weight of the soil samples. Similarly, polypropylene fiber was mixed 0.5%, 1%, 1.5% and 2% by weight of the soil samples and hybrid fiber mixed soil samples randomly distributed.

Jaspreet Singh et al., (2021) three different percentages of S.D will be incorporated in the proportions of 4%, 8% & 12%. After finding the MDD (in KN/m3) and UCS (in KN/m2), the Optimal Percentage of Stone Dust will be used to make a blend with the three varying percentages of LDPE (i.e. 1%, 2% and 3%) and furthermore the properties engineering properties will be checked. The length of the fibers is 6 mm respectively. In the previous years, the research on fiber reinforced soils revealed that this material is to be cost effective technique for reinforcement of sub grade soils in flexible pavements as compared to systematically reinforced soil. LDPE is an economical material that offers good physical, chemical, mechanical, thermal and electrical properties, not found in any other synthetic plastic.

Ghritartha Goswami et al., (2021) The present study aims to investigate the suitability of bagasse ash and stone dust as the admixtures for stabilizing soft clay, in terms of compaction and penetration characteristics. The studies were conducted by means of a series of laboratory experimentations with standard Proctor compaction and CBR tests. From the test results it was observed that adding bagasse ash and stone dust significantly upgraded the compaction and penetration properties, specifically the values of optimum moisture content, maximum dry density and CBR. Comparison of test results with available data on similar experiments conducted by other researchers was also performed.

Bohra Vinay Kumar Jain et al., (2022) this experimental work briefly outlines the availability of Stone Dust (SD) in the area and how it could be used in the building sector to reduce the quantity of waste that would otherwise be dumped in the environment, hence reducing pollution. The rising price of stabilising materials like cement, lime, etc., is making traditional soil stabilisation methods increasingly expensive. Replacement of some stabilising drugs with SD and RHA could reduce stabilisation costs. It will reduce pollution and other environmental problems. The soil sample used in the research is medium-plasticity black soil, which needs to be fortified. Rice husk ash and stone dust are used in varying proportions to stabilise the soil. Maximum dry density (MDD), optimal moisture content (OMC), and unconfined compressive stress (UCS) are only a few of the soil parameters monitored for variations (UCS). With increased Stone Dust and RHA, soil UCS is significantly enhanced.

3. Materials

3.1 SOIL

Source of soil

The soil used in this study was obtained from village. As per IS classification of soil, the soil used is low compressibility silt. The soil properties are given in the table as under:

Table no. 1 Properties of soil used in the study

		Result
1.	Liquid limit (%)	48
2.	Plastic limit (%)	26
3.	Plasticity Index (%)	22
4.	Specific Gravity	2.69
5.	Maximum Dry Density (KN/m³)	15.36
6.	Optimum Moisture Content (%)	18.45
7.	Soil Classification	CI (Intermediate Compressive Clay)
8.	CBR (%) (soaked)	2.41
9.	CBR (%) (Unsoaked)	4.1
9.	UCS (kN/m$^{2)}$	270.71

3.2 BAGASSE ASH

Source of BAGASSE ASH

Bagasse Ash used in this research work was collected from mukerian sugarcane mill. The Bagasse Ash was dried in oven and then it was sieved for the removal of foreign particles. Then it was packed in polythene bags to protect it from moisture and used further in the study. Properties and composition of Bagasse Ash as obtained from the thermal plant shown in table no. 2 and 3

Table 2: Engineering Properties of Bagasse Ash

Sr.no.	**Properties**	**Value**
1	Colour	black
3	Specific gravity	0.78

3.3 STONE DUST

Source of STONE DUST

Stone dust, which is used as a civil construction material, is a waste material generated while crushing stones in a stone crusher that produces angular aggregates in different sizes. Stone dust is mostly reduced into powdered form after the breakdown of boulders and rocks and appears grayish in color. Minor minerals in soils can be found in abundance in the igneous and metamorphic rocks from which these materials are generated.

When used on soil, this has tremendous positive effects. It's up to the producer or their community to decide whether or not to use the dust themselves or offer it for sale. Since charcoal promotes the growth of soil microorganisms, adding a few pieces to the drum will maximise the advantages of the treated soil. It is largely available in Guwahati and in other parts of Assam, India.

The geotechnical properties of the stone dust obtained from laboratory tests are given in Table 3 and 4

Table 3:- Physical Properties of Stone dust

Property	Value
Specific gravity, *G*	2·852
Liquid limit, w_L/%	35
Plastic limit w_P/%	NP
D_{10}/mm	0·15
D_{30}/mm	0·6
D_{50}/mm	1·45
D_{60}/mm	1·6
Uniformity coefficient, C_u	10·67
Coefficient of curvature, C_c	1·5
Maximum dry unit weight, γ_{dmax}/kN m^{-3}	21·3
Optimum moisture content, OMC/%	12·09
Coefficient of permeability, *k*/m s^{-1}	$8·53 \times 10^{-5}$

Table 4:- Chemical Properties of Stone dust

Component	Weight (%)
CaO	3.5-40
Al_2O_3	0.5-40
MgO	2.5-25
SiO_2	1-12
SO_3	0.23-3
Alkalis	0-4

4. EXPERIMENTAL RESULTS

4.1 STANDARD PROCTOR TEST

Table no. 5: Results of OMC and MDD for mix proportions of Soil–Bagasse Ash– Stone Dust

Proportion Soil : BA: SD	MDD (kN/m^3)	OMC (%)
100:0:0	15.36	18.45
82 : 15 :03	15.40	19.20
79: 15 : 06	14.70	20.40
76 : 15 : 09	14.30	21.70

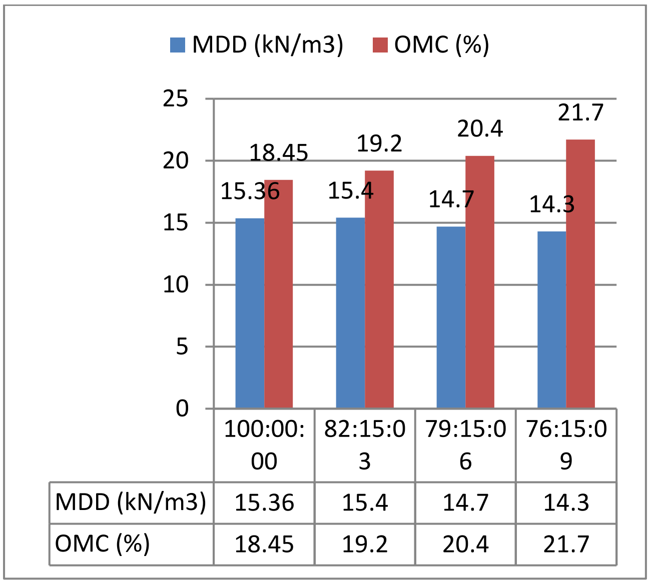


Fig:-1 variations b/w MDD and OMC of Soil–Bagasse Ash– Stone Dust with different proportions

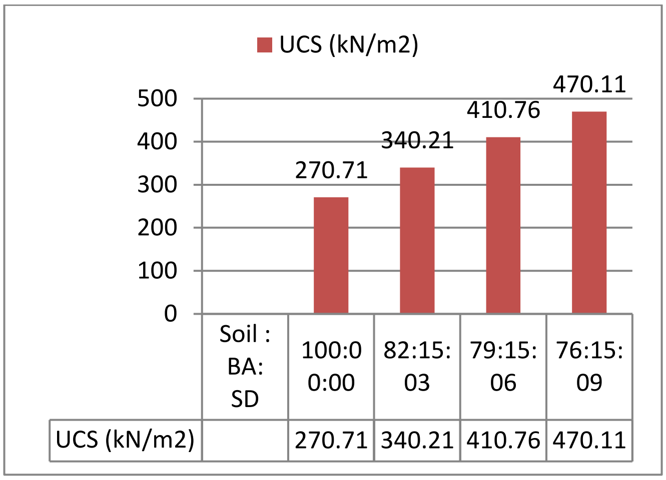


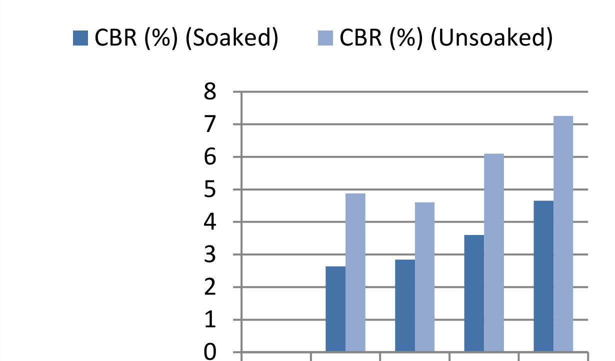
Fig:-2 Variations b/w UCS Values of Soil–Bagasse Ash– Stone Dust with different proportions

Table 6: Results of UCS of Soil–Bagasse Ash– Stone Dust Mix with Soil

Proportion Soil : BA: SD	Curing Period (Days)	UCS (kN/m^2)
100:0:0	7	270.71
82 : 15 :03	7	340.21
79: 15 : 06	7	410.76
76 : 15 : 09	7	470.11

Table 7: Results of CBR of Soil–Bagasse Ash– Stone Dust Mix with Soil

Proportion Soil : BA: SD	CBR (%) (Soaked)	CBR (%) (Unsoaked)
100:0:0	2.64	4.88
82 : 15 :03	2.84	4.60
79: 15 : 06	3.60	6.10
76 : 15 : 09	4.65	7.26



	Soil : BA: SD	100: 00:0 0	82:1 5:03	79:1 5:06	76:1 5:09
CBR (%) (Soaked)		2.64	2.84	3.6	4.65
CBR (%) (Unsoaked)		4.88	4.6	6.1	7.26

Fig:-3 Variations b/w CBR Values of Soil–Bagasse Ash–Stone Dust with different proportions

5. DISCUSSIONS

STANDARD PROCTOR TEST:

- An increase of OMC from 18.45 to 20.88% and decrease of M.D.D. from 15.36 to 14.62% when the percentages of Bagasse Ash are used as 10%,15% and 20% respectively.
- There is an also increase of OMC from 18.45 to 21.70% and decrease of MDD from 15.36 to 14.30% when the percentages of stone dust vary from 3.0%, 6.0% and 9.0% and Bagasse Ash is fixed at 15%.
- With Bagasse Ash kept constant at 15% MDD increases with an addition of Stone Dust content in soil and Bagasse Ash mix. The reason behind of such behavior is Bagasse Ash is lighter in weight and it has high water absorption properties because of presence of calcium oxide and hence OMC increases with increase of Bagasse Ash content.

CBR TEST:

- Presence of pozzolanic compounds in Bagasse Ash and CaOH available in soil might be increase the CBR value due to formation of cementitious compounds in soil. Due to excess of Bagasse Ash in soil ultimately occupies spaces within sample because of this Bagasse Ash could not be mobilized for the reaction at 15% of Bagasse Ash in soil.
- The CBR value of virgin soil is 2.64 and it increases to 2.31times with addition of 20% Bagasse Ash when observed in soaked conditions. This enhancement is because of binding action of Bagasse Ash.
- The CBR value of virgin soil is 2.64 and it increase to 2.5 times when Bagasse Ash 15% and Stone Dust 9% is added to virgin soil. This enhancement in CBR may be because of the gradual formation of hydration compounds in the soil due to the reaction between the stabilizers and the essentials particle present in the soil.

UCS TEST:

- UCS value of virgin soil enhances fundamentally with expansion of Bagasse Ash contents. The UCS value increment from 270.71kN/m² to 430.47kN/m² with expansion of Bagasse Ash upto 20% in the wake of curing time of 7 days. U.C.S. value increases with more expansion of Bagasse Ash. The expansion in U.C.S. value might be a direct result of the slow advancement of the cementitious mixes in the soil by the response between pozzolanic mixes in Bagasse Ash and CaOH accessible in soil.
- The UCS values of virgin soil also improve considerably with expansion of Bagasse Ash 15% and Stone Dust 9%. The value increases

from 270.71kN/m² to 470.11kN/m² with addition of Bagasse Ash and Stone Dust.

- The reason behind of this when Bagasse Ash and Stone Dust comes in contact with water, pozzolanic reactions takes place during the curing period.

6. CONCLUSIONS

Following conclusions can be inferred on the basis of the experiments performed:

1. A comparative study to justify the suitability of the two different admixtures implies that bagasse ash produced relatively less increment in the optimum moisture content, and almost an identical decrease in the maximum dry density, compared to stone dust. This indicates comparatively lower water requirements for initiating compaction in the case of bagasse ash. Additionally, the use of bagasse ash enhanced the soaked CBR significantly, thereby implying higher penetration susceptibility, compared to the stone dust.
2. Bagasse Ash is a waste product of Sugar manufacturing process which can be effectively used in the stabilization process of soil due to its silious properties that helps in increasing the strength of soil.
3. Stone Dust on the other hand is a cheaply available material which can be added to soil in less quantity to make big changes in its strength parameters.
4. The C.B.R value increases with increase of Stone Dust along with fixed quantity of Bagasse Ash. It increased 2.5 times from the untreated soil.
5. The optimum value of Stone Dust and Bagasse Ash required for soil stabilization is 9% and 15% by weight of soil respectively.
6. Unconfined compressive strength increases with increase of quantity of Stone Dust and with fixed quantity of Bagasse Ash.
7. As far as cost effectiveness is concerned, the use of bagasse ash and stone dust can reduce costs significantly. Hence, the appropriate admixture choice would depend on several other factors, including local availability and site treatment procedure costs.

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