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Strength improvement of subgrade in clayey soil by geosynthetics and sugarcane bagasse ash

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Abstract:
Geo-synthetics are revolutionary products and has tremendous uses in the field of road construction and are widely used as are inforcement to increase strength of the soil. This paper discloses the strength improvement of subgrade by using geo-synthetics and sugarcane bagasse ash. Geotextiles has been effectively used for reinforcement of soil to recover the bearing capacity. Sugarcane bagasse ash (SBA) is an industrial waste, and is difficult to dispose. Sugarcane bagasse ash is an effective stabilizer for subgrade soils. Geotechnical properties of soil were determined. By adding different percentage of SBA like 5%, 10%, 15% and 20% the optimum percentage of SBA were determined. CBR test were conducted for four configurations each with and without optimum SBA. The different configurations are; one with geotextile at top, second one with geogrid at middle, third one with geogrid at middle and geotextile at top, fourth one with combination of geogrid and geotextile atthe top. And acomparative study was conducted between the results. The data obtained from the California bearing ratio(CBR) test shows an increment in the strength of subgrade from 1.67 to 7.08% when placing both Geogrid and Geotextile at top with SBA.

Keywords:*Geo-synthetics,CBR,SBA*

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I. Introduction

Improving the strength of subgrade in clayey soil is essential for enhancing the durability and performance of roadways. Clayey soils often pose challenges due to their poor strength, low CBR value, shrinking and swelling property.These characteristics can lead to pavement failures, increased maintenance costs, and reduced lifespan of road infrastructure.To address these issues, innovative and sustainable soil stabilization techniques are essential.Geosynthetics, a category of synthetic products used to stabilize terrain, have emerged as effective solutions for soil reinforcement. Geotextiles, function as separation, filtration, and drainage agents while providing reinforcement. Geogrids, on the other hand, improve the load distribution and enhance the bearing capacity of subgrade soils by interlocking with the soil particles, thereby increasing their shear strength and reducing deformation under loads.The integration of geosynthetics into road construction not only improves the mechanical properties of the subgrade but also offers economic and environmental benefits.In addition to geosynthetics, incorporating waste materials like sugarcane bagasse ash into soil stabilization presents an environmentally friendly and costeffective solution. Sugarcane bagasse ash, a byproduct of the sugar industry, can enhance the strength of subgrade soil, reducing the need for traditional materials and addressing waste disposal issues. This dual approach leverages the tensile resistance of geosynthetics and the stabilizing properties of sugarcane bagasse ash, providing a sustainable method to improve the engineering properties of clayey subgrade soils. This study focusses on evaluating the combined effect of geosynthetics and sugarcane bagasse ash on the strength improvement of subgrade in clayey soils, aiming to give a practical and eco-friendly solution for road construction.

II. Objective

The main objectives are to study the following:

- Toquantify the improvement in strength of clayey soil subgrades when reinforced with geosynthetics and SBA.
- Toidentify the optimal percentage of SBA to be mixed with clayey soil for the best stabilization results
- To evaluate the performance of different configurations of geotextile and geogrid placement in the subgrade.

- To Conduct California bearing ratio (CBR) tests to measure and compare the bearing capacity of various reinforcement arrangements in soil.
- Topromote sustainable construction by utilizing SBA as a soil stabilizer, reducing industrial waste disposal problems.

III. MATERIALS AND METHODOLOGY

The materials used for the study were clayey soil, Geotextile, Geogrid and Sugarcane bagasse ash. The details of the materials, methodology andexperimental setup are explained in the following sections.

A. *Materials*

The various materials required for the study are listed below:

1) ***Clayey Soil:*** The clayey soil for the study was collected from Chenkal, Thiruvananthapuram, Kerala.The engineering properties of the soil were determined.

Fig. 1 Clayey Soil

TABLE I
PROPERTIES OF SOIL

Property	Result
Specific Gravity, G	2.22
Liquid Limit , W_L	57%
Plastic Limit, W_P	34%
Plasticity Index, I_P	23%
Soil Classification	CH
Percentage of Clay	63%
Percentage of Silt	37%
Unconfined Compressive Strength	18.15kN/m²
Maximum Dry Density	13.63kN/m³
Optimum Moisture Content	24%
California bearing ratio (CBR)	1.67%

2)***Geotextile:***
Geosyntheticsaresyntheticsproductusedtostabilizetheter rainwhichismadeupofpolymers. They providefiltration, Seperation, and reinforcement insoil structures. Placed beneath roads or structures, they prevent mixing of soil layers, enhance drainage, and increase stability, extending the lifespan of infrastructure. Non-woven geotextiles used in subgrade application are engineered fabrics made from synthetic fibers as shown in figure

Fig. 2 Geotextile

TABLE 2
PROPERTIES OF GEOTEXTILE

PROPERTIES	RESULT
Colour	White
Type	Non-woven
Punctureresistance	37.67mm
Averagethickness	0.15mm
Massperunitarea	876.3gm

3)***Geogrid:*** Geogrids are manufactured using polymers as the strips perpendicularly crossing each other as shown in figure.3 They are attached at the intersections. Commonly made of polymermaterials,themajorfunctionofthegeogri disintheareaofreinforcementtoresistthe tensile force. Other specifications are as provided by the manufacturer.

Fig. 3 Model Square Footing

Table 3
PROPERTIES OF GEOGRID

PROPERTIES	RESULT
Colour	Black
Type	Polyester biaxial geogrid
Thickness	3mm

4)*Sugarcane bagasse ash*

Sugarcane bagasse ash(SBA) is a sustainable solution for reinforcing subgrade stability, enhancing load-bearing capacity, and reducing environmental impact as shown in figure4.Ithas constituteddisposalproblemswhichisamajorprobleme ncounteredinareasofgreatsugarcane production as it is thought of as asolid waste thatis non-biodegradable.Hence using it as soil stabilizer will be environmental friendly. It contain high amount of silica content making it to possess highly pozzolanic properties as like cement.

Fig. 4 Sugarcane bagasse ash

Table 4
MINERAL COMPOSITION OF SUGARCANE BAGASSE ASH

Chemicalelement	% byweight
Silica(SiO_2)	64.27
Iron oxide (Fe_2O_3)	5.76
Aluminium oxide (Al_2O_3)	5.53
Loss On Ignition (LOI)	4.97
Potassium oxide (K_2O)	2.96
Calcium oxide (CaO)	3.73
Sulphur Trioxide (SO_3)	1.84
Manganese (Mn)	0.35
zinc (Zn)	0.46
Copper (Cu)	0.18

B. *Methodology*

- Collection of Journals.
- Procurementofmaterials.
- Determinationofbasicpropertiesofsoil.
- Compaction test were conducted with different percentages.
- CBRtestareconductedusingdifferentconfiguration arrangements.
- Comparingthetest results.

C. *Experimental Setup*

The experimental setup for the CBR test begins with the preparation of the necessary materials, including soil, geogrid, geotextile and sugarcane Bagasse ash(SBA).The soil sample is first prepared and mixed with varying percentages of SBA (5%,10%,15% and 20%).Proctor compaction tests are conducted on these mixtures to determine Optimum Moisture Content(OMC) and Maximum Dry Density(MDD),identifying the optimum percentage of SBA that enhances soil compaction properties.

For the reinforced soil specimens, geogrid and geotextile are cut in to cylindrical disks to fit the CBR mould. The experimental setup involves preparing soil samples in four configurations: one with geotextile at the top, another with geogrid in the middle, third with geogrid in the middle geotextile at the top, a fourth with both geogrid and geotextile at the top, and control samples without SBA for comparison. Each configuration is compacted in the CBR mould in the fivelayers with 56 blows per layer using a standard compaction hammer.

The CBR test is then conducted by penetrating a plunger in to the soil at a standardized rate and measuring the resistance offered by the soil. The CBR values for each configuration, both with and without the optimum percentage of SBA are recorded. Finally, a comparative analysis is performed to evaluate the impact of geogrid, geotextile and SBA on the soils load-bearing capacity, proving insights in to most effective reinforcement method

Fig.5 Experimental setup

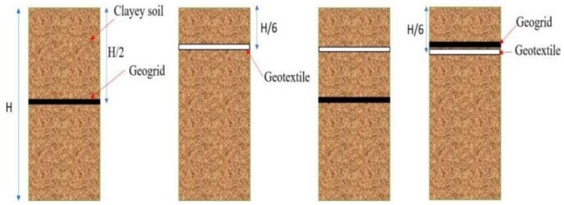

Fig.6 Schematic diagram of configuration arrangements

IV. Results And Discussion

A. Compaction test

The compaction test for soil with various percentage of SBA were studied.

Table 5
Variation of MDD and OMC with percentage of SBA

	MDD(g/cc)	OMC (%)
Soil	1.39	24
Soil+5%ofSBA	1.40	24
Soil+10%ofSBA	1.44	26
Soil +15%ofSBA	1.49	28
Soil +20%ofSBA	1.45	30

The original soil has a Maximum Dry Density(MDD) of 1.39g/cc and an optimum moisture content (OMC) of 24%.when 15% of Sugarcane Bagasse Ash(SBA) is added, MDD increases to 1.49g/cc and OMC rises to 28%.

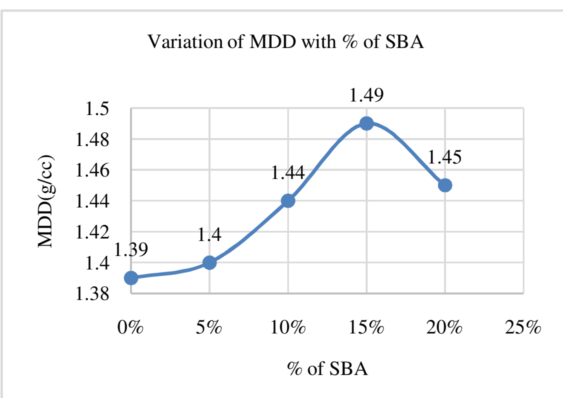

Fig.7 variation of MDD with % of SBA

B. Effect of different percentage of Sugarcane bagasse ash on clayey soil

Table6
Results of CBR Test adding with various percentages of SBA

DifferentpercentagesofSBA	CBRvalue (%)
CBRTestonoriginalsoilsample	1.67
CBRTestonSoil+5%ofSBA	2.04
CBRTestonSoil+10%ofSBA	2.33
CBRTeston Soil+15%ofSBA	2.55
CBRTestonSoil+20%ofSBA	2.40

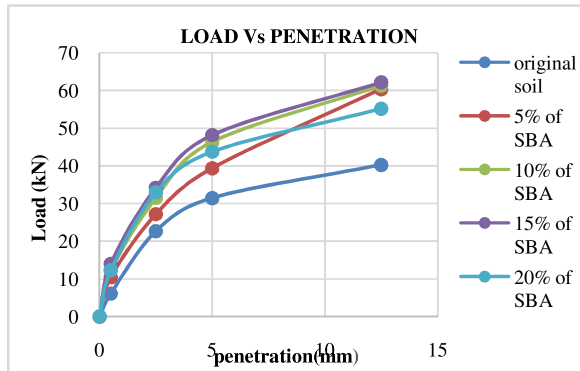

Fig.8 Load Vs penetration graph for adding various percentages of SBA

Load -Penetration graph for adding different percentage of Sugarcane bagasse ash(SBA) were studied. optimum percentage of SBA were studied.

C. EffectofGeosynthetics placedatvariousdepth in soil without SBA

The CBR values of different configuration arrangements of geosynthetics without sugarcane bagasse ash were studied and values are given in table 7.

Table 7
CBR results of Different configuration arrangements without SBA

Different configuration arrangements without SBA	CBR Values (%)
Original soil	1.67
Soil +Geotextile(h/6)	3.09
Soil +Geogrid(h/2)	2.04
Soil +Geotextile(h/6) +Geogrid(h/2)	4.59
Soil+combinationof geosynthetics(h/6)	6.05

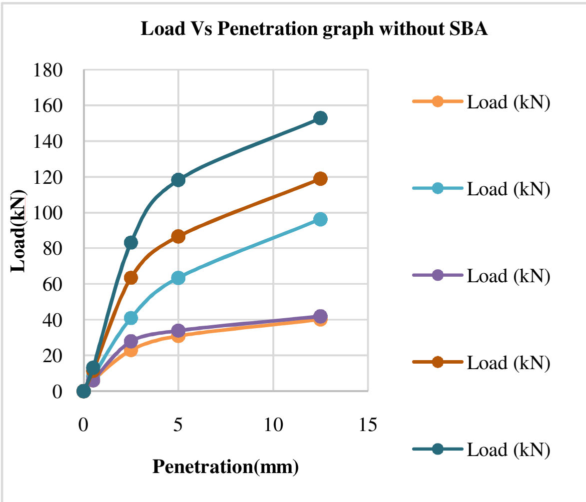

Fig.9 LoadVspenetration graphfor different configuration arrangements of geosynthetics without SBA

The load- penetration graph for different configuration arrangements of geosynthetics without Sugarcane bagasse ash were studied.

D. EffectofGeosynthetics placedatvariousdepth in soil withSBA

The CBR values of different configuration arrangements of geosynthetics with sugarcane bagasse ash were studied and values are given in table 8.

Table 8
CBR results of Different configuration arrangements with SBA

Different configuration arrangements with SBA	**CBR Values (%)**
Original soil	1.67
Soil +Geotextile(h/6)	3.40
Soil +Geogrid(h/2)	3.06
Soil +Geotextile(h/6) +Geogrid(h/2)	5.03
Soil+combination of geosynthetics(h/6)	7.08

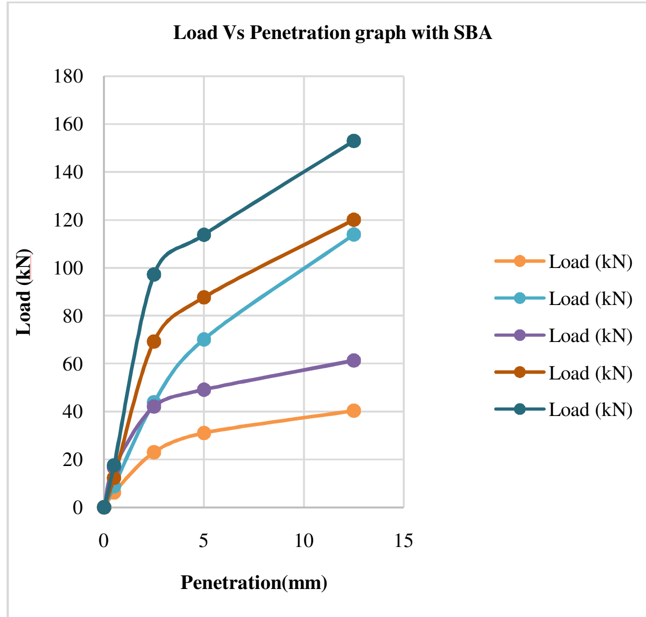

Fig.10 LoadVspenetration graphfor different configuration arrangements of geosynthetics with SBA

Theload-Penetration graph for different configuration arrangements with Sugarcane bagasse ash were studied.

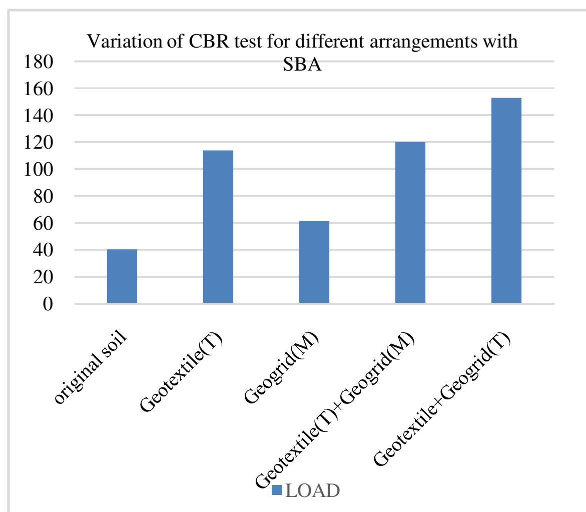

Fig.11 Variation of different configuration arrangements of geosynthetics with SBA

The fig.11 shows thevariation of different configuration arrangements of geosynthetics with SBA.The Graph shows that when the combination of geosynthetics placed at h/6 depth with the presence of SBA CBR Value were increased.

V. Conclusions

This paper deals with the study of strength improvement on the soil collected from chenkal, Thiruvananthapuram. CBR test were conducted on the soil with different percentages of sugarcane bagasse ash and various arrangements of geosynthetics and following results were obtained:

- The highly compressible clay soil can be stabilized with an optimum of 15% of SBA and combination of Geotextile & Geogrid placed at H/6 height of the mould from the base.
- An optimal percentage of SBA were determined to enhance soil stabilization effectively.
- The increase in the strength of the treated soil sample is observed to be 7.08% of that the unmodified soil sample.
- As per IRC-SP-72-2015 the strength of the subgrade for design shall not be less than 5% and quality of subgrade for design purpose should be atleast fair. From the results while placing combination of geotextile & geogrid at H/6 height in the presence of sugarcane bagasse ash, the subgrade strength is improved as 7.08% and quality of subgrade for design purpose is good.
- Different reinforcement configurations showed varying degrees of effectiveness, with the combination of geogrid and geotextile at the top being the most effective.
- Utilizing SBA as a soil stabilizer promotes sustainable construction and addresses industrial waste disposal issues.

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