Fly ash and bagasse ash embankment in flexible pavements for the analysis and strengthening of black cotton soil's strength stabilized properties

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Abstract. Soil stabilization is necessary to increase the soil's durability, volume stability, and engineering expansion strength. Expansive soils (also known as black cotton soil), a problem that affects the entire world and poses various challenges for civil engineers, are extremely hard while dry but completely lose their strength when wet. In this study, fly ash has been employed to stabilize the soil. Five, ten, twenty, and twenty-five percent of fly ash was used in the experiments. Bagasse ash is an easily accessible byproduct of the sugar cane refining process that has negative environmental effects. In this study, any potential pozzolanic benefits are evaluated while taking into account bagasse ash. material that stabilizes elongated soil In order to examine the soils' geotechnical characteristics, the experimental investigation focuses on altering the fly ash content of the soils. The goal is to learn more about the characteristics of black cotton soil's tensile strength. The primary goal of this research is to examine the effects of bagasse ash on the engineering expansive soil's properties as revealed by various lab tests, and after improving the treated soil through embankment work at various civil engineering activities, such as roadways.

Keywords- Fly ash, black cotton soil, Bagasse ash, Soil strength properties

1. INTRODUCTION

The majority of extensive soils, especially "Black Cotton Soils," are located in arid and semi-arid regions of the world. It covers about 30% of India's land area and generally includes the states of Karnataka, Maharashtra, some of Gujarat, western Madhya Pradesh, and Andhra Pradesh, which make up the entire Deccan Plateau. The name "Black Cotton" has a connection to agriculture. The majority of these soils are dark and ideal for cotton cultivation. These soils can be used as building materials if they possess engineering properties including high strength, low settlement, and exceptional durability.

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When it comes to field compaction, working with such soils might be difficult. Volumetric changes are brought on by suction and variations in water content. soiled black cotton, A type of porous, highly plastic soil called black cotton soil can retain water for the duration of the summer. However, because of water evaporation, there is swelling in the rainy seasons and shrinkage in the summer. The soil is considered unsuitable for construction because of its peculiar qualities, which include high plasticity, excessive swelling and shrinking, and low strength when wet. It costs a lot of money to build roads, canals, and embankments since there isn't enough good soil The construction of large thermal power plants, however, has resulted from the rising need for energy in developing countries like India due to industrial growth.

Now operating in India are 87 thermal power plants. The creation of byproducts like fly ash as a result of this progress has been significant. The disposal of fly ash requires the use of sizable holding ponds, lagoons, landfills, etc. To reduce these harmful by-products' harmful impacts on the environment, it is essential to use them. The strength and compressibility of the soil are increased by the cementitious chemicals that are created when moisture is present, despite the fact that fly ash has a poor cementitious value. The sugar-refining industry frequently produces bagasse ash, a fibrous byproduct that can be used for free or at a very low cost. With the growing awareness of this material's potential impact on the environment, it must be appropriately disposed of and its potential for recycling must be investigated. The first goal of this study is to locate and identify the properties of black cotton soil, fly ash, and bagasse ash. (General and Power) Identification of the properties of fly ash, bagasse ash, and black cotton soil mixture (iii) Determine the CBR values and strengths of black cotton soil containing various fly ash and bagasse ash concentrations at various curing durations. (0,15,30,60,120 days)

2.MATERIALS USED

2.1 BLACK COTTON SOIL:

Using soil that was easily accessible locally, the experimental study was carried out. Black natural cotton was used to create the soil, which was obtained from Tadepalli in the Andhra Pradesh state's Guntur area. 1.5 meters below the typical ground level, the earth was removed. The color of the soil ranges from dark brown to black. The earth that had been dug up was air-dried manually crushed and then sieved using a 425-micron IS. Many studies were carried out to determine the soil's characteristics.

Fig 1: Black Cotton soil

 https://doi.org/10.1051/e3sconf/202339101005

Table 1: The characteristics of black cotton soil

S.NO	SOIL PROPERTIES	SOIL SAMPLE
1.	Water Content(w)	30.50%
2.	Specific Gravity(G)	2.70
3.	Wet sieve analysis	Grave=0%, Sand=3% Clay =56%, Silt=41%
4.	Soil Classification	CH
5.	Liquid limit (WL)	75%
6.	Plastic limit (WP)	30%
7.	Plasticity Index (IP)	45%
8	Free swell index (or) Swelling index (%)	90% (High)
9.	OMC (%)	26.50%
10.	MDD (gm/cm3)	1.50
11.	Unconfined Compressive strength (UCS) (tones/m2)	12.0
12.	Direct Shear Strength (KPa)	75.70
13.	CBR Value (Soaked)	1.48%
14.	CBR Value (Un soaked)	2.97%

2.2 FLY ASH:

Typically at a thermal power plant, fly ash is a waste product that is extracted from the gases that coal-fired furnaces produce. The VTPS at Ibrahimpatnam, Vijayawada, provided the fly ash used in this study. As a result of burning coal, fly ash is produced. Electrostatic precipitator apparatus is used in the power plants to collect these fly ashes (ESP). Mostly composed of alumina, silica, and iron, fly ashes are minute particles. Due to their typical spherical shape, fly ash particles are simple to flow and combine with the appropriate combination. Amorphous and crystalline minerals make up fly ash's mineral composition. Despite the composition varying based on the type of coal burned, it is generally non-plastic silt. Before being used again, the samples were baked for around 24 hours to dry them out. The type of coal used in the burning process is crucial, even though its composition changes according to n-plastic silt. The samples were dried in the oven for roughly 24 hours before being used again.

Fig:2 Class C

Fig 3: Class F

TABLE 2: PROPERTIES OF FLY ASH

S.NO	INDEX PROPERTIES	SOIL SAMPLE
1.	Specific Gravity(G)	2.63
2.	Liquid Limit (%)	40
3.	Plastic limit (%)	Non-Plastic
4.	Plasticity Index (%)	-
6.	OMC (%)	14%
7.	MDD (gm/cm3)	1.1
8.	Unconfined Compressive strength (UCS) (KPa)	0.76
9.	Direct Shear Strength (KPa)	112.10

2.3 BAGASSE ASH

In order to collect bagasse ash, various sugarcane juice stands were gathered and burned at KL University. Between 300 and 500 °C was suggested as the burning temperature for bagasse ash. Lists the physicochemical makeup of bagasse ash in the table. 3. The bagasse ash used in this study was adequately sifted using a 0.425mm aperture sieve to get rid of unburned and large-size particles.

Fig 4: Bagasse ash

TABLE 3: PROPERTIES OF BAGASSE ASH

S.NO	INDEX PROPERTIES	SOIL SAMPLE
1.	Specific Gravity(G)	2.40
2.	Liquid limit (%)	24
3.	Plastic Limit (%)	Non-plastic
4.	Plasticity Index (IP) (%)	-
5.	Free swell index (%)	Non-Swelling
6.	OMC (%)	15
7.	MDD (gm/cm3)	1.020
8.	Unconfined Compressive strength (KPa)	1.1
9.	Direct Shear Strength (KPa)	100.10

3. METHODOLOGY

The soil, as well as soil containing fly ash and bagasse ash, underwent the experiments that follow. We calculated the engineering characteristics and soil index.

- **Analysis of grain size (IS:2720-part 4,1985)** The mechanical analysis, commonly known as the grain size analysis, can be used to determine the distribution of grain sizes in any soil. The first stage in mechanical analysis is to filter the soil using several sieves with different aperture sizes.

- **Atterberg limits (IS:2720-part 5,1985)** To identify the moisture content at which fine-grained clay and silt soils transition phases, a classification test known as the Atterberg limits test is utilized. The portion of soil that can pass through a No. 40, 425 mm, or 0.425 mm sieve is used for the Atterberg limits test in accordance with ASTM D 4318-00.
- **Specific gravity (IS:2720-part 3,1980)** The specific gravity of soil can be determined using a pycnometer (for soils with coarse grains) and a density bottle test (fine-grain soils). The term "specific gravity" refers to the ratio of the mass of a unit volume of distilled water at a given temperature to that of a unit volume of soil at that same temperature.
- **Proctor's compaction test (IS:2720-part 8, 1983**) An experimental method called the Proctor compaction test is used to determine empirically the ideal moisture content at which a given type of soil becomes the densest and reaches its maximum dry density. Ralph Roscoe Proctor, who demonstrated in 1933 that the amount of water in the soil at the moment of compaction determines the dry density of the soil for a given compaction effort, is honored to have his test bear his name.
- **Unconfined compressive strength test (IS:2720-Part 16, 1987)** A lab method called the Proctor compaction test is used to empirically determine the ideal moisture content at which a particular type of soil becomes the densest and reaches its maximum dry density. It is a test that bears Ralph Roscoe Proctor's name, who demonstrated in 1933 that the amount of water present in the soil at the time of compaction affects the dry density of soil for a given compaction effort.
- **Consolidation Test (IS:2720-part 15,1965**) Consolidation tests are used to quantify the volume and rate of soil consolidation under axial and lateral loads. Other names for the consolidation test include the one-dimensional compression test and the standard oedometer test. Soil samples that have been saturated are employed for this test, especially if the soil is cohesive.
- **California bearing ratio test (IS:2720-part 16, 1987)** The CBR test involves piercing the soil at a rate of 1.25 mm/min with a standard piston with a diameter of 50 mm (1.969 in). The ratio decreases because, although the force increases with penetration depth, it typically does not increase as quickly as it would with conventional crushed rock. CBR values have a considerable impact on pavement thickness.

4. RESULTS AND DISCUSSION

Reporting in this section are the findings and analysis of the current inquiry.

Table 4: Varying percentages (%) of Fly ash with soil on geotechnical properties

% Of FA with Soil	G	WL (%)	WP (%)	IP (%)	SL (%)	FSI (%)	OMC (%)	MDD (gm/cm3)	CBR (Soaked) %	CBR (Unsoaked) %
0	2.69	65	26	40	11	70	21.58	1.50	1.5	2.80
5	2.62	50.2	33	15.56	10.51	50	23.78	1.47	3.5	5.9
10	2.59	46.3	36	9.32	10.08	40	24.35	1.44	4.9	8.9
15	2.56	43	39	4	9.22	30	26	1.42	6.8	10.5
20	2.47	41.5	40	1	8.40	20	28	1.37	8.5	14.5
25	2.42	35	NP	NP	7.15	10	29.55	1.33	7.1	15.5
30	2.37	23	NP	NP	7	NP	31	1.31	5.5	8.7

Table 5: Shows how varied percentages of Bagasse Ash affect the geotechnical characteristicsof the soil.

% Of BA with soil	G	WL (%)	WP (%)	IP (%)	SL (%)	FSI (%)	OMC (%)	MDD (gm/cm3)	CBR (Unsoaked) %	CBR (Soaked) %
0	2.70	75	30	45	10.01	90	26.50	1.50	2.8	1.5
10	2.65	42	22	20	9.54	70	28.90	1.47	4.0	5.5
20	2.60	35	18	17	8.46	40	30.45	1.45	7.2	9.0
30	2.55	20	NP	NP	8.10	25	33.95	1.40	6.5	8.2
40	2.50	15	NP	NP	7.8	15	35.15	1.35	6.0	6.5

Table 4 and 5 demonstrates that as the percentage of Liquid limit (WL), plastic limit (WP), and plasticity index (IP) of the soil decrease when fly ash and bagasse ash content rises, while MDD, OMC, CBR (unsoaked & soaked), and UCS values rise.

Figures 5 to 14 show the variation of various geotechnical parameters because of varying the individual proportions of fly ash and bagasse ash.

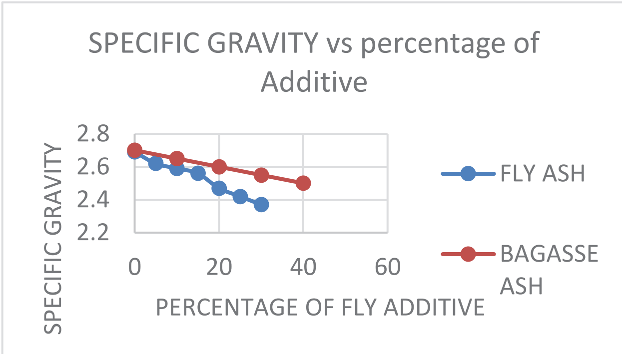

Fig 5: Variation of specific gravity Vs Percentage of additive

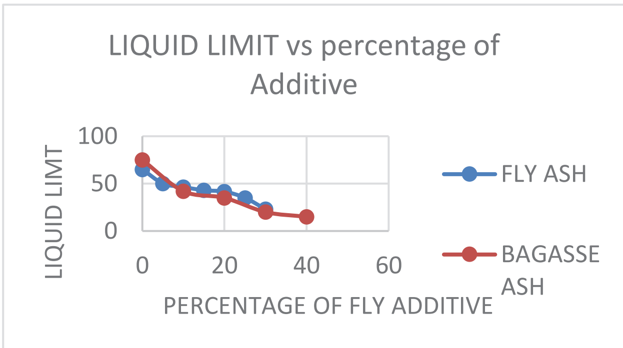

Fig 6: Variation of liquid limit Vs Percentage of additive

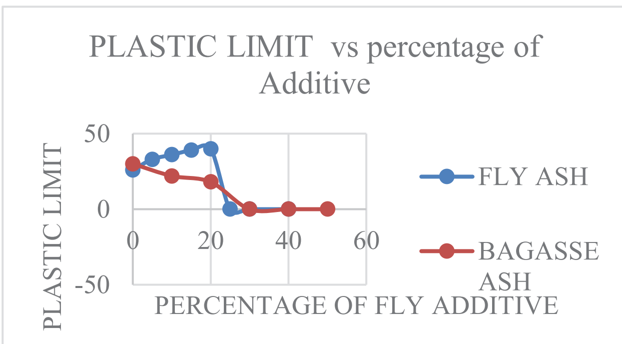

Fig 7: Variation of plastic limit Vs Percentage of additive

 https://doi.org/10.1051/e3sconf/202339101005

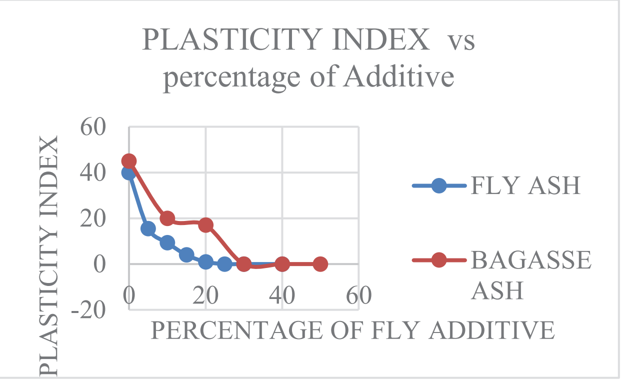

Fig 8: Variation of Plasticity index Vs Percentage of additive

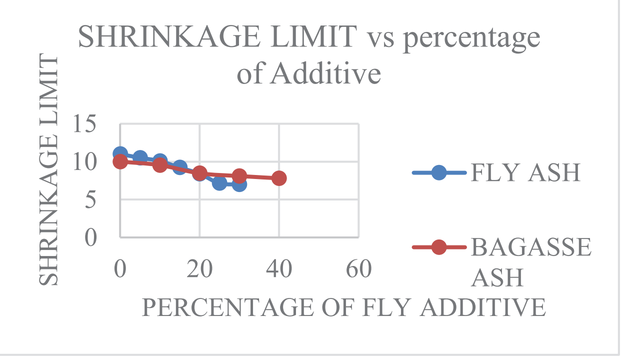

Fig 9: Variation of Shrinkage limit Vs Percentage of additive

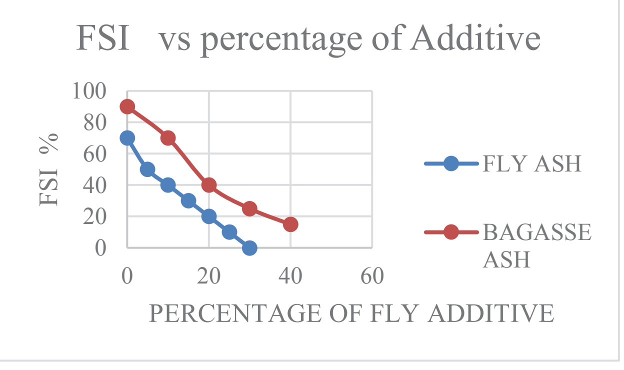

Fig 10: Variation of Free Swell Index Vs Percentage of additive

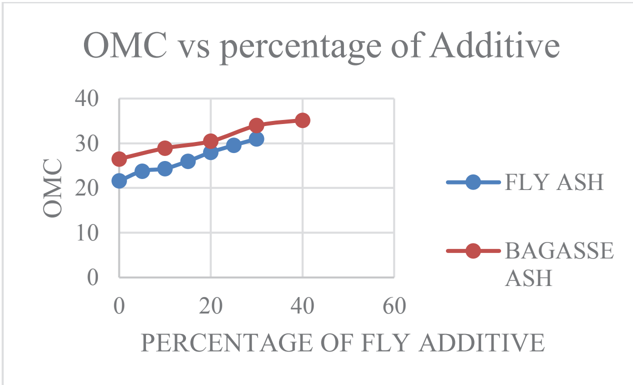

Fig 11: Variation of Optimum Moisture Content Vs Percentage of additive

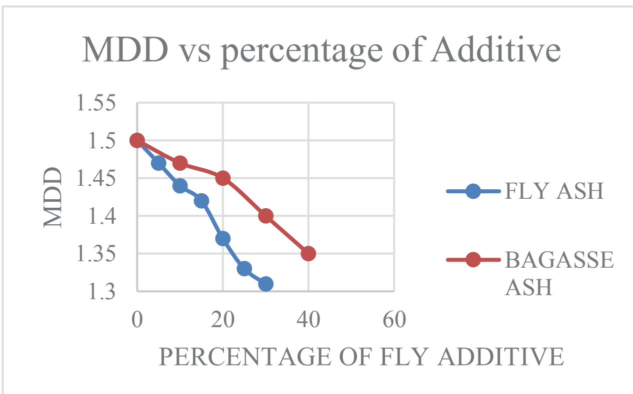

Fig 12: Variation of Maximum Dry Density Vs Percentage of additive

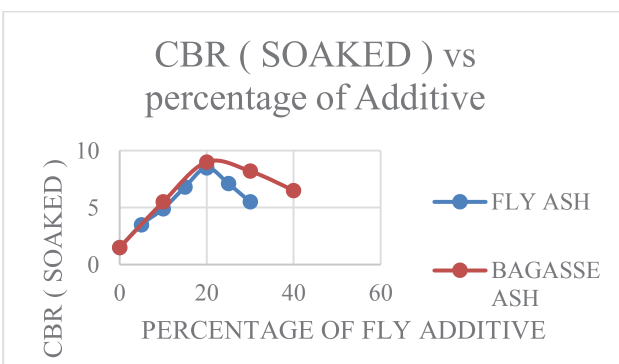

Fig 13: Variation of Soaked California Bearing Ratio Vs Percentage of additive

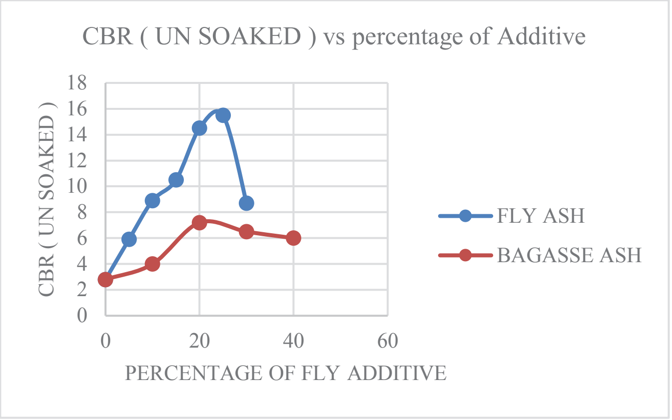

Fig 14: Variation of Unsoaked California Bearing Ratio Vs Percentage of additive

The plastic limit rises as fly ash content in the soil rises (fig 7). While fly ash content in mixed samples increases, shrinkage values decrease (fig 9). The propensity of mixed samples to shrink is decreased by adding non-shrinking, low-cohesion fly ashes to the soil. Lower water proportions entering the system are indicated by liquid limit values, which may be the cause of the diminishing linear shrinkage. The free swell index value decreases as fly ash content in the soil rises (fig 10). As the amount of fly ash in the soil grows, the specific gravity (G) values decrease (fig.5) Using common Proctor compaction tests, Table 1 illustrates the connection between dry density and moisture content for a mixed sample of local clay soil and soil-fly ash. As the amount of fly ash rises, the MDD declines (fig12). The OMC and the quantity of fly ash both increase (Fig 11). The perception of these changes is affected by the quantity of injected ash as well as the chemical composition of the clay minerals and ash. Flocculation of clay particles, which aggregated when there was enough water present to create an increase in voids and a matching fall in dry densities, was responsible for the decline in density. In the soil-fly ash mixed samples, more may have been required to complete the cation exchange reaction, and as compaction force is applied, more water fills the spaces. This may be what led to the increased OMC. A soil's stability and bearing capacity are evaluated using the CBR value. The local soil CBR value for% is regularly utilized in the design of foundation and sub-base materials. The CBR value rises with fly ash content in the mixture up to 20% before starting to fall after that point. The CBR value decreased after the 20% increase because the flocks were pore water-filled (figs 13 and 14).

 https://doi.org/10.1051/e3sconf/202339101005

Table 6: Variations of properties of Soil + fly ash +Bagasse ash

Fly Ash (%)	**Bagasse ash (%)**																			
	10					**20**					**30**					**40**				
	OMC (%)	**MDD (g/cc)**	**FSI (%)**	**CBR (%)**		**OMC (%)**	**MDD (g/cc)**	**FSI (%)**	**CBR (%)**		**OMC (%)**	**MDD (g/cc)**	**FSI (%)**	**CBR (%)**		**OMC (%**	**MD D (g/cc)**	**FSI (%)**	**CBR (%)**	
0	28.90	1.47	70	4	5.5	30.45	1.45	40	7.2	9.0	33.95	1.40	25	6.5	8.2	35.15	1.35	15	6.0	6.5
5	29.50	1.45	50	5.1	6.5	30.75	1.43	30	7.8	10.2	34.50	1.38	15	8.0	9.5	36.18	1.32	5	7.1	8
10	30.50	1.43	30	7.2	8.1	32.0	1.42	20	8.5	11.5	35.25	1.35	10	10	10.9	38.40	1.30	NS	8.5	9
15	32.70	1.41	20	8.55	9.5	34.20	1.40	10	10	12.8	36.70	1.33	NS	11.2	11.8	40.75	1.27	NS	10.1	11
20	34.50	1.40	10	10.5	12.2	35.45	1.38	NS	11.9	13.5	37.45	1.32	NS	12.5	14. 5	42.10	1.25	NS	11.5	12.5
25	36.40	1.39	NS	10	11.2	37.01	1.35	NS	11	12.5	38.52	1.30	NS	12	12.5	44.30	1.22	NS	11	11.4
30	37.50	1.36	NS	9.50	11.5	38.50	1.32	NS	10	11.2	40.50	1.28	NS	11.2	11.5	46.50	1.20	NS	10.2	10.5

Table 7: Variations of UCS values of Soil+ Fly ash +Bagasse ash

Fly ash (%)	**Bagasse Ash (%)**			
	10	**20**	**30**	**40**
	UCS (tones/m2)	**UCS (tones/m2)**	**UCS (tones/m2)**	**UCS (tones/m2)**
0	13.5	15	17	18
5	15	16.5	19.8	21
10	17	18.5	20.0	22.5
15	18.5	20	21.5	22.1
20	20	21.7	23.1	21
25	21	22.4	22	22
30	24	24.6	24	22.5

Table: 6 & table 7 represents various proportions of fly ash (5, 10, 15, 20, 25, and 30) and Bagasseash (10, 20, 30, and,40) with soil on identified geotechnical characteristics like OMC and MDD, FSI, CBR & UCS values

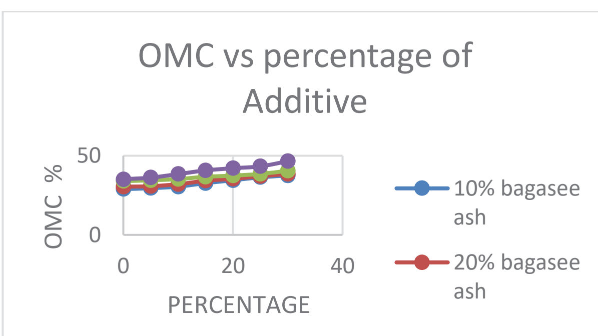

Fig 15: Variation of Optimum Moisture Content Vs Percentage of additive

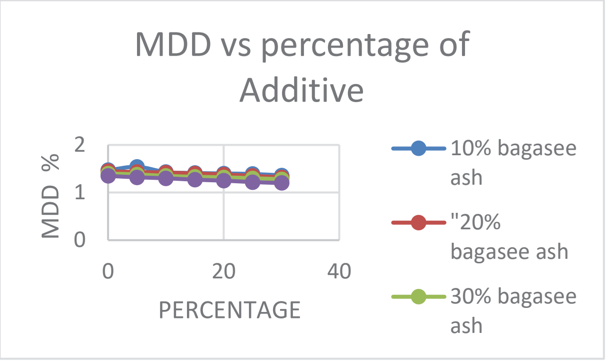

Fig 16: Variation of Maximum Dry Density Vs Percentage of additive

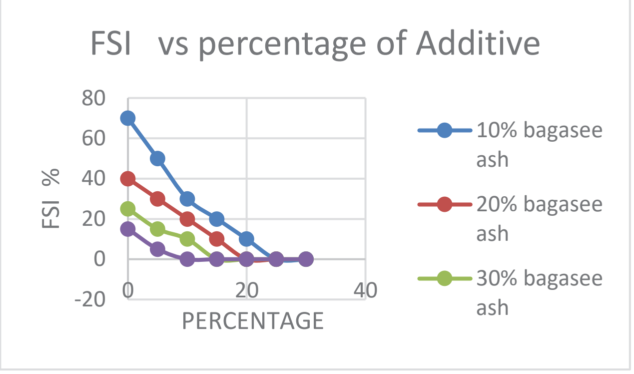

Fig 17: Variation of Free Swell Index Vs Percentage of additive

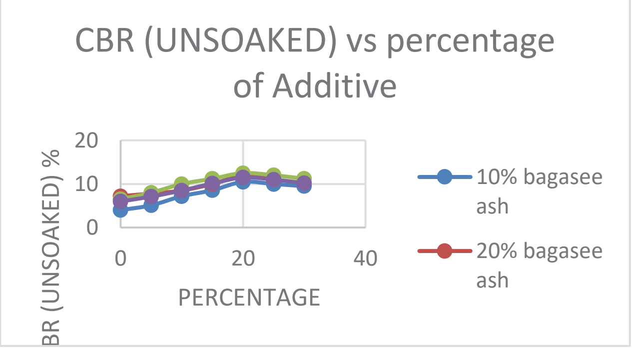

Fig 18: Variation of Unsoaked California Bearing Ratio Vs Percentage of additive

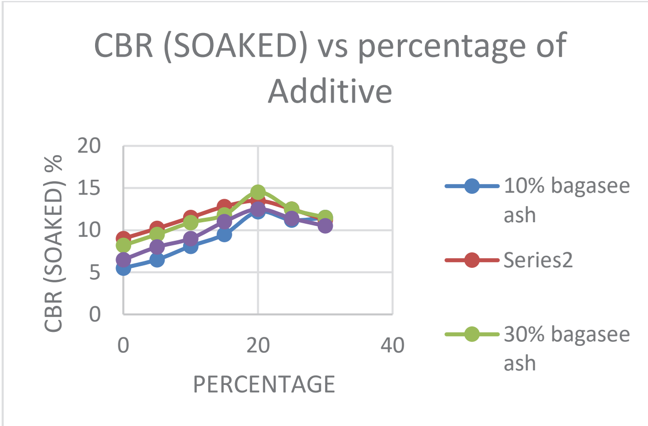

Fig 19: Variation of Soaked California Bearing Ratio Vs Percentage of additive

OMC increases as the proportion of fly ash and bagasse ash increases (fig 15). As bagasse ash and fly ash (FA) percentages rise, MDD decreases (fig 16). The Free Swell Index falls as fly ash and bagasse ash concentrations rise (fig 17). The amount of fly ash at 25% and bagasse ash at 10% and 20% causes a rise in the CBR Soaked value. Moreover, CBR value increases with concurrent declines in the amounts of Fly ash and bagasse ash and increases of 20%, 30%, and 40% for each, respectively (fig 19). The percentage of fly ash increases to 25% and that of bagasse ash to 10%, 20%, and 30% as the CBR Unsoaked value increases. Moreover, the CBR value rises as the percentages of Fly ash and bagasse ash grow by 20% and 40%, respectively, while simultaneously falling (fig 18)

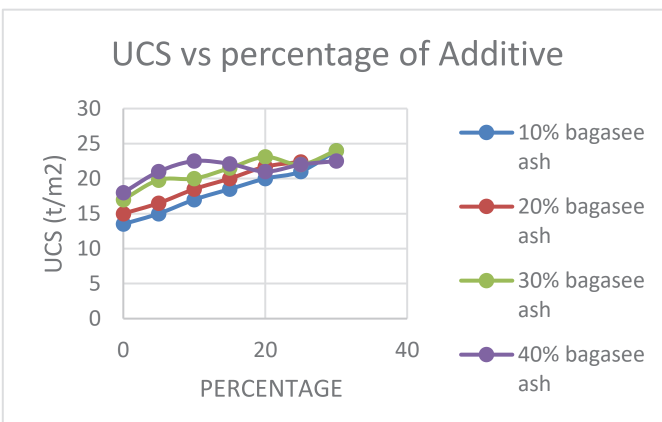

Fig 20: Variation of Unconfined Compressive Strength Vs Percentage of additive

The UCS value rises as fly ash content at 25% and bagasse ash content at 10% and 20% do. Nevertheless, 20% higher growth in quantities of Fly ash, 30% Coir Ash, and 40% Coir Ash all raise UCS value, while increments of 20% Bagasse ash and fly ash lower UCS value

5.CONCLUSION

1. The clayey soils' ability to compact is improved by the addition of fly ash and bagasse ash.

2. The index properties, compaction, and potential characteristics of clayey soils are significantly improved by the addition of fly ash and bagasse ash mixture.
3. The effects of the fly ash cure vary depending on how much fly ash is mixed with the clayey soil samples.
Building on readily available local soil was difficult because of its frequent high plasticity (LL> 50).
Unconfined compressive stress increased normally with varying fly ash addition rates to natural soil.
4. As the less dense ash particles replaced some of the soil particles, the amount of OMC increased and the amount of MDD decreased in the optimal additive content.
The blend of 20% fly ash and 30% bagasse ash has been shown to be the best additive content out of all the additive combinations because samples mixed with it demonstrated enhanced CBR and UCS values of 12.5%, 14.5%, and 23.5t/m2, respectively. These soil samples were processed for use as a foundation and subgrade for the construction of roads.

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