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SOIL STABILIZATION STUDIES ON THEIR UTILIZATION IN ROADS AND EMBANKMENTS

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Abstract:
Black cotton soils tend to expand as their water content increases and contract when it decreases. The water may originate from rain floods, leaking water or sewer lines, or decreased evapotranspiration when an area is covered by a structure or pavement. It is vital to modify the geotechnical qualities of expanding soil in order to achieve economic efficiency and optimal structural performance. Flyash is an industrial waste coming out by burning of coal. Therefore, if it can be effectively used to improve the undesirable properties of expansive soils, the increase in the cost and maintenance of a project where large quantities of expansive soils are involved will not be high and at the same time the disposal problem of flyash will also be solved. Through geotechnical uses such as embankments, back-fill material, and sub-base material, this waste material may be used in large quantities. Soil treatment with lime is a tried and true approach for saving time and money on building projects. Lime drying of wet soils reduces weather-related construction delays and facilitates the resumption to work within hours. The alteration of clay soils with lime renders them friable, workable, and compact. Unstable clay soils undergo long-term chemical changes as a result of lime stabilisation. We obtained Black cotton soil samples from Shad-Nagar in MahbubNagar District for this investigation (Telangana).
Due to pozzolanic properties of lime-flyash mixtures, its use in road construction will eliminate the need for expansive borrow materials, improve the quality of wet and unstable sub-grade, results the decrease in pavement thickness as a consequence of improvement in sub-grade conditions and permits substitution of certain low cost or inferior type of materials in the pavement construction.
In this project, the results of an experiment designed to determine the influence of Fly-Ash and lime on expansive soil are presented and discussed.

I. INTRODUCTION

Need for Stabilization of soil

It may be defined as the modification of soil done to improve their certain characteristics. It develops the shear capacity and shrinking, swelling of soil. It boosts the load carrying power to assist the construction works. In our project work we have undertaken clayey soil, substituted with Fly-Ash by adding lime. Due to urbanisation and industrialization's fast expansion, soil improvement is a crucial problem for construction projects. Soil improvement refers to approaches that enhance the index characteristics and other engineering features of poor soils. In India, expansive soil covers around 0.8 x 106 km2, or almost one-sixth of its surface area. These soils include the mineral montmorillonite; as a result, they inflate and contract excessively with changes in water content. Due to the presence of clay particles that inflate when they come into touch with water, soils tend to alternately expand and contract, causing differential settling of structures. With the addition of a little amount of lime and other admixtures, expansive soils can be stabilised. These strategies have been utilised to enhance subgrades and subbases in a variety of construction applications, including highway, railroad, and airport building. Quarry dust is a byproduct created in granite companies during the shaping of enormous granite blocks. Approximately 3000 metric tonnes of granite dust/slurry are created daily as a byproduct of the production of granite tiles and slabs from raw blocks. These wastes are dumped in neighbouring pits or on open ground by the marble and granite industry. Especially as the slurry dries, this results in severe environmental damage and the occupancy of a huge amount of land. This study examines the effects of granite dust on the consistency limits and differential free swell (DFS) of Black Cotton Soil mixed with 2 to 6 percent lime and 6 to 30 percent granite dust by weight of soil.

Expansive Soils
Expansive soil deposits are found in arid and semi-arid parts of the world, and their inclination to heave during the rainy season and contract during the dry season is troublesome for engineering buildings. It expands and contracts excessively with changes in its water content. This is due to the presence of small clay particles that expand when they come into touch with water, causing the soil to alternately swell and contract, resulting in differential structural settling. Using lime and Fly-Ash as an additive, the black cotton soil was stabilised in this experiment.

Black Cotton Soil
Expansive soils are soils or soft bedrock that grow in volume when wet and contract when dry. In India, this Extensive soil is known as "black cotton soil." This soil's colour ranges from reddish brown to black, which facilitates the growing of cotton, hence the name black cotton soil. This expanding soil covers around 30 percent of India's geographical area. They are also known as expanding or Black Cotton soil. Extensive sections of the Deccan Trap in India contain Black Cotton soil, commonly known as "regurs." Black Cotton soil is one that, when coupled with an engineering structure and in the presence of water, causes the structure to experience moments that are entirely unrelated to the direct action of loading by the structure.

These clays are characterized by
- Having a particle size, below 2 micron.
- A large specific surface area (SSA) and
- A high Cat ion Exchange Capacity (CEC).
- High liquid limit and plasticity index.

Problems Associated With Black Cotton Soil
Black Cotton soils are problematic for engineers everywhere in the world, and more so in tropical countries like India because of wide temperature variations and because of distinct dry and wet seasons, leading to wide variations in moisture content of soils. The following problems generally occur in black cotton soil.

(a) High compressibility
Black Cotton soils are highly plastic and compressible, when they are saturated. Footing, resting on such soils under goes consolidation settlements of high magnitude.

(b) Swelling
A structure built in a dry season, when the natural water content is low shows differential movement as result of soils during subsequent wet season. This causes structures supported by such swelling soils to lift up and crack. Restriction on heaving developed due to swelling pressures making the structure suitable.

(c) Shrinkage
A structure built at the end of the wet season when the natural water content is high, shows settlement and shrinkage cracks during subsequent dry season.

II. MATERIALS USED

a. Soil

The soil used for this investigation is obtained from *Shad-Nagar* in *MahbubNagar* District. The dried and pulverized materialpassing through I.S.4.75 mm sieve is taken for the study. The properties of the soil are given in Table 2.1. The soil is classified as “CH” as per
I.S. Classification (IS 1498:1970) indicating that it is highly compressible clay. It is highly expansive in nature as the Differential Free SwellIndex (DFSI) is about 55%.

Table 2.1: Properties of Untreated Soil

Sl.No.	Property	Value
1	Grain size distribution	
	(a).Gravel (%)	0.5
	(b).Sand (%)	12.2
	(c).Silt&Clay (%)	87.3
2	Atterberg Limits	
	(a).Liquid Limit (%)	57.5
	(b).Plastic Limit (%)	26
	(c).Plasticity Index (%)	31.5
3	Differential Free Swell Index (%)	55

4	Specific Gravity	2.69
5	Shrinkage limit (%)	13.33
6	Compaction Characteristics (a).Maximum Dry Unit Weight (kN/m^3) (b).Optimum Moisture Content (%)	 16.9 23.2
7	California Bearing Ratio Value (a) @ 2.5mm Penetration (b) @ 5.0mm Penetration	 2.8 2.53
8	Unconfined Compressive Strength (kN/m^2)	161.2
9	Direct shear parameters (a).Cohesion(kg/cm2) (b).Angle of internal friction(degrees)	 0.08 20

b. Lime

Quicklime is calcium oxide (CaO), which has variable particle size depending on the end use and high available calcium content. After mixing initially, the calcium ions (Ca++) from hydrated lime drift to the surface of the clay materials and displace water and other types of ions. The soil becomes friable and granular, makes it easier to work and compact. The overall procedure, which is called "flocculation and agglomeration," normally occurs in a few hours. Using certain amounts of CaO and water, acidity decreases rapidly and pH becomes more than 10.5 eventually breaking down the clay matters. Productsreleased that are Silica and alumina combine with Ca to produce calcium-silicate-hydrates (CSH) and calcium-aluminates-hydrates (CAH). These are the cementitious by-products. The matrix that is formedby the products improves the strength of the layers of the lime-modified soil. After formation of the matrix, transformation of the soil happens from a void less material to a relatively firm impervious layerwith a massive load bearing power. Within the first few hours, initial stage of the procedure begins for a lengthy period of time which may last for years in a properly designed setup. At the end, the whole mix becomes impervious, firm and long lasting structurally.

c. Fly-Ash

Fly ash is an essential industrial by-product that comes from the burning of coal, used for the production of electrical energy. In our country, only a small percentage of this is used for the construction of technical projects, while the rest is dumped (stockpiled), which causes serious problems to the accessible environment. It has been found that stabilization with fly ash, improves the engineering and mechanical characteristics of soil, so it is a viable option to use fly ash as a modifier. Stabilization of soils and pavement bases with coal fly ash is gaining rising popularity among pavement engineers in the recent past. The fly ash used in this study was collected from the KOTHAGUDAM THERMAL POWER STATION. The grade of fly ash used in the experimental work is "F" grade. The chemical composition of fly ash shown in table.

Sl. NO.	Chemical component	Chemical content by % wt
1	SiO_2	59
2	AlO_3	16.40
3	$Fe\ O_3$	6.30
4	CaO	5.93
5	MgO	2.25
6	SO_3	1.00
7	LOI	4.62

Table 2.2: Product size analysis

The basic details are given below table 2.2 and geotechnical properties of Fly-Ash are shown in the table 2.3

No	Property Name	Value
1	Grain size distribution % of Gravel % of sand % of silt + clay	 Nil 6 94
2	Coefficient of Uniformity, C_u	2
3	Coefficient of Curvature, C_c	1.13
4	Specific Gravity	1.95-2.2
5	Direct shear test Cohesion Angle of Shear resistance	 0.0 27°
6	Proctor's Density Optimum Moisture Content Max. Dry Density	 18% 1.29 g/cc
7	Permeability Test Coefficient of Permeability	 $1.3x10^{-4}$ cm/sec

Table 2.3 Geotechnical Properties of Fly-Ash

III. EXPERIMENTAL PROGRAMME

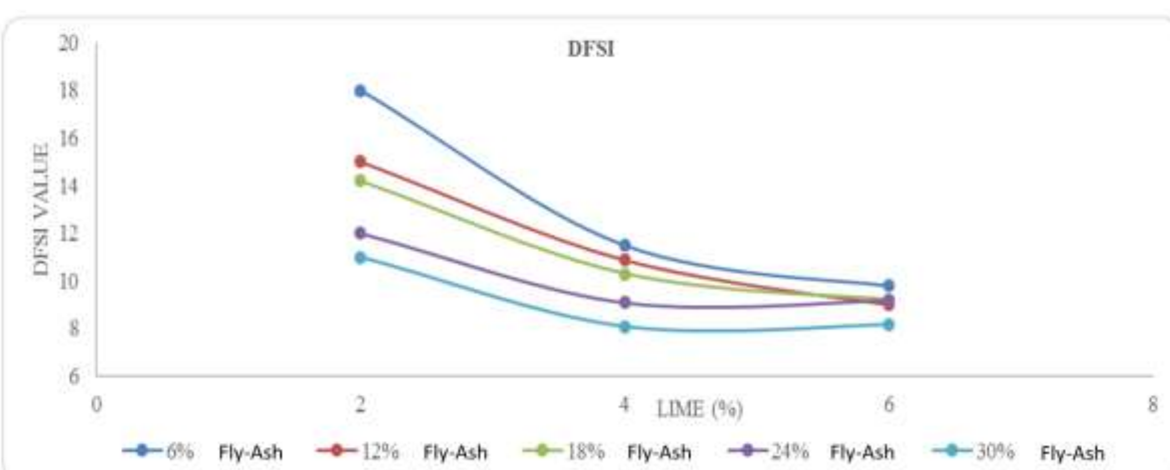
This study experimental programme investigates the index characteristics, Proctors compaction, differential free swell index and unconfined compression strength, and California bearing ratio. The site's soil is dried and manually sifted to eliminate any stones and plant material. It is then dried, ground, and sieved through a 4.75mm mesh to remove any gravel portion. The dried and sieved soil is kept in airtight containers until it is ready to be mixed with Lime & Fly-Ash. The soil sample so prepared is then mixed with various Proportions of Lime & Fly-Ash. The percent of Admixtures content is varied as 2% lime with 6% Fly-Ash, 2% lime with 12% Fly-Ash,4% lime with 6% Fly-Ash,4% lime with 12% Fly-Ash,4% lime with 18% Fly-Ash,4% lime with 24% Fly-Ash,4% lime with 30% Fly-Ash,6% lime with 6% Fly-Ash,6% lime with 12% Fly-Ash,6% lime with 18% Fly-Ash,6% lime with 24% Fly-Ash,6% lime with 30% Fly-Ash. The admixtures content is taken by weight of soil taken.

The experiments were conducted as per following IS codal provision:

- IS 2720 (Part 5) –1985 - Liquid limit & Plastic limit test
- IS: 2720 (Part 7) – 1980 - Standard proctor test (SPT)
- IS: 2720 (Part 10) – 1991 - Unconfined compressive strength (UCS) test
- IS: 2720 (Part 16) – 1987 - California bearing ratio (CBR) test

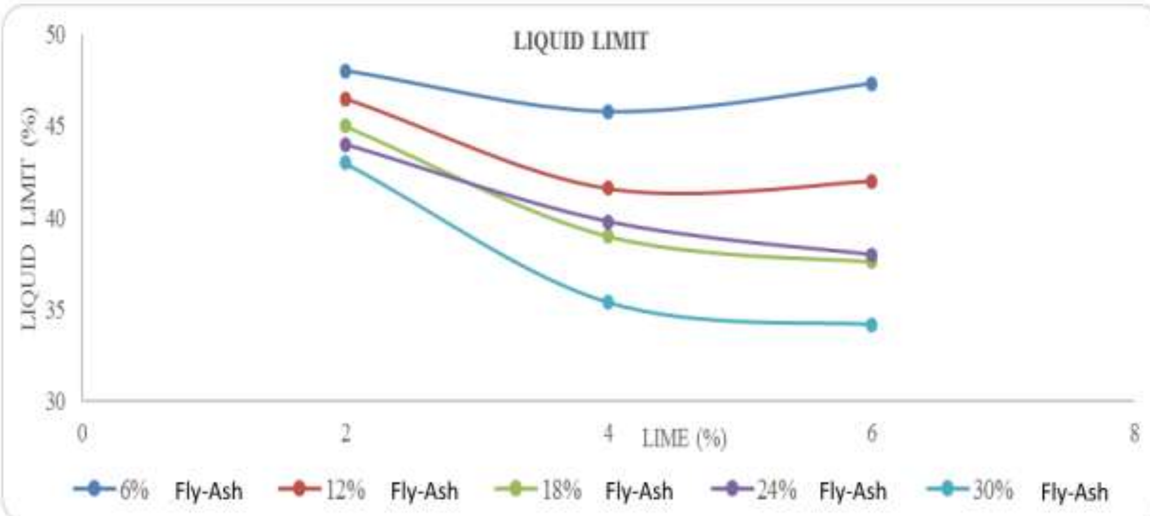
IV. COMPARISION OF RESULTS AND DISCUSSIONS

RESULTS:



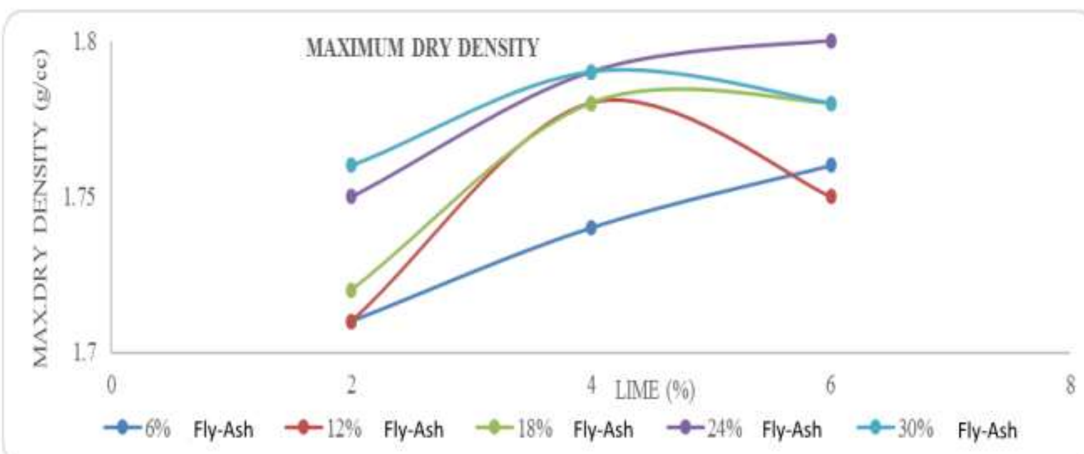
Graph: 4.1: Variation in Differential Free Swell Results.

Graph: 4.1 shows variation in differential free swelling value, it shows that maximum reduction in Differential Free Swelling was found ataddition of 6% lime and 30% Fly-Ash to black cotton soil.



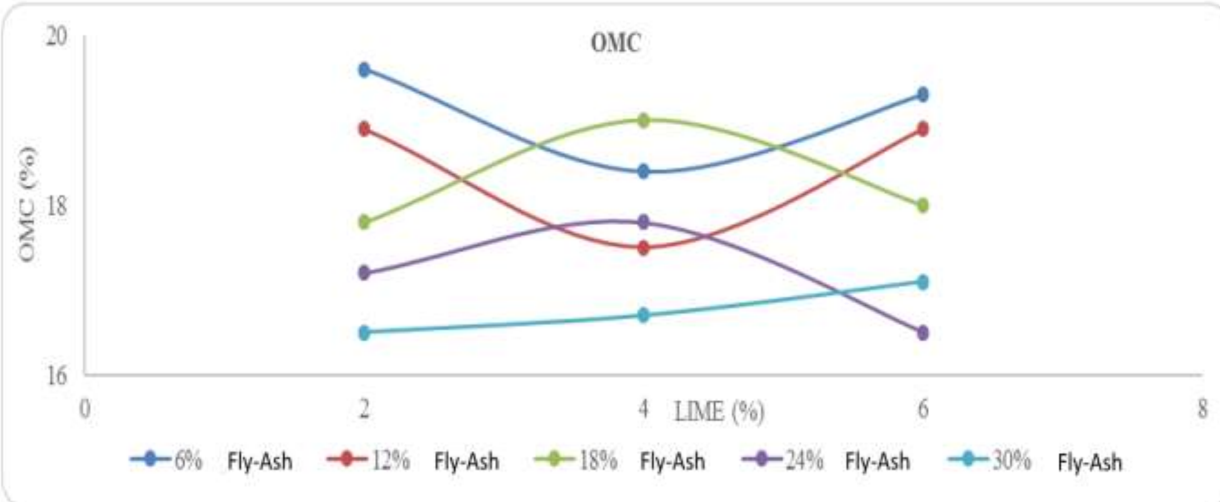
Graph 4.2: Variation in Liquid Limit

Graph: 4.2 shows variation in liquid limit of black cotton soil, it shows that maximum reduction in liquid limit was found with addition of 6%lime and 30% Fly-Ash in black cotton soil.



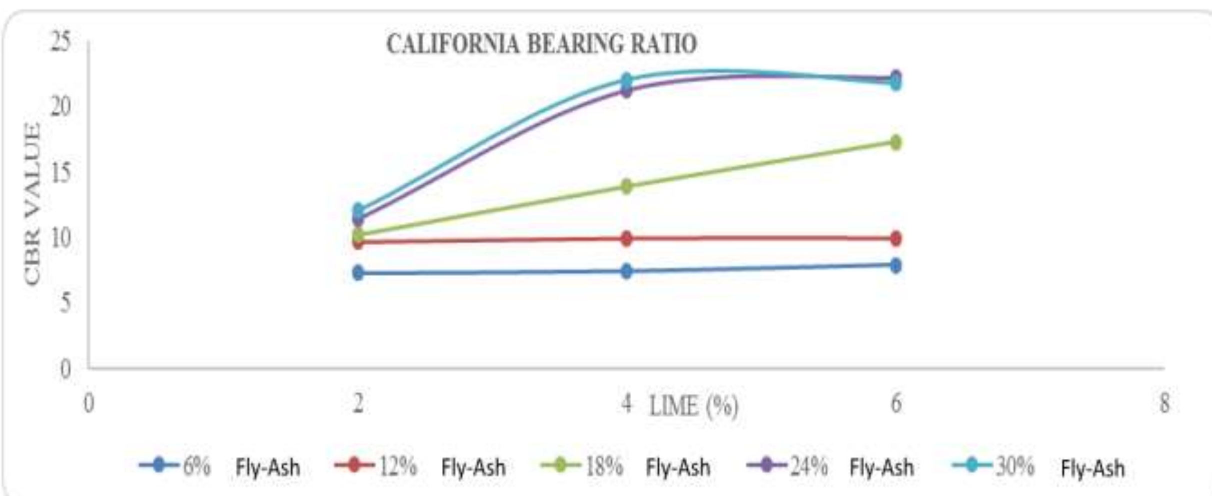
Graph: 4.3: Variation in Maximum dry density.

Graph: 4.3 shows variation in maximum dry density of black cotton soil, it shows that maximum dry density is increased with addition of 6%lime and 24% Fly-Ash in black cotton soil.



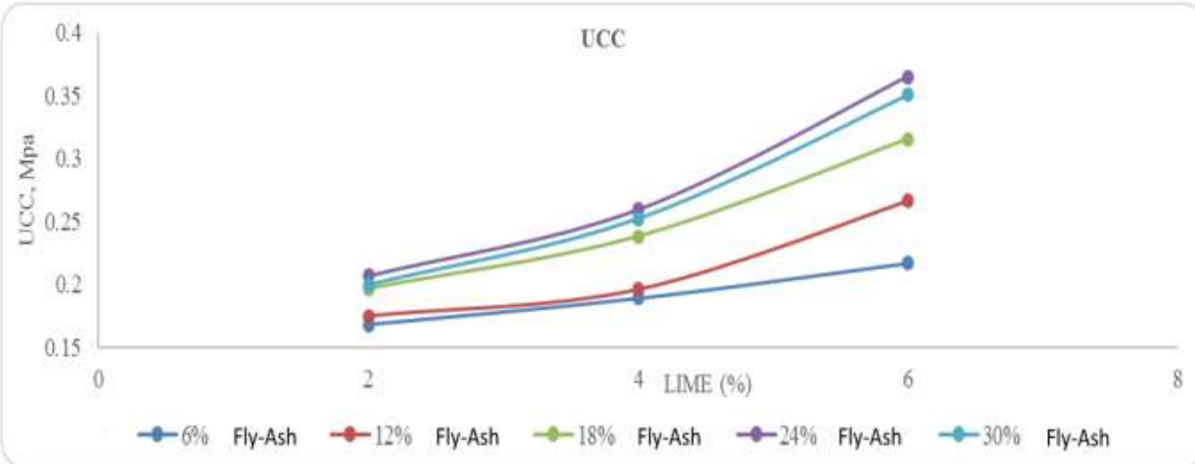
Graph: 4.4: Variation in Optimum Moisture Content.

Graph: 4.4 shows variation of optimum moisture content of black cotton soil, it shows that maximum reduction in OMC was found with additionof 6% lime and 24% Fly-Ash in black cotton soil.



Graph: 4.5: Variation in CBR Values.

Graph: 4.5 shows variation in CBR of black cotton soil, it shows that maximum CBR value was found with addition of 6% lime and 24% Fly-Ash in black cotton soil



Graph: 4.6: Variation in Unconfined Compression Strength of soil.

Graph: 4.6 shows variation in UCC of black cotton soil, it shows that maximum UCC value was found with addition of 6% lime and 24% Fly-Ash in black cotton soil.

DISCUSSIONS:

1. The results of differential free swelling tests on lime and Fly-Ash stabilized expansive soil treated with different percentages has been shown in above Figures. It is observed that by addition of lime and Fly-Ash, the differential free swelling index of soil decreases to 8.2% at 6% lime+30% Fly-Ash. The reason of which is the decrease in plasticity characteristics of soil due to reduction in clay content of soil because of replacement of clay with Fly-Ash. This is because of the pozzolanic reaction of lime with the amorphous silica and Alumina present in soil and Fly-Ash a strong inter particle bond develops, this cementing bond offers greater resistance to swelling and also does notallow the water to escape from soil to induce shrinkage.
2. Liquid limit of Black cotton soil was decreased by addition of lime and Fly-Ash at different percentages. This is because when quicklime chemically combines with water, it can be used very effectively to dry any type of wet soil. Heat from this reaction further dries the wet soils. The reaction with water occurs even if the soils do not contain significant clay fractions. When clays are present, lime's chemical reactions with clays increase the moisture-holding capacity of the soil, which reduces free liquids and decreases in liquid limit because clay particles are reduces by addition of Fly-Ash in black cotton soil.
3. It is observed that maximum dry density of Black cotton soil was increased upto addition of 6% lime and 24% Fly-Ash. This is because of the frictional resistance from Fly-Ash in addition to the cohesion from Black cotton soil and lime gives the binding property to soil.
4. The results of UCC tests on Black cotton soil treated with different percentages of lime and Fly-Ash are shown in above figures. By increasing the percentages of lime and Fly-Ash, UCC of soil increases upto a limit at addition of 6% lime and 24% Fly-Ash, further addition of admixture decreases the UCC of the expansive soil. The UCC of Black cotton soil increases to 0.3644N/mm^2 from 0.1612 N/mm^2, when 6% lime and 24% Fly-Ash was added. This is because of the additional frictional resistance. Reduction in UCC occurs due to reduction in cohesion because of the reduction in expansive soil content.
5. The results of CBR tests on black cotton soil with lime and Fly-Ash are shown in above figures. It is observed that by addition of lime and Fly-Ash at different percentages, rate of increases in the CBR of soil increases to 792% from 260% upto addition of 6% lime and 24% Fly-Ash, further addition of admixtures slightly decreases the CBR of the soil. The CBR attains the highest value when the percentage of 6%lime and 24%Fly-Ash was added. There is a 792% increase in CBR of the virgin soil by the combined effect of lime and Fly-Ash. The reasonof this effect is the pozzolanic reactions of lime with the amorphous silica and Alumina present in soil and Fly-Ash. After addition of 6% lime and 24% Fly-Ash the strength decreases because of the availability of extra admixtures to react with the insufficient amorphous silica and Alumina present in soil and Fly-Ash which results in carbonation reaction and thus strength decreases.

V. CONCLUSIONS

The present study can serve as an effective method to utilize Fly-Ash and lime in the stabilization of expansive soil. The conclusions are based on the tests carried out on various clay-Fly-Ash and lime mixes selected for the same.

1. It has been seen that differential free swelling index and liquid limit decreases by adding lime and Fly-Ash up to 4%lime & 30% Fly-Ash, whereas further addition of admixtures increases it.

2. The optimum value of maximum dry density and unconfined compressive strength was found at 6% lime & 24 % Fly-Ash.
3. Optimum moisture content was found gradually decreasing by adding admixtures and maximum reduction in OMC was found at 6% lime & 24 % Fly-Ash.
4. Increase in plastic limit was very less up to addition of 2% lime & 6% Fly-Ash further addition of admixtures plastic limit was gradually decreased up to 6% lime & 6%Fly-Ash and after addition soil was found non plastic.
5. Maximum CBR value was found at addition of 6% lime & 24 Fly-Ash.
6. It was found that there is a maximum improvement in strength properties for the combination of lime and Fly-Ash as compared to lime/Fly-Ash individually. This helps to find an application for industrial waste to improve the properties of expansive soil both in embankments and pavement constructions.

So the optimum percentages of lime and Fly-Ash were observed at 6% lime and 24 % Fly-Ash for improving the properties of expansive soil. Fly-Ash and lime has good potential for use in geotechnical application of soils is a proven method to save time and money on construction projects. Lime drying of wet soils minimizes weather-related construction delays and permits the return to work within hours. Lime modification chemically transforms clay soils into friable, workable, compactable material. Fly-Ash and lime stabilization creates long-term chemical changes in unstable clay.

VI. REFERENCES

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