
ABSTRACT

Infrastructure projects such as highways, railways embankments etc. require large quantities of soils for their construction. Structures like these located in expansive soil areas needs special attention and for the use of local materials. In this aspect use of stabilized materials gives are alternative solutions. Fly ash one such material and can be mixed with expansive soils can be used as geotechnical material. Fly ash is an industrial waste obtained from thermal power plants by burning of coal. In this an attempt is made for the utilization of Fly ash with cement in bulk quantities by adding these to expansive soil and tests like plasticity, swell potential, permeability and UCS were performed. From the test results it is identified that addition of Fly ash and cement decreases plasticity and improves strength characteristics. Addition of Fly ash-cement attain high compressive strength values of 2.55-3.72kPa and improves the seepage characteristics.

Keywords: Expansive soil, Fly Ash, UCS, Curing period

INTRODUCTION

Expansive soils are popularly called as Black cotton soils in India subjected to lot of swelling and shrinkage characteristics. These soils are available in huge quantities of North coastal districts of A.P. structures constructed on these soils have been facing differential settlements resulting severe damages. Katti(1979)⁷ has given properties of Black cotton soils which have Liquid limit 40%-100%, Plastic limit 20%-60%, Differential Free Swell index 20%-100%. Structures located on these soils subjected to differential settlements due to moisture variations (Bala Subramanian et.al 1989)¹. However these soils easily available at low cost and frequently used for construction purposes (Bell 1988)². Stabilization is one of the methods to improve expansive soil characteristics. In view of this an attempt is made to study the effectiveness of Fly ash in reducing swell and plastic characteristics when expansive soils mixed with Fly ash materials. Fly ash is an industrial waste obtained from thermal power plants by burning of coal. Therefore bulk stabilization of Fly ash becomes very essential in view of huge producing and to reduce the impact on disposal areas under Environmental concern. Utilization in Geotechnical applications are Sub-grades, Embankment materials, Backfill and Structural Materials. Some of the researchers Boominathan, A. et.al (1990)⁴ studied Behavior of Fly ash under Static and Cyclic Loading, Cokca, E. (2001)⁵ studied Use of class C fly ashes for the stabilization of an expansive soil, Boominathan, A et.al (1996)³ studied Lime treated Fly ash as Embankment Material, P.V.V.Satyanarayana et.al (2013)¹² studied on the Strength characteristics of Expansive soil-Fly ash mixes at various moulding water contents, Kiran B.Biradar et.al (2014)⁸ studied the Influence of steel slag and Fly ash on Strength Properties of Clayey soil, Ramakrishnan, A.K. et.al(2001)⁵ Stabilization of Annamalainagar Clay with lime-Fly ash, Nalbantoglu, Z. et.al(2004)¹⁰ studied Effectiveness of class C fly ash as an expansive soil stabilizer, Satyanarayana.P.V.V et.al (2013)¹³ studied the Bulk utilization of Fly ash lime sodium silicate mixes in geotechnical applications, Satyanarayana.P.V.V et.al(2016)¹⁴ studied on the Engineering Properties of Expansive Soil Stabilized with Fly ash and Lime Mixes, Sridharan, A. et.al (1997)⁶ studied Effect of Fly ash on the unconfined strength of black cotton soil, Pandian N.S et.al (2004)¹⁰ studied Fly ash characterization with reference to geotechnical applications.

In present investigation various percentages of Fly ash and cement mixes were added to expansive soils and effect of these mixes was studied in terms of plasticity, swell pressure, permeability and strength characteristics at various curing periods 7days and 28days.

MATERIALS

To study the performance of Fly Ash and Cement admixtures on expansive soil, which was obtained from delta areas of Godavari River in Bhimavaram, Andhra Pradesh, India and Fly Ash was collected from NPTC, Parawada of Visakhapatnam district, Andhra Pradesh, India and OPC 43 grade cement from local markets.

2.1. BLACK COTTON SOIL:

Expansive soils in India are popularly known as Black cotton soils and the collected soil was dried and pulverized into the required sizes and tested for properties like gradation, compaction, strength as per IS2720 and the results are shown in table-1 and fig-1

Table.1. Geotechnical properties of Black cotton soil

Property	Values
Gravel (%)	0
Sand (%)	4
Fines (%)	96
a) Silt	50
b) Clay	46
Liquid Limit (%)	74
Plastic Limit (%)	29
Plasticity Index (I _p)	45
IS Classification	CH
Optimum moisture content (OMC) (%)	26
Maximum dry density (MDD) (g/cc)	1.52
California bearing ratio (%) (CBR Soaked)	1.0
Angle of shearing resistance (Ø)	15
Cohesion (t/m ²)	10

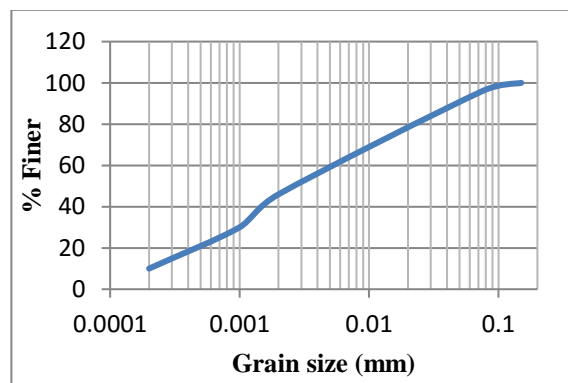


Fig-1: Gradation curve of Black Cotton soil

From the test results it is identified that it contains fines (less than 75µm) of 95% .shows alluvial origin out of which 40% of silt and 55% as clay particles. The presence of fines contributed for high liquid limit (w_L) of 74% and plasticity index of 45% can be classified as CH soil based on IS1498 1970 It also exhibited high swelling characteristics with FSI as 100 and swell pressure as 90kpa and very low strength values under soaking in terms of CBR as 1%

2.2 FLY ASH:

Fly ash was collected from National Thermal Power Corporation (NTPC), which is located at Parawada, Visakhapatnam, Andhra Pradesh. The collected dried Fly Ash was subjected to various geo-technical characterizations such as gradation, compaction, strength, permeability etc., and the test results are shown in table -2 and Fig 2

Table 2. Geotechnical Characterizations of Fly ash

Property	Values
Gravel (%)	0
Sand (%)	28
Fines (%)	72
a. Silt (%)	72
b. Clay (%)	0
Liquid Limit (%)	28
Plastic Limit (%)	NP
Specific gravity	2.1
Optimum moisture content (OMC) (%)	21
Maximum dry density (MDD) (g/cc)	1.28
California bearing ratio (CBR) (%)	4

Coefficient of uniformity (Cu)	28.89
Coefficient of curvature (Cc)	2.13

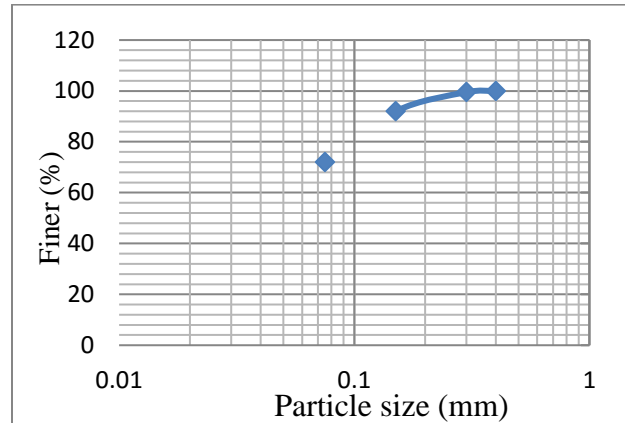


Fig-2: Gradation curve of Fly ash
Table 3. Chemical Composition of Flyash

Compound Formula	Percentage
SiO ₂	59.83
Al ₂ O ₃	30.48
CaO	1.74
MgO	0.86
TiO ₂	6.91
V ₂ O ₅	0.09
ZnO	0.09

From the test results it is identified that, it has 72% fine particles (<75µm) and all these particles are silt ranges. It is non-plastic and incompressible material. It has low specific Gravity and attained less dry Density with high Moisture Contents due to nature of Flyash particles. From the chemical composition it is identified that it has less percentage of CaO (1.74<15%) classified under class F flyash (ASTM) and presence of high percentages of SiO₂ and Al₂O₃ (90%) make the Flyash Pozzolanic with addition of Lime, Cement and other additives.

RESULTS AND DISCUSSIONS

Effect of Fly ash on Engineering Properties of Expansive Soils

To study the effect of Fly ash on expansive soil, various percentage of fly ash i.e. 0,20,...50% by dry weight of soil were added and effectively mixed and tested for characteristics like consistency, compaction, Swell pressure and permeability as per IS2720 and the results are shown in table-4 and fig-3(a)-3(d). In addition to these soil-Fly ash mixes were respected for compressive strength values at various curing periods. The samples were prepared at their MDD and cured for 7 and 28 days and tested as per relevant IS 2720 parts. At these conditions, the soil samples were also tested for their coefficient of permeability values at 7 days the results are shown in tables 4(a),4(b) and figures 3(a),3(b), 3(c),3(d)

Table 4(a)& (b). Various characteristics of soil-Fly ash mixes

FLYASH	W _L	W _P	I _P	SWELL PRESSURE(Ps) (kPa)
0	74	29	45	105
10	66	30	36	85
20	55	32	23	60
30	40	34	6	35
40	24	NP	NP	10
50	NP	NP	NP	5

FLY ASH	UCS (kPa)		K cm/sec
	7	28	
0	0.2	0.2	4.6x10 ⁻⁷
10	0.28	0.32	6.0x10 ⁻⁷
20	0.34	0.45	8.5x10 ⁻⁷
30	0.44	0.53	1.8x10 ⁻⁶
40	0.48	0.58	4.6x10 ⁻⁶
50	0.42	0.54	7.1x10 ⁻⁶

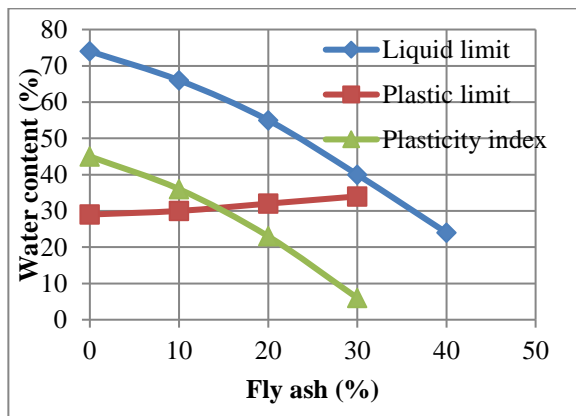


Fig 3(a). Consistency limits

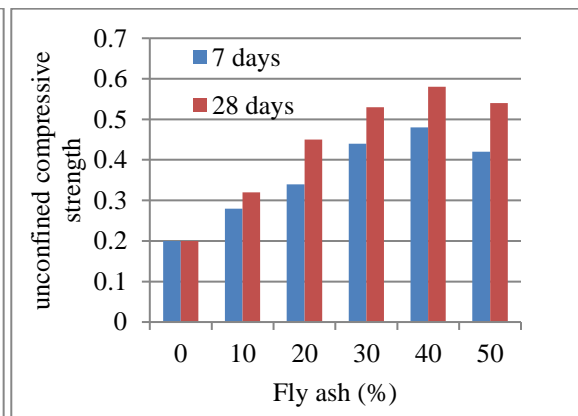


Fig 3(b). UCS Vs Fly ash (%)

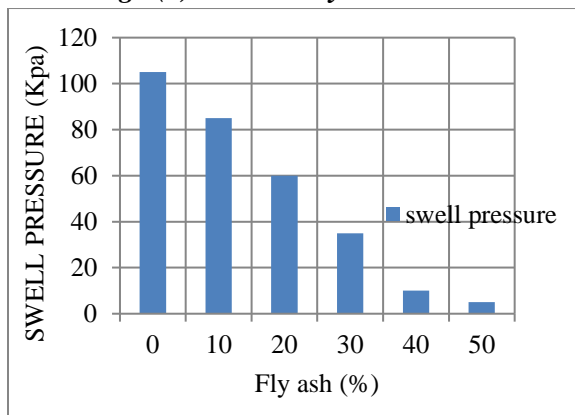


Fig 3(c). swell pressure Vs Fly ash (%)

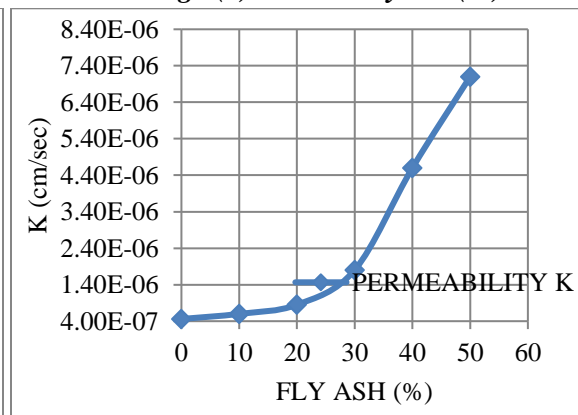


Fig 3(d). permeability Vs Fly ash (%)

From the consistency test data, it is identified that as the percentage of fly ash is increasing liquid limit and plasticity index values are decreasing and plastic limit values are increasing. This phenomenon is continued up to 30% after it became non-plastic. The decrease in liquid limit is due to the decrease in diffused double layer by replacement of clay particles by fly ash particles and increase in plastic limit is due to the development of shear resistance at inter particle level and also the particles in soil-fly ash matrix require more water to mobilize for rolling.

From the shear test data it is identified that with increasing percentage of fly ash, UCS values are increasing with curing time the same trends was continued up to 40% as there decreasing the increase in compressive strength values are in small quantity. This is due to availability of cement in small quantities generates less quantities of C-S-H and C-A-H gels. This phenomenon creates amorphous cementitious compounds.

From the swelling characteristics, it is identified that as the percentage of Fly ash is increasing in the soil-Fly ash matrix, swelling pressure values are decreasing. At 40% of Fly ash swelling pressure became 10Kpa which soil-Fly ash mix shows non-swelling nature. At higher percentage of Fly ash repulsive forces are decreasing and shearing resistance at particle level is increasing which reduces the thrust transfer to the surrounding soil + Fly ash particles results reduction of swelling pressure values.

From the experimental data it is observed that as the percentage of Fly ash is increasing the coefficient of permeability values are increasing. Increase in the coefficient of permeability values are due to occupation of more Fly ash particles in place of soil particles. Hence a combination of soil and Fly ash particles accept impervious to semi-impervious conditions.

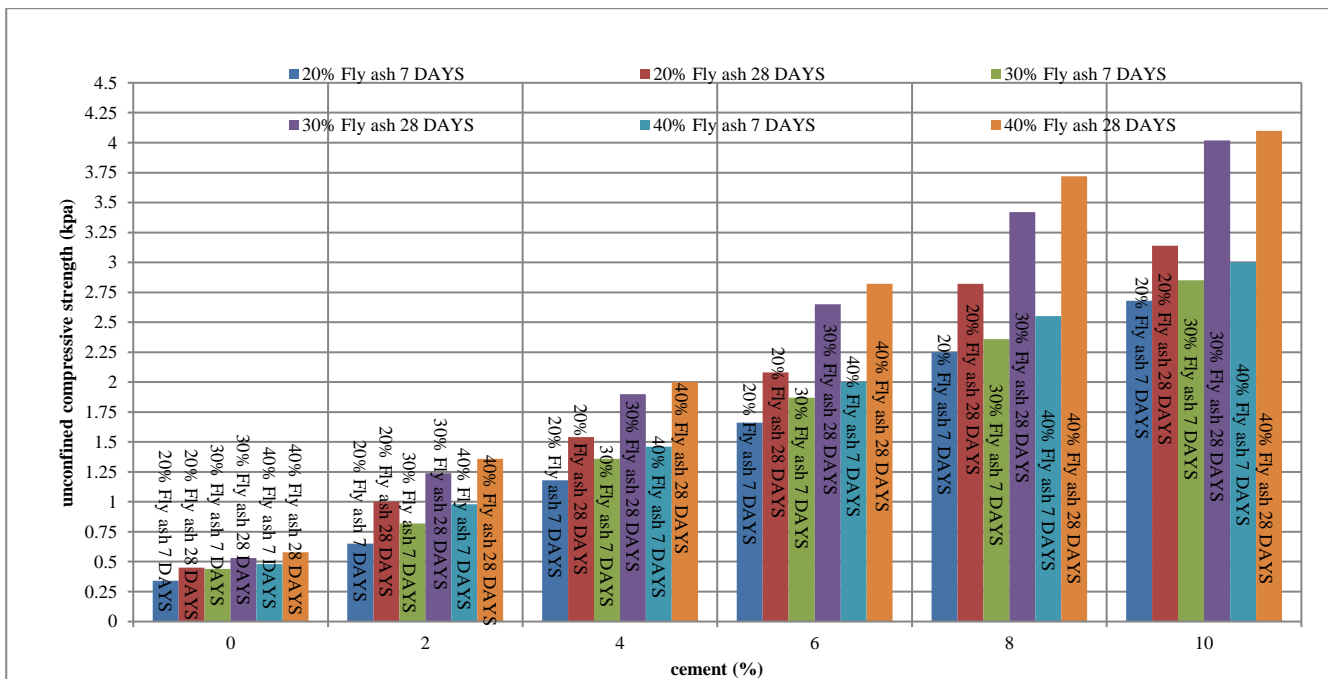
EFFECT OF CEMENT ON FLY ASH STABILISED EXPANSIVE SOIL

To study the effect of Cement on Fly ash stabilized expansive soil, various percentage of cement i.e. 2,4,6,....10% by dry weight of soil were added and effectively mixed and tested for characteristics like strength and seepage at various curing periods as per IS2720, and the results are shown in below.

Table.5.various Characteristics of cement Stabilized Expansive soil-Fly ash mixes

CEMENT (%)	Fly ash (%)					
	20		30		40	
	UCS (kpa)		UCS(kpa)		UCS(Mpa)	
	7	28	7	28	7	28
0	0.34	0.45	0.44	0.53	0.48	0.58
2	0.65	1.0	0.82	1.24	0.98	1.36
4	1.18	1.54	1.36	1.9	1.46	2.0
6	1.66	2.08	1.87	2.65	2.0	2.82
8	2.25	2.82	2.36	3.42	2.55	3.72
10	2.68	3.14	2.85	4.02	3.0	4.1

CEMENT %	Fly ash (%)		
	20	30	40
	k(cm/sec)	K(cm/sec)	K(cm/sec)
6	2.6×10^{-7}	4.4×10^{-7}	5.0×10^{-7}
8	1.8×10^{-7}	2.5×10^{-7}	3.2×10^{-7}
10	1.2×10^{-7}	1.6×10^{-7}	1.8×10^{-7}



From the test results it is identified that as the percentage of cement is increasing UCS values are increasing with curing periods . at low percentages of cement (2-4%) less values were observed comparing at higher percentages (6-10%) of cement with respect to compressive strengths

At low % of cement clay particles absorbs calcium ions on to the surfaces which make less quantities of free calcium ions are available to react with silica and alumina from the fly ash and soil particles from forming C-S-H&C-A-H gel compounds which are responsible for cementitious action on Amrofous. This exhibited low UCS values at low % of cement. At high % of cement more free calcium ions are available to react with silica and alumina particles from fly ash and soil particles to form CSH& CAH gels make soil fly ash compounds high cementitious and becoming crystalline with curing period. This phenomenon more pronounced at 28 days curing period. From the test results it is identified that as the % of lime is increasing UCS values are increasing with curing period. At low % of lime i.e is at (2-4%) and earlier curing periods(7days) a study increase were observe, whereas at higher %(6-10) and high curing period 28days a rapid increase in strengths were observed. It is also identified that high dosage of RHA required. High % of lime which have given high strengths.

APPLICATIONS

Addition of 40%Fly ash to Black cotton soil gives high unconfined strength values(2.55-3.77Mpa) and less values of coefficient of permeability. This percentage the mix of this soil impervious it can be used as liner material, fill material and sub-base material.

CONCLUSIONS:

Black cotton soil is used as liner material and fills material stabilized with 30-40% Fly ash and 6-8% of cement. At dosage of Fly ash and cement the soil became a high compressive strength values and improves the seepage characteristics.

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