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A Study on Strength Characteristics of BC Soil-Flyash Mixes

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Abstract—Soil stabilization is one of the most important processes which is broadly used in the road and foundation construction, because it modifies the engineering properties such as strength & resistance to penetration. Fly ash is creating environmental pollution & large area of costly land required for its disposal. Fly ash is proved to be good material for geotechnical application. The BC soil is not suitable for sub grade and its swelling & shrinkage characteristics cause damages to the structure. The objective of this study is to evaluate the effect of fly ash on unconfined compressive strength & resistance to penetration of BC soil. A series of laboratory unconfined compression strength test and California bearing ratio test were carried out. The study concludes that the addition of fly ash resulted in appreciable increase in UCS & CBR of the soil. The percentage of fly ash was varied from 10 to 50% & peak strength was observed for fly ash content, in between 20 to 30%.

Keywords—UCS, CBR, Fly Ash, Soil Stabilization, BC Soil

I. INTRODUCTION

Black cotton soil is a good example of expansive soil. The term expansive soil applied to soil that have the tendency to swell and shrink in presence & absence of moisture respectively. These soils are available in huge quantities in central part of the India. Structures constructed on these soils have been facing server damages. These damages are due to swelling action, observed in the form of cracking and break up of pavement roadways building foundation and reservoir linings. Expansive soils are a worldwide problem that imposes several challenges for geotechnical engineers. Various techniques are adopted to improve the engineering properties of BC soil. Apart from this technique stabilization of expansive soil with different admixtures, including fly ash, lime and cement is popular and effective. The stabilization of the expansive soil very important for various geotechnical application such as pavement structures, roadways & building foundation. Stabilization of the expansive soil with admixtures controls the potential of soil for a change in volume and improves the strength of soil.

Addition of fly ash to expansive soil is one of the promising techniques to understand the possible mechanism governing the behavior of expansive soil-fly ash mixture. Fly ash is an industrial by product obtained from thermal power station by burning of coal that is relatively inexpensive compared to cement & lime. In India these plant produce 130 MT of fly ash as a waste material. This paper presents a laboratory study conducted to evaluate the effect of fly ash on different strength properties including resistance to penetration & unconfined compression strength. The experimental program included CBR test & UCS to evaluate the bearing strength of stabilized soil used as subgrade in road construction.

II. LITERATURE STUDIES

Fly ash alone has less cementation effect but in the presence of water it reacts chemically and creates cementations compound and alter the strength and compressibility characteristics of expansive soil. Fly ash is now established as a most promising stabilizing agent in an expansive soil.

Erdal cokca (2001)[1], studied the effect of fly ash on expansive soil, concluded that expansive soil can be effectively stabilized by cation exchange mechanism using fly ash. Pandian et.al., (2002)[2]studied the effect of (class C) & (class F) types of fly ash, on the CBR characteristics of the BC soil, concluded that addition of fly ash to BC soil increases the CBR up to optimum level, then further addition of fly ash causes reduction in the CBR value, reported that increase in the strength by the fly ash contents is due to additional pozzolinic reaction by the fly ash on BC soil. S. Bhuvaneshwari et. Al., (2005)[3] concluded extensive laboratory/ field test on BC soil-fly ash mixes, the % of fly ash varied from 10 to 40% reported improvement of unconfined compression strength by the addition of fly ash. Improvement in strength properties was observed on optimum dose of fly ash. Phanikumar et.al., (2004)[4]conducted various index and strength test on a expansive soil with different fly ash content. i.e. 0 to 20%, reported an improvement in the index properties by the addition of fly ash. The increment in undrained shear strength of the expansive soil by the addition of fly ash was observed. Uday Shankar D. Hakari et.al., (2012)[5]studied effect of fly ash on three types of expansive soil of Hubballi- Dharwad areas, reported that geotechnical properties of the black cotton soil improves considerably by using fly ash as a stabilizer, concluded that the CBR as well as UCS of the expansive soil shows an increase in their values upon the addition of fly ash. The most favorable results were obtained at the fly ash content in between 20-40% may be termed as optimum dose. Bidula Bose (2012)[6] studied the effect of fly ash on a high plastic commercial clay various index & strength properties were evaluated. Soil was stabilized with fly ash content ranging from 20-90% fly ash content. The CBR value was observed maximum at 20% fly ash content, which is termed as optimum dose. Tuncer B. Edil et.al., (2006)[7] studied the effect of self cementing fly ash (class C type fly ash) on soft fine grained soil, conducted California bearing ratio (CBR) was conducted on mixture of plastic fine grained soil & high quality fly ash. The % fly ash was ranging from 6 to 18%, concluded that addition of fly ash resulted in appreciable increase in the CBR. Karthik S. et.al., (2014)[8] conducted different engineering test on a expansive soil. A series of index, CBR and other strength test conducted on soil fly ash mixture, concluded that addition of fly ash resulted in increase in CBR of the soil at optimum water content. The % of fly ash content was ranging from 3 to 9% & an optimum dose observed to be 6%. Afaf Ghai's Abadi Ahmed (2014)[9]conducted geotechnical analysis on soil- fly ash mixture reported optimum ratio of the fly ash with clay soil understudy is 15% an increment of soaked CBR from 3 to 56% was observed. M.N.V. Surya Narayana Raju et. Al., (2015)[10]Conducted number of laboratory test on a expansive soil pre & post stabilized result were compared, reported strength aspects for soil specimen with different fly ash content by conducting UCS & CBR test, concluded both UCS & CBR is maximum at optimum dose of fly ash µ 20%. Ashish Mehta et.al., (2013)[11] reported the stabilization of soil with fly ash content ranging from 10 to 50% concluded that addition of fly ash improves the CBR of expansive soil. The fly ash content was varied from 10 to 50%. An improvement of CBR was observed at 20% fly ash content. K. Bandopadhyay et.al., (2009)[12] conducted CBR in fly ash at different mode of compaction (static & dynamic) concluded that fly ash is effective in stabilizing road sub grade strata. P.V.V. Satyanarayana et.al., (2013)[13] concluded that 20 to 30% fly ash is an optimum dose of fly ash for the stabilization of expansive soil.

III. EXPERIMENTAL PROGRAMME

3.1 Materials

3.1.1 Black cotton soil

Black cotton soil sample were collected from Green Park area, Pusad, at a depth of 2.0 m beneath the ground surface. The soil is primarily allowed to dry for 2 days and dried soil is thoroughly grinded. Its engineering and index properties are given in a table no. 1.

Table 1: The Engineering and index properties of the BC soil

Sr.No.	**Properties**	Values
1	Liquid Limit	72.46%
2	Plastic Limit	32.55%
3	Shrinkage Limit	20.69%
4	Plasticity Index	39.91%
5	Free swell Index	61.11%
6	Maximum Dry Density (γ) Optimum moisture content	1.5 gm/cm³ 29%
7	Unconfined Compression Strength	52.39 KN/m^3
8	CBR (Soaked)	1.8 %
9	CBR (Unsoaked)	3.15%
10	IS Classification of soil	CH

3.1.2 Fly Ash

The Fly ash used in this study was procured from, thermal power plant Koradi, Nagpur. The chemical composition of fly ash is shown in table. No. 2

Table 2: Chemical composition of fly ash

Sr. no.	**Chemical constituents**	**Average%**
1	Silica	40.18
2	Iron oxide	6.48
3	Calcium oxide	1.23
4	Titanium oxide	0.04
5	Potassium oxide	0.18
6	Magnesium oxide	0.14
7	Phosphorous pentaoxide	0.19
8	Sulphur trioxide	0.04
9	Disodium oxide	0.05
10	Aluminium	1.42
11	Manganese	0.02
12	Chloride	194mg/kg

3.1.3 Sample proportions

The general expression for the total dry weight W of a soil fly ash mixture is

W=WS + Wf

Where Ws & Wf are weight of soil & fly ash respectively. The proportions of soil & fly ash mixture are defined as the ratio of their respective dry weight to the combined dry weight of soil fly ash.

Thus above equation can be written as

W= (Ps +Pf) (Ws + Wf)

Ps= proportion of soil= $\frac{Ws}{(Ws+Wf)}$

Pf= proportion of fly ash = $\frac{Wf}{(Ws+Wf)}$

During the entire experimental programme the sample of soil fly ash blend was prepared by choosing by value of MDD and OMC at different fly ash content as per given in table 3.

Table 3: OMC and MDD with varying fly ash content

Fly ash %	MDD (gm/cm³)	OMC (%)
10	1.57	22.5
20	1.59	19
30	1.60	18.2
40	1.58	13
50	1.56	10

3.2 Test Conducted

3.2.1 Unconfined compression test

The unconfined compression test was conducted as per IS 2720 (part X), 1991

3.2.2 California Bearing Test

The CBR test was conducted as per IS 2720 (part XXI) 1979.

IV. RESULT AND DISCUSSION

4.1 Unconfined Compression Test

The Unconfined compression test is a special form of triaxial test in which the confining pressure is zero. The test can be conducted only on clayey soil which can stand without confinement. The cylindrical soil sample of soil fly ash mixes was prepared with sample size 5.0 cm diameter and 10.0 cm height, at optimum moisture content and maximum dry density Fig. 1 shows photographs of static compaction mould for preparing the specimen for UCS tests of size 5.0 cm diameter and 10.0 cm height.

(a) (b)

Fig. 1 (a) &(b) : Static Compaction Mould for UCS test of Size 5.0 cm dia. x 10.0 cm height with plunger

Fig. 2 show the variation of Unconfined Compression Strength with fly ash content and curing days, it is exhibited that the UCS of the black cotton soil samples increases with the addition of different percentage of fly ash; suggest an improvement taken in the strength characteristics of the black cotton soil + fly ash mixes. It is observed that, an increase in the values of UCS is gradual and relatively small for smaller curing periods of 7 days and 14 days. The improvement in the UCS is comparatively better for a longer curing period of 28 days; as can be seen from the graph pertaining to 28 days curing.

It is seen that the strength increases on addition of small percentage of 20% or 30% of fly ash. Further increase in fly ash percentage shows no considerable increase in the strength.

This is due to the probable disturbance of soil skeleton and consequent reduction in cohesion. The strength of soil is observed to improve considerably with curing time which is due to the pozzolanic reactivity of the free lime content of the fly ash.

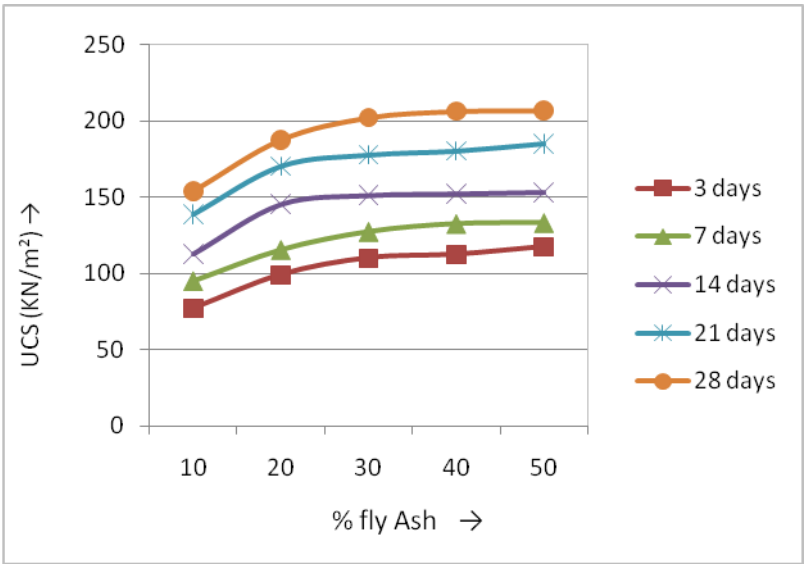

Fig. 2 : Variation of UCS with % of fly ash content and curing days

4.2 California bearing Ratio Test

The variation of CBR (Soaked & Unsoaked) of BC soil with % fly ash content and curing days is shown in fig. 3 & 4 respectively.

The CBR value of the soil increases with the addition of different % of fly ash up to a certain percentage of fly ash (20-30%) and there after it starts decreasing for further addition of different % of Fly Ash. The low CBR of the black cotton soil (as compared to the black cotton soil-fly ash mixes) is attributed to its inherent low strength which is due to the dominance of the clay fraction. In soaked CBR test the CBR values increasing with increasing % of fly ash upto 20 to 30% beyond which there is gradual drop in CBR value after 30%. While in case of unsoaked CBR the CBR value is increasing at small rate with increasing % of fly ash, it reaches to peak between 20% to 30% of fly ash and start to decrease beyond 30%.

Addition of fly ash to the black cotton soil increases gradually the CBR of the mix up to a peak value of addition of 20-30% of fly ash. This is due to the frictional resistance contributed from the fly ash in addition to the cohesion from the black cotton soil. Further increase in the fly ash percentage causes a reduction in the CBR due to the reduction in the cohesion because of the decreasing black cotton soil content in spite of increase in strength due to increase in fly ash content.

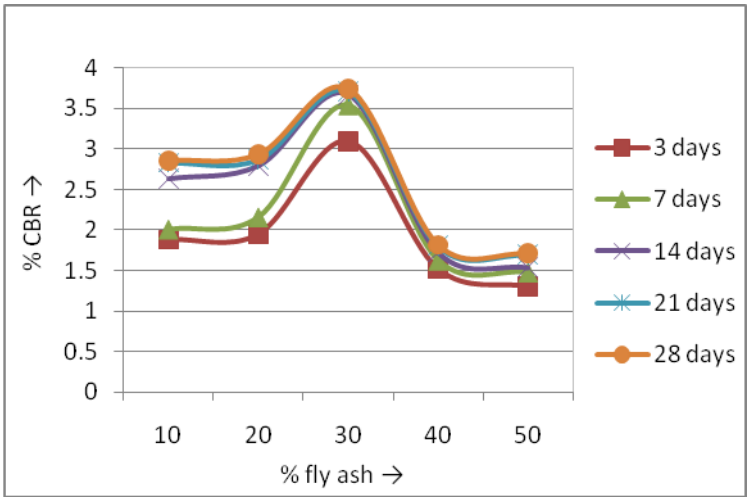

Fig. 3 : Variation of %CBR values (soaked) % of fly ash & curing days

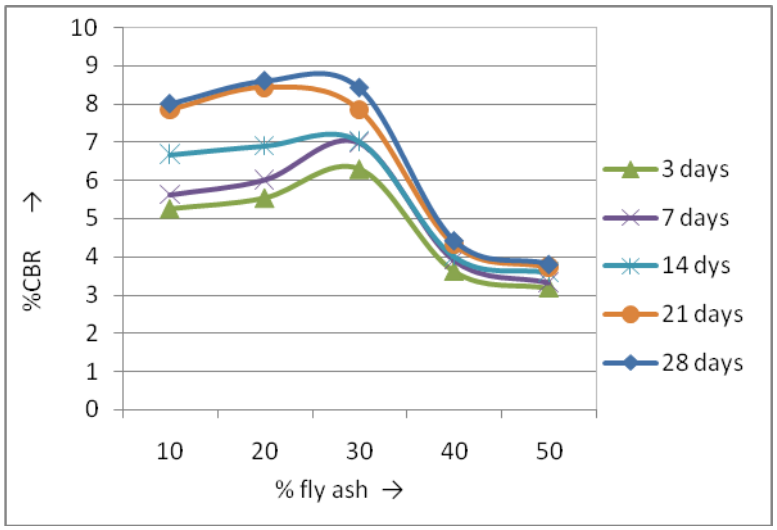

Fig. 4 : Variation of CBR value (unsoaked) with % of fly ash and curing days

Table 4 present optimum dose of fly ash assigned for different strength parameters of the trial soil. Remarks made here in the table explain the effect of addition of fly ash beyond the optimum percentage of these parameters.

Table 4 : Recommended Optimum dosage of fly ash for the stabilization of the BC (Expansive) soils

Soil parameters considered for assessment of stabilization results	**Optimum Dosage of fly ash (%)**	**Value of the parameter at optimum fly ash%**	**Remarks**
Unconfined compressive strength (kN/m^2)	30	202.4 kN/m^2	Unconfined compressive strength attains peak value at fly ash % between 20 and 30, beyond which the increase in the strength is marginal. The trend is same for increased curing periods.
California Bearing Ratio (soaked)	30	3.75 %	California bearing ratio reaches peak value when the fly ash % is at 30, beyond which it starts decreasing with further addition of fly ash.
California Bearing Ratio (unsoaked)	20	8.61 %	California bearing ratio reaches peak value when the fly ash % is between 20 and 30, beyond which it starts decreasing with further addition of fly ash.

V. CONCLUSIONS

- The unconfined compressive strength of BC soils increases upon the addition of fly ash. The increase in strength may be due to flocculation of clay particles promoted by cations in fly ash. The trend of improvement in the unconfined compressive strength is observed to be more pronounced with the curing of the soil + fly ash mix.
- Penetration resistance of expansive soil can be effectively improved by addition of fly ash. In the present study CBR value both soaked and unsoaked condition increases with increase in fly ash content. CBR value increases with higher rate up to 20-30 % of fly ash and beyond which, further increase in fly ash percentage is observed to cause a decreasing trend in the California bearing ratio values. The increase in CBR of all the mixtures for 7, 14 and 21 days curing time is more in 28 days than that of other cure time.

- In all cases results are optimum at 20 to 30% fly ash content and 28 days curing period, thus it is preferable to adopt 20 to 30% fly ash content as a optimum dose.

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