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Geotechnical Characteristics of Black Cotton Soil Mixed with Flyash: An Experimental Evaluation

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ABSTRACT**:** *The degree and level of soil engineering problems run high and become multifold in case of expansive soils which exhibit the characteristics of swelling and shrinkage. The widespread of the black cotton soil in the city of Chitradurga has posed challenges and problems to the construction activities. A task was therefore undertaken to investigate and improve the engineering properties of Chitradurga black cotton soils so that a better understanding is facilitated for practicing civil engineers, when dealing with these types of soil. Bellary Thermal Power Station at Kudutini (Bellary District, Karnataka), located at about 150 km from Chitradurga, generates huge quantity of fly ash and the fly ash management is posing serious problem. Considering the proximity and availability aspects, Bellary fly ash was used as a stabilizer for black cotton soil. This paper investigates the effect of fly ash treatment on Chitradurga black cotton soil to improve their index, compaction and strength properties.*

Keywords - *Black cotton soil, Compressive Strength, Flyash, Stabilization, Swelling potential.*

1. INTRODUCTION

Thermal power plants, cement, steel and paper industries all over the world contribute enormous quantity of fly ash every year. Environmentally safe disposal of fly ash has necessitated the exploration of innovative and cost effective methods of utilizing the fly ash in many fields. The major uses of fly ash mostly arise out of its pozzolanic property which can be used for stabilization of soils. Pozzolanic fly ashes can be advantageously made use of to improve the geotechnical properties of black cotton soils (Yudhbir and Honjo, 1991). The use of fly ash for stabilization of soils in road construction was studied by Amarjit Singh (1967). Uppal and Dhawan (1968) reported that fly ash is useful for stabilization of various Indian soils. Fly ash has been successfully used as stabilizing agent for different soils by various researchers, both in laboratory and also in field. Amos and Wright (1972) reported the effect of mixing fly ash with clayey and loamy soils on their geotechnical properties. The properties of soil are improved by cation exchange, flocculation and pozzolonic cementation (Bell, 1988).The addition of fly ash to clayey soils reduced their plasticity and swelling characteristics (Shivapullaiah et.al.1996). This paper presents the attempts made in utilizing the Bellary fly ash for improving the geotechnical characteristics of the black cotton soils under study and briefly covers the experimental evaluation carried out in this regard.

2. MATERIALS AND METHODS

2.1 Black Cotton Soil

The investigations contained in this work has been carried out on the black cotton (BC) soils obtained from Chitradurga region, which are tropical black clays derived from the weathering of meta volcanic rocks. These soils cover more than 50% of the city corporation area. The geotechnical properties are given in Table 1.

Table 1. Properties of BC soil.

Properties	**Values**
Liquid Limit, *LL* (%)	69
Plastic Limit, PL (%)	23

Plasticity index, PI (%)	46
Shrinkage Limit, SL (%)	10.34
Specific gravity, G	2.62
Sand (%)	58.0
Silt and clay content (%)	42.0
MDD (g/cc)	1.45
OMC, (%)	23.0
UCS (kN/m^2)	101.77
Classification of Soil	CH

2.2 Flyash

The black cotton soil and fly ash were mixed thoroughly on dry weight basis in the said proportions at their fine states. The finely blended mixes were then kept for oven drying for 24 hours and tests were conducted immediately after wet mixing with distilled water in required quantity depending on the test. For the strength test, curing period of 7 days were considered. Bellary flyash sample is of class-C category and its properties are given in Table 2.

Table 2. Properties of Flyash

Properties	**Values**
Specific Gravity	2.07
Liquid Limit (%)	Non- Plastic
Plastic Limit (%)	
Plasticity Index (%)	
Shrinkage Limit (%)	Vary with initial water content
OMC (%)	36.00
MDD (kN/m^3)	11.60

Test Procedures

The tests for specific gravity, Atterberg limit, compaction parameters and unconfined compressive strength were conducted as per relevant Indian Standard (I.S.) codes.

3.RESULTS AND DISCUSSION

The engineering behavior of soils, the black cotton soils in particular, can be accessed from their plasticity values as well as from their compaction and strength parameters. The effect of addition of fly ash without any additives and the resulting changes in the index, compaction and strength parameters of the virgin black cotton soil has been studied.

3.1 Index Parameters

Liquid Limit

The variation of liquid limit on addition of fly ash to the black cotton soil is shown in Fig.1. The liquid limit decreases with the addition of fly ash, showing a marginal decline up to 30% of fly ash (FBC-30 mix) and then decreases considerably with the addition of more than 30% flyash (FBC-40 and FBC-50). The primary clay mineral present in the black cotton soil is montmorillonite and as such, the liquid limit of these soils is essentially controlled by the thickness of diffused double layer and the shearing resistance at particle level. The addition of fly ash results in the decrease of liquid limit due to the effect of reduction in the diffused double layer thickness as well as effect of dilution.

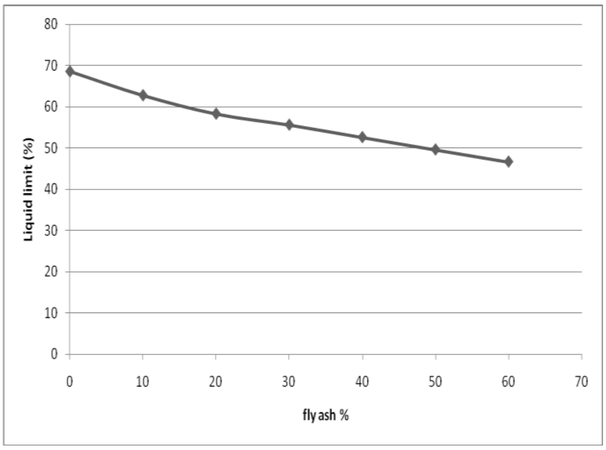

Fig.1 Variation of LL with Flyash Added

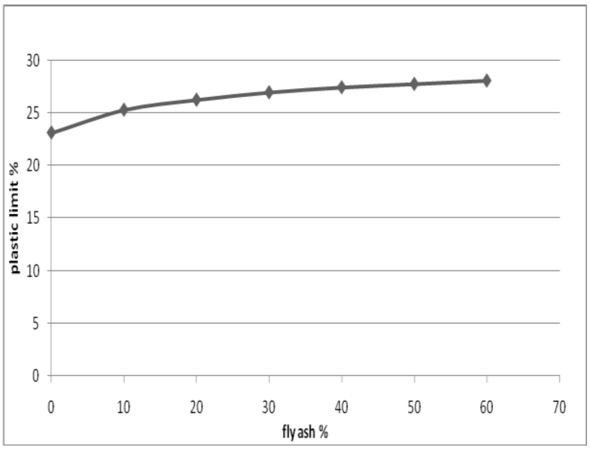

Fig.2 Variation of PL with Flyash Added

Plastic Limit

The addition of fly ash shows a continuous incline in the plastic limit as shown in the Fig.2. The addition of 10% fly ash slightly increases the plastic limit, which is due to flocculation owing to the presence of free lime in the fly ash. Further increase in the addition of fly ash results in the marginal increase of plastic limit. This is because, with increased addition of fly ash, the amount of soil to be flocculated decreases and the finer particles of fly ash may be incorporated in the voids of flocculated soil ; thereby decreasing the water held in the pores leading to the flatter variation in the plastic limit.

Shrinkage Limit

As can be seen from Fig.3, the addition of fly ash increases the shrinkage limit of black cotton soil. It increases with increasing percentages of fly ash. The gradual increase is observed up to 30% of fly ash added and is considerable on further addition of fly ash. The increase in the shrinkage limit is mainly due to flocculation of clay particles by free lime present in the fly ash.

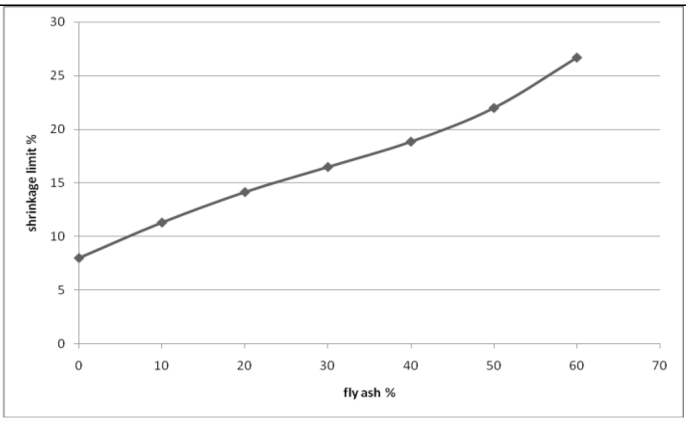

Fig.3 Variation of SL with Percentage Flyash Added

3.2 Effect of Fly ash on Compaction Parameters

The compaction characteristics of standard Proctor compactive effort for the black cotton soil- fly ash mixes reveal that the MDD increases and the OMC decreases with increasing fly ash content upto 30% of flyash. However, beyond 30% fly ash, only marginal increase in MDD is observed, with gradual increase in the OMC (Fig.4 and Fig.5).

The behavior of black cotton soil is controlled by diffused double layer. The addition of fly ash in small percentage results in the decrease of repulsive pressure of soil particles. This in turn reduces the resistance to compactive effort and the mix gets compacted to relatively higher densities.

Though there will be flocculation due to free lime of fly ash, this effect is dominated when the fly ash percentage is low. Hence a marginal increase in dry density is observed. Further addition of fly ash beyond 30% results in increased flocculation due to increased availability of free lime content of fly ash. This would increase the repulsive forces of soil particles, thereby increasing the resistance to compactive effort and hence the density of mix starts decreasing. The compaction curve becomes flatter with increasing quantity of fly ash.

The variation of MDD and OMC with flyash content is shown below;

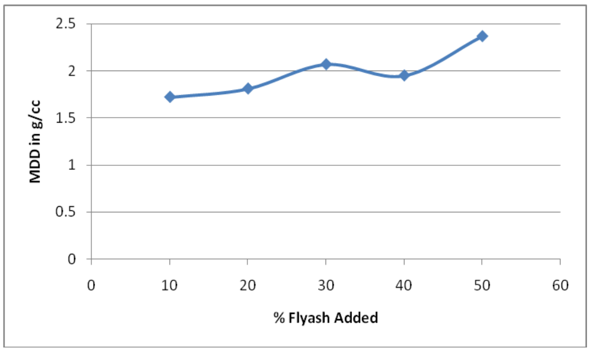

Fig.4 Variation of MDD with Flyash added

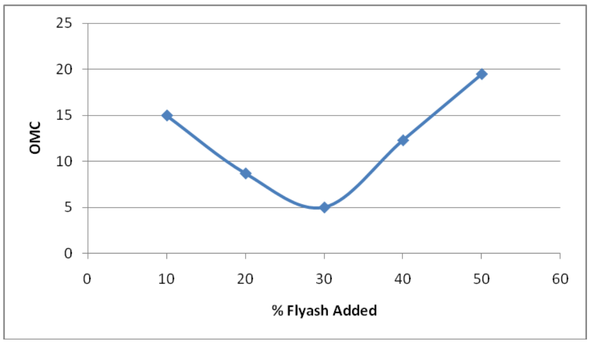

Fig.5 Variation of OMC with Fly ash added

3.3 Strength Parameter: Unconfined Compressive Strength.

The variation of unconfined compressive strength with addition of the different percentages of fly ash for 0 and 7 days curing period is shown in Fig.6. It is observe that the strength increases with addition of small percentage of 10% fly ash, but this increase occurs upto 30% of flyash content then drops beyond it. This is due to the probable disturbance of soil skeleton and consequent reduction in cohesion. For both the samples with curing and without curing, addition of 30% Flyash shows the maximum unconfined compressive strength.

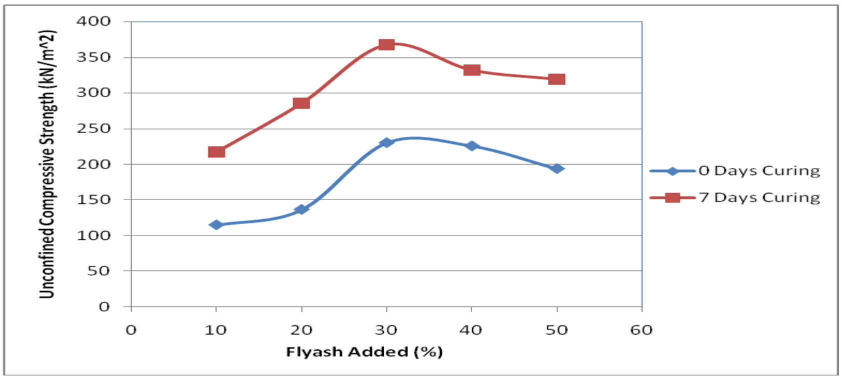

Fig.6 Variation of Unconfined Compressive Strength with Curing Period

4. CONCLUSIONS

The following conclusions are drawn from the present investigation:

(1) The black cotton soils of Chitradurga region have high degree of expansion and possess high swelling potential which requires stabilization for their better performance.

(2) The index parameters of the study soil improves with the addition of flyash. The liquid limit and plasticity index decreases with increase in percentage of flyash.

(3) The plastic limit and shrinkage limit increases with the addition of flyash from 10% to 60%.

(4) With respect to the compaction parameters, the maximum dry density is found to increase from 1.72 g/cc for FBC-10 mix to 2.07 g/cc for FBC-30 mix. However further addition of flyash the MDD value is observed to decrease. The optimum moisture content decreases from 15% for FBC-10 mix to 5% for FBC-30 mix.

(5) The unconfined compressive strength of these soils increases from 114.89 kN/m^2 for FBC-10 mix to 230.28 kN/m^2 for FBC-30 mix, with no curing. For a curing period of 7 days, the trend of increase in the strength is found to be more pronounced and the unconfined compressive strength increases from 217.45 kN/m^2 for FBC-10 mix to 367.87 kN/m^2 for FBC-30 mix. Considering both the cases, maximum unconfined compressive strength is found on addition of 30 % of flyash.

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