

Experimental Investigations of Chemical and Geotechnical Properties of Fly Ash Mixed Black Cotton Soil

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Abstract—Fly Ash generation and utilization both are expected to increase but the gap between them will also increase. Researchers are finding out new area for utilization of Fly Ash to minimize its environmental impact. One such area is Geotechnical Engineering. Black Cotton Soil is a problematic soil with respect to Soil-Structure interaction. In this paper, various properties of Black Cotton Soil like pH, plasticity index, volume change behavior and dry density are studied after mixing Fly Ash in different proportion and are presented. It can be concluded that 30% Fly Ash by weight mixed with Black Cotton soil gives optimum result for most of the properties.

Key Words: Fly Ash, Black Cotton Soil, Geotechnical properties, pH

I. INTRODUCTION

As per the data of 2010-11, fly ash utilization in India is about 100 million tonne per year against the generation of 140 million tonne. This figure is expected to increase to 115 million tonne and 160 million tonne respectively for 2012-13. By the year 2031-32, it is expected that 900million tonne of fly ash will be generated. Such a huge volume is very difficult to manage (store) and will have telling impact on environment.[2],[3],[4]

The use of fly ash is largely limited in cement concrete as a replacement to binding material. There is increased awareness in this area and guidelines are also available in relevant Indian Standard codes of practice. Not similar progress has been seen in the area of use of fly ash as partial replacement to soil or mixing with soil, may be due to insufficient research work in that direction.

This study explores the use of fly ash to improve the soil characteristics and thereby providing solution to following two major problems:

- 1) Large quantity of Un-utilized fly ash (and the volume will increase every year)
- 2) Soft soils which requires costly treatment to stabilize it e.g. Black Cotton Soil.

We know that Black Cotton soil is very unsuitable for durability of any type of construction. Indian state of Gujarat has vast region formed by Black Cotton soil and therefore it is very important to study its properties for any kind of project.

II. SAMPLE COLLECTION

The Black Cotton Soil for this study was collected from a field near town *Dakor*, the area covered entirely by the Black Cotton Soil. The Fly Ash sample was collected from *The Kutch Lignite Thermal Power Station* located near Panandhro village in Kutch District of Gujarat State.

III. SOIL-FLY ASH MIXTURE DESIGNATION

The study was carried out on following combinations.

Soil-Fly Ash Combinations	Soil (in %)	Fly Ash (in %)
AM1	100	0
AM2	90	10
AM3	80	20
AM4	70	30
AM5	60	40

Table. 1 Soil – fly ash combinations (by weight)

IV. CHEMICAL PROPERTIES

A. Black Cotton Soil

The chemical properties suggest that harmful chloride is absent and soil is alkaline in nature. High Sulphate amount is the reason behind expansive nature of the soil.

Test Parameter	Value
Calcium mg/kg	87412.59
Chloride mg/kg	0.0
E C Extract mmho/cm	0.482
Lithium mg/kg	44.95
Magnesium mg/kg	652.45
pH of 5% solution at 300 C	9.23
Potassium kg/HA	155.52
Sodium mg/kg	2382.61
Sulphate mg/kg	619.24

Table. 2 Chemical properties of black cotton soil

B. Fly Ash:

From the chemical properties of fly ash, it can be classified as Class-F fly ash but close observations will suggest that it has high silica content and therefore will behave differently from Class-F fly ash generated by burning of regular sub-bituminous coal.

Test Parameter	
% Al ₂ O ₃	19.26
% CaO	1.96
% Fe ₂ O ₃	2.26
% K ₂ O	0.075
Loss of Ignition at 800+/-200 C	96.75
% MgO	0.13
% Na ₂ O	2.91
% SiO ₂	71.46
E C Extract MMHO/cm	0.396
pH of 5% solution at 300 C	11.38
Sulphate mg/ Kg	269.82

Table. 3 Chemical properties of fly ash

The pH of the Fly Ash is higher than the Black cotton Soil, so by mixing the Fly Ash in Soil the pH of the mix increases and improves anti-corrosive property.

AM2	AM3	AM4	AM5
9.18	9.51	9.65	9.63

Table. 4 pH of soil - fly ash mixtures

When the underground structures are placed in the soil, they are subjected to the corrosive effect of the soil. From the above result of pH for the Soil Fly Ash mixture, the pH increases as Fly Ash content increases which helps in reducing the corrosive effect of the soil.

V. ENGINEERING PROPERTIES OF FLY ASH

All the tests are performed as per the Indian Standard codes of Practice.

Specific Gravity:	2.793
Liquid Limit:	NP
Plastic Limit:	16.251
OMC:	14.7
MDD:	1.733 gm/cc
Free swell Index:	18.18%
Shrinkage ratio:	1.6%

Table. 5 Engineering properties of fly ash

VI. EFFECT OF FLY-ASH ON VARIOUS GEOTECHNICAL PROPERTIES OF BLACK COTTON SOIL

A. Specific Gravity

AM1	2.5
AM2	2.56
AM3	2.58
AM4	2.67
AM5	2.72

Table. 6 Specific Gravity of fly ash mixed black cotton soil

The Specific Gravity of the Fly Ash is higher than the Black Cotton Soil. So as Fly Ash content increases, the Specific Gravity of the Soil Fly Ash mix is also increases.

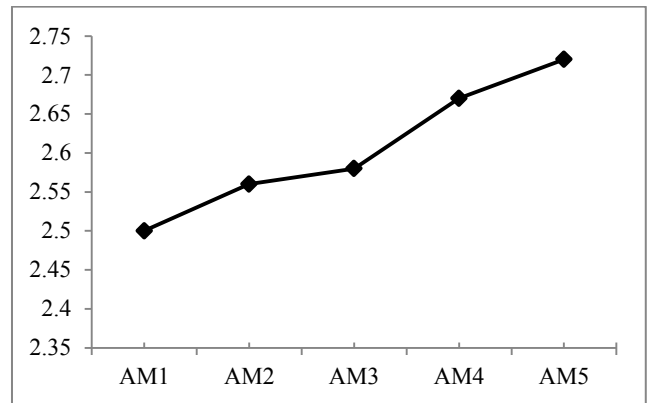


Fig. 1 Specific Gravity of various Soil - Fly Ash combinations.

B. Consistency Parameters

The Fly Ash particles are finer than the Black cotton Soil particles. So mixture of these shows good effect on the Liquid Limit, Plastic Limit, and the Plasticity Index.

	Liquid Limit	Plastic Limit	Plasticity Index
AM1	38.61	20.30	18.31
AM2	46.98	27.33	19.65
AM3	44.65	30.30	14.35
AM4	43.13	31.83	11.3
AM5	41.91	32.60	9.31

Table. 7 Consistency parameters for fly ash mixed black cotton soil

It can be seen that initially, Liquid Limit increases upto 10% of Fly Ash content, afterwards it decreases. Plastic Limit increases steadily and therefore Plasticity Index decreases after initial increase.

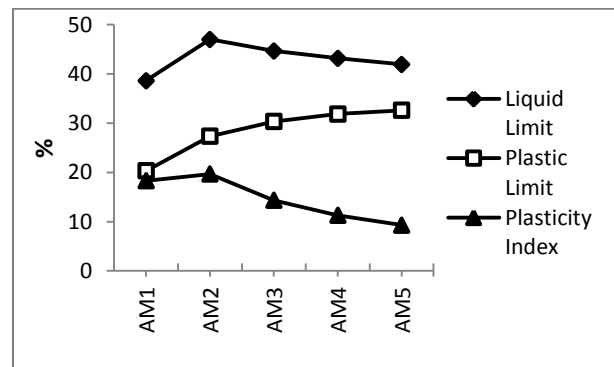


Fig. 2 Consistency Parameters of various Soil - Fly Ash combinations.

C. Expansive Properties:

Black Cotton soils are difficult to deal with when designing the foundation due to its swelling and shrinkage

characteristics. This can be attributed to non-plastic characteristic of Fly Ash.

	Shrinkage Ratio (%)	Free Swell Index (%)
AM1	50.31	57.89
AM2	30.83	33.33
AM3	20.52	28.57
AM4	8.00	17.39
AM5	12.55	8.33

Table. 8 expansive properties of fly ash mixed black cotton soil

Free swell index is one of the most important properties of expansive soil like Black Cotton. The addition of the Fly Ash with Soil decreases the Swelling and Shrinkage ratio of the Black Cotton soil.

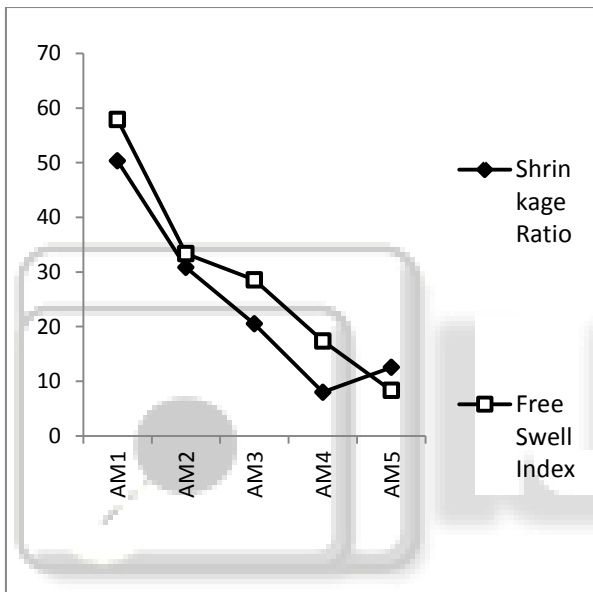


Fig. 3 Expansive Properties of various Soil - Fly Ash combinations.

D. Compaction Parameters

Soil Fly Ash mixture shows well defined relation for the Compaction parameters.

	Optimum Moisture Content (%)	Maximum Dry Density (gm/cc)
AM1	14.8	1.774
AM2	12.8	1.795
AM3	12.2	1.813
AM4	13	1.829
AM5	11.2	1.822

Table. 9 Consistency parameters of fly ash mixed black cotton soil

By increasing Fly ash content, the MDD increases. Maximum dry density increases with increase in Fly Ash content upto 30% at the optimum moisture content of 13%.

VII. CONCLUSION

From the various laboratory test performed on various Soil-Fly Ash combinations, following points were concluded:

- 1) The pH of Fly Ash is 23.29% higher than the Black Cotton Soil collected for study.
- 2) At 40% Fly Ash content the Specific Gravity increases upto 10%.
- 3) The Liquid Limit initially increases for 10% of Fly Ash content and then it decreases and the Plastic Limit increases by 60% at 40% Fly Ash content. The Soil is having low plasticity which decreases further by 45% with increase in Fly Ash content by 40% .
- 4) It can be seen that by mixing 40% Fly Ash, FSI reduces by 85%. At 30% of Fly Ash content, FSI reduces by 70% .
- 5) For 30% Fly Ash content, Shrinkage ratio decreases by 84%.
- 6) The optimum MDD is obtained for 30% Fly Ash content at 13% OMC.

Overall it can be concluded that 30% Fly Ash content is the optimum content for which all above properties shows good amount of improvement.

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