Fly Ash Utilization in Soil Stabilization

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Abstract--- Fly ash is an important industrial by-product of coke combustion. In Sudan, there is low use of fly ash in construction application; it is stockpiled and landscaped, causing serious environmental problems. Because of its great availability and its low cost, the possibility of its usage should be investigated. In the present study, clay soil was stabilization for the construction of durable urban roads is investigated using fly ash. Geotechnical analysis of soil-fly ash mixture characteristics involving physical, mechanical properties, show that the index properties of clay soil have been improved. The clay Atterberg limits improved and an increase of bearing capacity was observed with various ash ratios.
It was found that the optimum ratio of the fly ash with clay soil under study is 15wt%. The liquid limit and plasticity index reduction is 54.12%, 29.57% respectively while the soaked CBR of the soil increased from 3 to 56 %.

Keywords —Engineering Properties, Fly Ash, Soil Stabilization

I. Introduction

FLY ash (FA) is one of environmental risks associated with electricity production from fossil fuel combustion, with costly landfill disposal and environmental health problems.

FA can be classified as Class C, Class F or Class N (ash that does not meet Class C, Class F specification[1]). Based on ASTM C 618 standards, Table 1. Class C fly ash can be used as stand-alone material, while Class F is commonly blended with chemical additive [1].

Common binders include cement, lime, and fly ash. Additives reduce both the water content and bind the soil particles, which results in an increase in strength and stiffness. In practice, reducing the water content of high-water content soils to the optimum water content (OWC) is difficult and time-consuming. Therefore, the use of fly ash additive is attractive because fly ash is an industrial by-product that is relatively inexpensive, compared with cement and lime . Fly ash utilization for soil stabilization, that would be land filled, promotes sustainable construction through reduction of energy use and reduction of greenhouse gases [2].Pandian, Studied the effect of two types of fly ashes (Class F) and (Class C) on the CBR characteristics of the black cotton soil, the CBR is effect depend on the soil cohesion and fly ash type and ratio[3]. Phanikumar and Sharma, study the effect of fly ash on engineering properties of expansive soil. Parameters like plasticity, compaction, strength and hydraulic conductivity of expansive soil was studied. The plasticity was reduced by about 50% by the addition of 20% fly ash [4].

Depending upon the soil type, the effective fly ash content for improving the engineering properties of the soil varies between 15 to 30% [5]. Also it was proven that ash can be used successfully as an additive for the base and sub-base layer construction of pavement, as well as for the construction of embankments in compressed soils [6],[7].

This paper illustrates the feasibility of using local Sudanese fly ash, which produced from the coke combustion unit in Garry electrical station, Khartoum North, Sudan, for modification of Clay soil. The present research work involves the analysis of a fly ash sample to determine its classification according to ASTM- C 16standards, and to investigate the possible improvement of clay engineering properties when mixed with ash.

II.Experiments

A.Experiments Matreials

The reasearch mateial is fly ash from Garry electrical station.Various ratio ranging from 5to 20% by wt together with 5% by wt cement were added to soil sample.

B. Engineering Properties of Soil

A soil specimen particle size distribution presented in Table I. The soil was classified according to American Association of State Highway and Transportation Officials (AASHTO) as GC [8]. The engineering properties of the soil show that the soil has a high liquid limit, low dry density, Table I.

C. Physical properties and Chemical Compositions of Fly Ash

The physical properties and chemical composition of fly ash sample under study were carried out in Sudanese Geological Researches Laboratories Table II.

TABLE I
SOIL ENGINEERING PROPERTIES

No.	Parameter	Value
1	Optimum moisture content	23%
2	Max. dry density	1.55 g/cm^3
3	Liquid limit ,LL	55.3 %
4	Plastic limit ,PL	25.6 %
5	Plasticity index, PI	29.7 %
6	Fines fraction	19%
7	Coarse fraction	81%

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TABLE II
CHEMICAL COMPOSITIONS AND INDEX PROPERTIES OF FLY ASH

Parameters	Percent of Compositions		
	Gary Ash	Typical Class C	Typical Class F
SiO_2	46.47	40	55
Al_2O_3	ND	16	26
Fe_2O_3	1.08	6	7
$SiO_2+Al_2O_3+Fe_2O_3$	47.55	63(50Min)	88(50 Min)
CaO	18.52	24	9
MgO	0.18	2	2
SO_3	0.03	3	1
LOI	18.97	6.0	6.0(12 Mix)
Specific Gravity	1.029	-	-

LOI: Loss on Ignition
According to ASTM- C618, Gary Ash sample is an off specification (i.e., does not meet Class C or Class F specification).

III. Effect Of Fly Ash On Soil Stabilization

Utilization of fly ash on soil stabilization is performed by analysis of the Atterberg limits (Liquid limit, plastic index), soil compaction (Optimum moisture content, Maximum dry density) and California Bearing Ratio (CBR) of soaked samples. The results of soil ash mix properties are shown in Fig.1 to Fig.5.

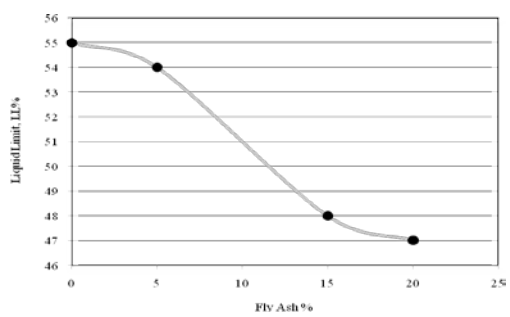

Fig. 1: Liquid Limit of Soil with Fly Ash

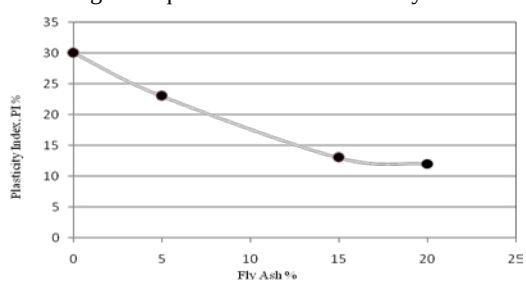

Fig. 2: Soil Plastic Index with Fly Ash

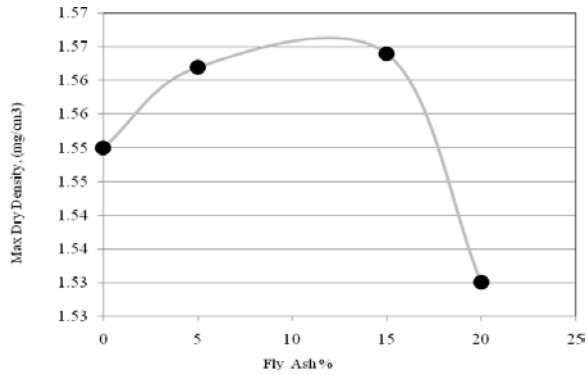

Fig. 3: Soil Maximum Dry Density with Fly Ash

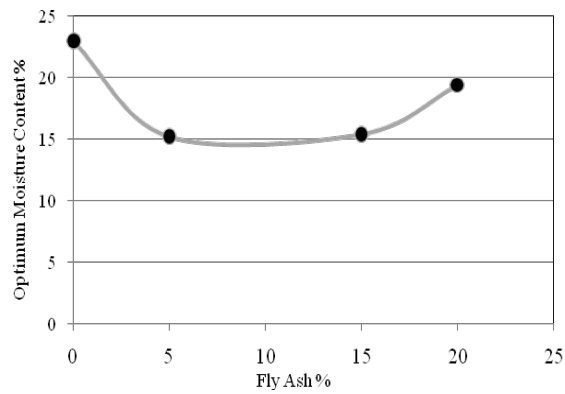

Fig. 4: Soil – Fly Ash Optimum Moisture Content

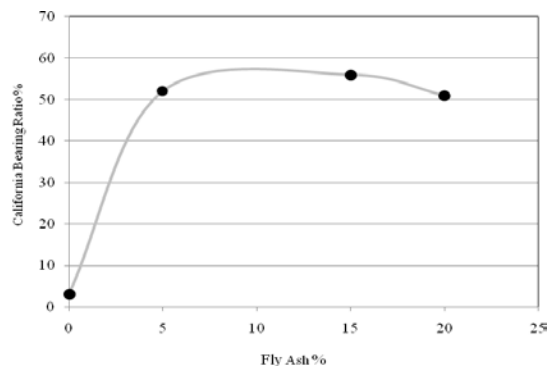

Fig. 5: California Bearing Ratio with Soil Fly Ash

IV. Results And Discussion

The addition of fly ash reduces the plasticity characteristics of the soil. The liquid limit decrease and plastic limit increases with an increase in fly ash content.

The analysis shows that increasing ash content from zero (unmixed soil) to 20wt% decreases liquid limit, increases the plastic limit and decreases the plastic index .A dramatic reduction comes into view in the range of (0 – 15%) ash. No noticeable decline appear in the range (15- 20%). For compaction test, the dry density and optimum moisture were

measured for various fly ash ratios. The dry density incresaces as the fly ash raise up to 15 % ,then reduced to 1.53 at 20% ash,Fig. 3. The optimum mositure content decreases until 15 % ,then after that it starts to increase,Fig. 4. Soaked CBR value considerably increased with the increase of ash content in the soil mixture. Slightly reduction of CBR value appears when soil ash mixture contains more than 15% ash, Fig. 5.The effect of fly ash addition, on physical and mechanical properties improves the index properties of clay, reduces the liquid and plastic index, increases bearing capacity. Addition of 15 wt% ash, 5wt% cement to soil can be utilize in the field of soil stabilization, which is within the range of international results.

V. Conclusions

Based on the experiments the following conclusions have been drawn:

- The addition of 15 wt% fly ash , 5wt % cement improved the index properties of clay and increased the bearing capacity.
- The soil under study is not appropriate for embankments, paving and foundation due to its plasticity. Nevertheless, the Atterberg limits the mixture of fly ash with the clay soil, has improved. A reduction of the liquid limit and plasticity index up to 47% and 13% respectively (case of 15 % ash), resulting in the soil maintaining its stability while decreasing the moisture content.
- Fly ash can be mixed with cement and water to stabilize granular materials with few fines ash particles, producing a hard, cement-like mass. Its role in the stabilization process is to act as a pozzolan and/or as a filler product to reduce air voids. A common application is of a cement/fly ash mixture (CF) is to stabilize coarse-grained soils that possess little or no fine grains.
- The addition of ash increased the optimum moisture content in the compaction tests by increasing the soil great specific surface and decreasing the maximum dry density because of a lower specific weight. This can be applied in soils that contain a high percentage of moisture resulting in greater compaction due to the evaporation of a considerable quantity of the contained moisture.
- The soil became more resistant to additional water infiltration, provides additional support for traffic, creates a more stable work platform and reduces dusting from construction traffic.
- The increase of the optimum moisture content contributed to an increase of the stabilized soil's capability .The results, that agree with of other researchers[9] will provide a stable soil, suitable for construction of new, financially viable and durable pavements.
- Class C, Class F fly ash has been used in road construction in other regions. The current study shows that even Class N fly ash could be used in road construction, when it used with cement.
- The use of stabilized soil in this way, has the dual benefits of removal of harmful materials from the environment and at the same time the usage of cheap construction material in road networks.

Acknowledgment

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