Recent Research in Science and Technology 2013, 5(5): 30-32
ISSN: 2076-5061
Available Online: http://recent-science.com/

Use of fly ash in black cotton soil for road construction

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Abstract
Waste products from various industries normally deposited in landfills, have been proposed for use as an alternate construction material. The utilization of these alternate materials needs to be encouraged for economy of construction and conservation of materials. One by-product that has shown as an alternate construction material is fly ash. In this paper an effort is made to use fly ash to stabilise soils for road construction, in order to reduce the amount of waste globally. In the present assignment, black cotton soils were stabilized with different quantities of fly ash. On the basis of preliminary investigations, it has been found that stabilization with fly ash, improves the CBR and plasticity characteristics of black cotton soils.For hydration of fly ash, the lime content is responsible, so substantial improvements in desired properties can be achieved by addition of small quantity of lime.

Keywords: Black cotton soil, Fly ash, CBR

INTRODUCTION

Road plays a crucial role in the development of country. They are lifeline providing a smooth flow of man and materials. Road pavement in general consist of a relative thin wearing surface built over a base course and sub base course resting on the sub-grade (Compacted or natural). The sub-grade is normally in-situ soil over which the road is being constructed.

Soft sub-grade soils are a common problem in Chhattisgarh. In summer the moisture evaporates quickly causing deep and wide shrinkage cracks. In the rainy season water enters the cracks and causes enormous swelling. Highway embankments in such type of soils suffer severe damages and the pavement gets disrupted, the soil most of the state are mainly black cotton soil, which is clayey soil that can bear almost no load when wet. This causes the land to erode heavily during the rainy seasons and especially the roads are damaged.

The supportive power of sub grade generally depends upon the following properties of soil:

(1)Shear strength
(2)Bearing power
(3)Penetration resistance of soil.

The typical approach for redemption of soft sub-grade has consisted of removal of poor soil and its replacement with large quantities of crushed rock. The high cost for removal of poor soils and transportation of selected aggregates, along with increasing interest in re-usable industrial by products, has prompted investigations to find solutions that complement the need of highway construction with those of the environment. Use of fly ash for stabilization of sort sub-grade is one of these solutions being evaluated.

Fly ash is a pozzolanic material recovered from the flue gases of coal combustionprocesses. A pozzolan is defined by ASTM as “A siliceous or siliceous and aluminousmaterial, which by itself possess little or no cementitious value, but will, when in a finelydivided form and in the presence of moisture, chemically react with calcium hydroxide atordinary temperature to form compounds possessing cementitious properties.” Thus aLFA mixture can act as a cementing agent for soil stabilization.

In view of the above an attempt has been made to utilize fly ash in different proportions to black cotton soil and the effect and engineering properties was evaluated.

SOIL AS ROAD MATERIAL

Soil used as a highway material should posses the following properties

(a) Stability
(b) Incompressibility
(c) Good drainage
(d) Ease in compaction
(e) Minimum volume change
(f) Permanency of strength etc.

Table 1.The most common desirable properties of soil as road material are listed below [1]

Property	Sub base	Base course	Surface course
Liquid limit	20% Max.	25% Max.	35% Max
Plasticity Index	6% Max.	6% Max.	5 to 10% Max.
CBR	>15%	100%	100%

SOIL FOR PRESENT STUDY

Black cotton soil found in large parts of our state is a typical clayey soil, which exhibits high shrinkage and swelling properties.

Consolidation of pavement takes much time, due to poor drainage capacity of soil. Shear strength of soil decreases with increase in moisture. Bearing capacity of soil is very low, resulting in extra thickness of pavement.

Chemical composition of fly ash

Table 2.Chemical composition of Indian Fly ash[2]

Constituent	Percentage Range (%)
Silica (SiO_2)	49-67
Alumina (Al_2O_3)	16-29
Iron Oxide (Fe_2O_3)	4-10
Calcium Oxide (CaO)	1-4
Magnesium Oxide (MgO)	0.2-2
Sulphur (SO_3)	0.1-2
Loss on ignition	0.5-3

LABORATORY TESTS ON SOILS, FLY ASH &THEIR MIXTURES

In Experimental investigation the soil-Fly ash mixtures were prepared by mixing 10,20,30,40 and 50% of fly ash (by weight).All these mixtures were tested in the laboratory for their index properties, compaction characteristics and California Bearing Ratios.

Compaction Test- The test were carried out to determine the maximum dry density (MDD) and optimum moisture content (OMC) of soil mixtures using Heavy compaction (Modified Proctor Test) asper IS 2720-PartVII-1974. The mould used was 100 mm in diameter and 127.3 mm high. The samples were compacted in 5 layers by applying 25 blows to each layer with a free fall of 450 mm of 4.89 Kg weight.

California Bearing Ratio- The samples were prepared at OMC and compacted using Dynamic Compaction (Modified Proctor Test) as per IS: 2720-Part VII-1974. The mould used was 150 mm in diameter and 127.3 mm high. The samples were compacted in 5 layers by applying 56 blows to each layer with a free fall of 450 mm of 4.89 Kg weight. The penetration tests were carried out for samples soaked for 96 hours. The rate of penetration of the plunger was kept at 1.25 mm per minute.

Table3. Properties of BC Soil and Fly ash

S. No.	Soil Type	Liquid Limit (A_{wl}) %	Plastic Limit (W_P)	Plasticity Index I_p	Flow Index I_f	Tough ness I_T	Liquidity Index I_L	Consis tency Index I_C	Specific Gravity G_S	Classification
1	Fly ash	NP	NP	NP	-	-	-	-	1.72	ML
2	BC Soil	43.5	25.0	18.5	4.75	3.8	-1.08	2.08	2.54	MH

Table 4.Variation of Index Properties of Black Cotton Soil with Fly Ash Percentage.

S. No.	Fly ash content (%)	Liquid Limit (W_L)	Plastic Limit (W_P)	Plasticity Index (I_P)	Liquidity Index (I_L)	Consistency Index (I_C)	Specific Gravity (G_S)
1	0	43.5%	25.0%	18.5%	-1.081	2.081	2.540
2	10	36.0%	13.0%	23.0%	-0.356	1.356	2.465
3	20	34.25%	14.8%	19.45%	-0.534	1.534	2.403
4	30	33.8%	15.7%	18.1%	-0.618	1.618	2.350
5	40	34.25%	16.1%	18.15%	-0.644	1.644	2.305
6	50	33.0%	16.4%	16.6%	-0.735	1.735	2.266

Table 5.OMC, MDD and CBR of Black Cotton Soil and their admixtures with fly ash

S. No.	Fly ash content %	Black Cotton Soil			Fly ash		
		OMC %	MDD Kg/cm^3	CBR % (Soaked)	OMC %	MDD Kg/cm^3	CBR % (Soaked)
1	0	16.0	1.68	2.06	10.00	1.316	4.129
2	10	10.7	1.76	2.47	-	-	-
3	20	12.7	1.74	2.47	-	-	-
4	30	12.0	1.63	2.68	-	-	-
5	40	14.5	1.73	2.47	-	-	-
6	50	15.2	1.62	2.47	-	-	-

RESULTS AND DISCUSSION

Index properties of soil have an important role in selection of soil as a road construction material. Soils that undergo large volume changes with change in water content may be troublesome if used for highway bases. The volume change can result in bumps in road and crack the structures, since the volume changes over time may not and usually will not be equal. The liquid limit, plastic limit may be used to predict potential trouble in soil due to volume changes [5].

Plasticity Index

Plasticity index shows the range of moisture content within which soils mixture shows the plastic property. It gives an idea about the clay content in a soil. Plasticity index increases with increase in clay content.

The plasticity index of B.C. soil and fly ash mixture increased for 10% mix then decreased with increase in fly ash content.

California Bearing Ratio

It is observed that addition of fly ash increases the CBR of black cotton soil with 30% fly ash mixture.

OMC and MDD

In B.C. soil MDD increased slightly up to 20% of fly ash, and then it decreased. It is shown that for depressive clays the MDD first increases and then decreases with the increase in fly ash content.

In preliminary investigations (In soaked condition) the CBR of black cotton soil was not much improved by addition of fly ash however the plasticity characteristics improved. A reason for this may be that the fly ash available in Chhattisgarh is obtained from bituminous coal, having very low lime content. Addition of lime to fly ash, B.C. soil mixture result better bond between clay particles by flocculation and agglomeration action and may give the improved strength of road pavement with minimization of required pavement thickness. Similarly lime supplies an excess of Ca^{++} and cationexchange will occur by replacing dissimilarcation. Another important reaction takes place due to addition of lime in B.C. soil is pozzolanicreaction which involve the formation of various cementing agent like aluminous and siliceous minerals which make strong bond with cementing compound between clay particle and reactive component of fly ash which may also produce potentially strong cementaceous phase as on hydrated calcium silicate.

$CaO + H_2O = Ca(OH)_2$

$Ca(OH)_2 = Ca^{++} + 2(OH)^-$

The result may vary with the quality and type of fly ash. There are two types of fly ash as classified on the basis of chemical composition known as Class-F and Class-C fly ash. Class F fly ash produced by burning of anthracite and bituminous coal content has small quantity of lime (CaO).[4]

Formation of cementaceous materials by the reaction of lime with the pozzolans (Al_2O_3, SiO_2, Fe_2O_3) in the presence of water is known as hydration of fly ash. The hydrated calcium silicate gel and calcium aluminate gel (cementaeous) can bind inert material like (Al_2O_3, SiO_2).

$Ca^{++} + 2(OH)^- + SiO_2 = CSH$
(Silica) (Gel)

$Ca^{++} + 2(OH)^- + Al_2O_3 = CAH$
(Alumina) (Gel)

CONCLUSION

- The increase in California Bearing Ratio and dry density is maximum for 30% fly ash mixture with black cotton soil.
- Black cotton soil of low or medium plasticity can be used for base courses by stabilizing with fly ash due to improvement in its plasticity characteristics.
- The value of coefficient of compressibility of remoulded sample is $C_c=0.009(W_L-10\%)$ which gives change in compressibility with change in liquid limit. So as percentage of Fly Ash is increased the liquid limit of black cotton soil decreases, resulting in reduced swelling of soil. Thus improving its utility as road material.
- Maximum power production unit in Chhattisgarh state use the anthracite and bituminous type coal, producing a fly ash containing very less quantity of lime called “F” type fly ash having poor bonding and cementaceous property. Thus necessitating the requirement of some bonding agent. That’s why the lime should be added to increase and develop well cementaceous materials.
- Studies for leachability should be done to access possible environmental contamination.

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