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A PATH FOR HORIZING YOUR INNOVATIVE WORK

BEHAVIOR OF SWELLING PROPERTIES OF BLACK COTTON SOILS BY USING FLYASH

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Abstract: - Black cotton soil is the most problematic soil as it is subjected to volumetric changes in presence of water. Using Ground improvement techniques the physico-chemical behavior of black cotton soil can be modified and one of them being through admixtures. Stabilization techniques can be adopted on large scale when treatment is economical and permanent. Fly ash is the solid wastes in large scale generated by the thermal power plants throughout the world and moreover this waste product can be used in modifications of geotechnical properties of Black cotton soil. In this investigation we had checked the free swell index property of Black cotton soil by adding certain amount of Fly ash (0%,5%,10%,15%,20%....)until the soil gets stabilized and at that point the strength of the soil is determined and the difference between normal Black cotton soil and stabilized soil if found out and the results are been tabulated.

Keywords: Flyash, Black cottons oils, Frees well index, Atterberg Limits, Compaction

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INTRODUCTION

Expansive soils are well known by the term black cotton soils in India and they cover almost one fifth to one sixth of the total area. These expansive soils are colloidal soils containing two-micron clay fraction varying between 50% to 70% consisting of significant portion of montmorillonite and illitic minerals. These soils have been regarded as problematic to Geo-technical Engineers because of their susceptibitly to alternate swelling and shrinkage due to variation of moisture. Structures on these soils experience large-scale damage due to heaving accompanied but loss of strength of these soils during rainy season and shrinkage during summer. The problems associated with expansive soils include heaving and cracking of structures such as foundations, retaining walls, pavements, canal beds and linings.

Extensive work has been done on expansive soils all over the world and attempts have been made by several researchers to suggest solution to these problems each based on different concept. In India these soils are spread over the states of Maharashtra, Gujarat, Madhya Pradesh, Rajasthan, Andhra Pradesh, Tamilnadu and Karnataka.

In order to tackle the problems associated with swelling an attempt has been made to use Fly ash. Fly ash is an industrial waste coming out of the Thermal power plants and disposal of the material itself is a problem.

Expansive soils exhibit significant volumetric expansions in the presence of water. Expansive soils are formed through extensive physic-chemical alteration. Kaolinite, illinite, montmorillonite are the most commonly occuring minerals, among which montmorillonite is the more prone to volumetric changes due to its lattice structure on absorption of water. Subba Rao et al(1985) have emphasized that the montmorillonite content is the predominant clay mineral in the black cotton soils. Large portions of the world nations are covered with these soils. Indian black cotton clays are typical examples of soils covering an area about 20% of the total area.

Nature and Behaviour Of Expansive Soils

Soils that exhibit a peculiar alternative swell and shrink behavior due to moisture fluctuations are known as expansive soils. This behavior is attributed to the presence of the clay minerals with expanding lattice structure. Among them Montmorillonite clay mineral is very active and absorbs water many times its volume. The soil is hard as long as it is dry but looses its strength(stability) almost completely on wetting. On drying, the soil cracks very badly and in worst cases, the width of cracks is almost 150mm and travel down to 3m below ground level

(Uppal,1965). The formation of montmorillonite mineral is aided by an alkaline environment, presence of magnesium ions and a lack of leaching. Such conditions are favorable in semi-arid regions with relatively low rainfall. The parent minerals for the formation of montmorillonite often consists of Ferro magnesium minerals, calcic feldspars etc.

The black cotton soils are highly argillaceous and contain clay fraction varying between 50-70%.The high % of clay content with predominant montmorillonite mineral is responsible for high volumetric changes during wetting and drying. These volume changes cause huge damages to almost all civil engineering structures resting on them. The problems associated with these soils are heave, cracks in lightly loaded building foundation, pavements, earth retaining structures and canal linings. Inadequate bearing capacity and differential settlements are not true causes of foundation failure in such soils, but high swelling pressure and differential heaves are the causes.

Properties of expansive soils:

The range of variation of index, engineering and chemical properties of black cotton soils are summarized below (Katti, 1979)

Engineering properties:

SNo.	Description of Property	Average range of value
1.	Specific gravity	2.7-2.9
2.	Sand Fraction(%)(0.075-4.75mm)	1-26
3.	Silt Fraction(%)(0.002-0.075mm)	17-43
4.	Clay Fraction(%)(<0.002mm)	32-70
5.	Liquid limit(%)	40-100
6.	Plastic limit(%)	20-50
7.	Shrinkage limit(%)	8-18
8.	Plasticity index(%)	20-50
9.	Proctor's Maximum Dry density(t/cu.m)	1.3-1.7
10.	Optimum Moisture content(%)	18-30
11.	Soil Group Symbol(I.S)	CH
12.	Color	Dark Grey to Black
13.	Size of Shrinkage Cracks	About 10cm wide and 3m deep
14.	Free swell index(DFS)(%)	70-300
15.	Swell Potential(%)	1-15
16.	Swell Pressure(kg/sq.cm)	0.5-10
17.	Safebearing capacity(t/sq.m)	5.0-7.5

Chemical properties:

Description	Formula	Range(%)
Silica	Sio_2	48-58
Alumina	Al_2O_3	13-22
Lime	CaO	1-8
Magnesium Oxide	MgO	1.8-5
Ferric Oxide	Fe_2O_3	7.5-1.5
Titanium Oxide	TiO	0.3-2.2
Sulphates	SO_4	0.9-2
Carbonates	CO_3	0.5-6.6
Organic Matter		0.4-3.6
Loss on Ignition		4.8-16.5
p^H		6.7-8.9(not%)

Engineering problems of swelling soils:

The soils during rainy season absorbs considerable amount of water which cause excessive swelling of soils, while in summer the moisture in the soil is depleted, giving rise to shrinkage cracks on the surface. The alternative swelling and shrinkage causes differential moments in the structure built over these soils.

Damage to Pavements: The roads that pass through expansive sub-grades are subjected to heave and settlement of this treacherous soil. This results in irregularities ,cracking and rutting of pavement surface, requires high maintenance cost.(Uppal,1965)

Damage to Buildings: Buildings have represented the most obvious cases of damage caused by swelling and shrinkage of foundation soils. Light structures resting on spread footings undergo substantial damage due to severe cracking. Pile foundation has been completely sheared off(Jennings,1953)

Damage to Canals: The lined and unlined canals are subjected to vagaries of expansive soils. The side slope of canal embankment were found to be eroded and became soft when constructed using expansive soils. The canal beds obstruct the functioning of canal (Katti,1975)

Damage to Conduits: Conduits such as water supply lines and drainage pipes have been subjected to both lateral and vertical movements. In some cases, breakage of these services lines were reported, especially where relatively small diameter pipes have been employed, under extreme moisture condition(Zeiltlen,1965).

Solution For The Problem In Expansive Soils

Fly Ash Stabilization

Fly Ash is generated from coal fired generation units. Coal has a dominating role for the powder generation in India. Presently there are 70 coal based thermal power plants operating in India. Most of the thermal power plants in India use inferior quality coal, having low calorific value which after combustion, leaves behinds a larger per cent of ash. As the power required in industrial and agricultural sectors increase, production of ash increases. Fly ash contains many toxic elements. Abundant quantities of fly ash are being produced by thermal power plants situated all over the world. At present 70 MT of coal ash is produced annually in India. The quantity of fly ash generated per year is likely to exceed 100MT by the year 2000A.D. (Sridharan et al, 1996).

Disposal of large quantities of fly ash, which contains very fine particles that are easily blown off by air and possess toxic elements is very expensive and can cause environmental hazard.

Broadly three types of coal ash are obtained. Fly ash, bottom ash and pond ash. Of these pond ash is least useful for geo-technical constructions due to lesser lime activity, used as a road construction material.

Fly ash is a complex material and its characterization is quite difficult. It is observed that the overall chemical composition varies from particle to particle and from one sample another. Even initial pulverization of the fly ash produced. It appears that difference in particle size distribution; morphology and surface characteristics of fly ash would influence water demand and reactivity. The principal constituents of fly ash are silica (SiO_2), Alumina (Al_2O_3), Iron oxide (Fe_2O_3), Calcium oxide (CaO), smaller amounts of magnesium, sulphur, unburned carbon.

For the fly ash as a whole, the (SiO_2 + Al_2O_3) content is a measure of the proportion of active siliceous particles present and becomes a measure of the Pozzolanic activity of the fly ash at long periods of curing (Simons and Jeffery, 1960).

The index and engineering properties of fly ash are most likely to be affected by the free lime, iron oxide and unburned carbon present in it.

Fly ash can be divided into following two categories (Mehta, 1979), which differ from each other mainly in their calcium content.

CaO<5%, result due to the combination of anthracite and bituminous coals.

CaO up to 15-35%, due to the combination of lignite and sub bituminous coals.

Fly ash is characterized by low specific gravity. The specific gravity of fly ash particles varies with chemical composition. Ashes with high iron oxide contents have high specific gravity values (Seals etal, 1972). These characteristics (i.e., hollow spherical particles and uniform gradation) may also explain the lower compacted densities of fly ash relative to conventional earth fill compacted to the same effort (Gray and Lin, 1971).

The free lime influences the Pozzolanic reactivity of the fly ash while unburned carbon affects the compaction and strength characteristics because high carbon content cuts down the quantity of reactive materials available.

Properties of fly ash:

Most of the particles are spherical but some are cenospheric in nature. Fineness is the most important property, which influence the activity of fly ash, more than any other property and is expressed as its specific surface.

The specific surface of Indian fly ash is found to range between 2200-9850 Cm^2/gm. Thus, Indian fly ashes appear to be quite fine compared to those produced abroad.

The properties of fly ash are likely to vary from plant to plant and even in the same plant. They may change from time to time depending on the changes in quality of coal used. The variations can also be due to degree of pulverization, actual firing process, firing conditions etc. (UPPAL, 1974)

Raymond et al., (1966) reported that constituents most likely to affect engineering and physical properties of the fly ash are the free lime and unburned carbon contents. The former influences the age-hardening properties of the fly ash when it is compacted and the later, its compaction-strength characteristics.

Results of laboratory tests on compacted fly (Joshi, 1978) revealed that samples compacted to 90 to 95% of their maximum density can still absorb 10 to 15% additional water. This is due to capillary water rise due to initial partial saturation.

Joshi and Nagraj (1988) concluded that strength of compacted fly ash depends on the self-hardening characteristics. Optimum water content (OMC) ranges between 18-34%.

Properties of fly ash:

Chemical properties:

S.No.	Constitutents	Value
1.	SiO_2	58.88
2.	Al_2O_3	29.67
3.	Fe_2O_3	5.87
4.	TiO_2	0.27
5.	CaO	3.03
6.	MgO	0.24
7.	MnO	0.02
8	Na_2O	0.21
9	K_2O	0.28

PHYSICAL PROPERTIES:

S.No.	Description of property	Value(%)
1.	Color	Grey
2.	Liquid limit	44
3.	Plastic limit	Non plastic
4.	Shrinkage limit	42
5.	Specific gravity	2.03
6.	Fine sand size fraction	4
7.	Silt size fraction	89
8.	Clay size fraction	7
9	Optimum moisture content	41.9
10	Maximum dry density	1.00

Pozzolanic activity:

Pozzalona is a property of material, which makes is more workable evolving less heat during setting. The degree of Pozzolanic activity in fly ash determines its suitability for use in pozzolana in the production of Portland pozzolana cement as a place of replacement of cement in mortar and concrete of construction sites.

Any material is considered suitable for use as pozzolana, if its lime reactivity strength is not less than 4000kg/cm^2. Most of the Indian fly ashes have been found to possess the desired Pozzolanic activity.

Pozzolanic reactivity of fly ash plays an important role in the use of fly ash for most of geo-technical applications. Fly ash is non-plastic. Fly ash that develops good strength without addition of lime is widely used. In fly ash the reactivity is due to reaction between no crystalline silica and lime. They are self-Pozzolanic without addition of lime.

Experimental Study

The main aim of the present work is to stabilize the black cotton soil by adding fly ash.So,Black cotton soil form K.L.C.E.,Vaddeswaram,Guntur(Dt).was collected and various tests are been done on this black cotton soil, Fly ash and Fly ash added to soil, they are given as follows

Specific gravity:

Specific gravity of solids is an important parameter. It is used for determination of void ratio and particle size. The specific gravity of solid particles (G) is the ratio of the mass of a given volume of solids to the mass of an equal volume of water. The specific gravity of solids for most natural soil falls in the general range of 2.65 to 2.80; the smaller values are for the coarse – grained soils. The test is conducted in accordance with I.S.2720(part-iii)-1980.

$$\text{Specific Gravity of solids} = \frac{\textit{Mass of dry soil}}{\textit{Mass of equivalent volume of water}}$$

Sieve analysis:

The main aim of the 'Mechanical Sieve Analysis' is to determine the range of size of particles in the soil and the percentage of particles in each of the ranges. To find the gradation and Classification of soil. Grain size analysis expresses quantitatively the proportions by masss of various sizes of particles present in the soil. The grain size distribution is universally used in engineering classification of the soils. Sieve analysis was carried out using a set of standard

I.S.sieves. The sample was oven dried and a quantity of 300g is taken in a pan and is allowed to immerse in water for a period of30-60min.The sample is washed though 75-micron sieve and the retained part is dried and the mechanical sieve analysis is carried out according to I.S.2720 (Part-iv)-1985.

Atterberg limits:

Consistency of a soil is its resistance to flow, or to forces that tend to deform it, and is related to strength of clay soils. It is governed by the water content. The water content at which the soil passes form one state to the next, have been arbitrarily designated as “Consistency limits” – liquid limit, plastic limit and shrinkage limit. The plasticity index of the soil is determined to know the need of stabilization of the soil. If the plasticity index is more than 6% stabilization is essential

Liquid Limit

The liquid limit test was conducted as per I.S.2720 (Part-v)-1970.The test is conducted on the soil after passing 425 micron I.S. sieve using casagrande apparatus.

Plastic Limit

The plastic limit test was conducted as per I.S.2720(Part-v),1970.

Shrinkage Limit

The shrinkage limit test was conducted as per I.S.2720(part-vi)-1972.

Differential free swell index:

It is the property of soil which shows the swelling nature of soil. More the expansion more is upward thrust on the superstructure which causes cracks. High the percentage of expansion more is the thrust on the structure built on it. The main purpose is to know the swelling nature of soil since it indicates weak in strength

% of Expansion	Classification
< 20%	Low
20-35%	Moderate

35-50%	High
35-50%	Very High

Differential Free Sell Index = $\frac{vd - vk}{vk} X100\%$

Compaction: From the compaction test, the maximum dry density and optimum moisture content of the soil is found for the selected type and amount off compaction. These results have various uses.

a) The OMC of the soil indicates the particular moisture content at which the soil should be compacted to achieve maximum dry density. If the compacted effort applied is less, the OMC increases, and the value can again be found experimentally or estimated.

b) In field compaction, the compacting moisture content is first controlled at OMC and the adequacy of rolling or compaction is controlled by checking the dry density achieved and comparing with the maximum dry density achieved in the laboratory. Thus compaction test results (O.M.C. and maximum dry density) are used In the field control test in compaction projects.

The compaction test was performed in proctor mould. This was used to find the optimum moisture content and its corresponding dry unit weight. The test was carried out according to I.S: 2720(part-vii),1980

Observations:

Fly ash:

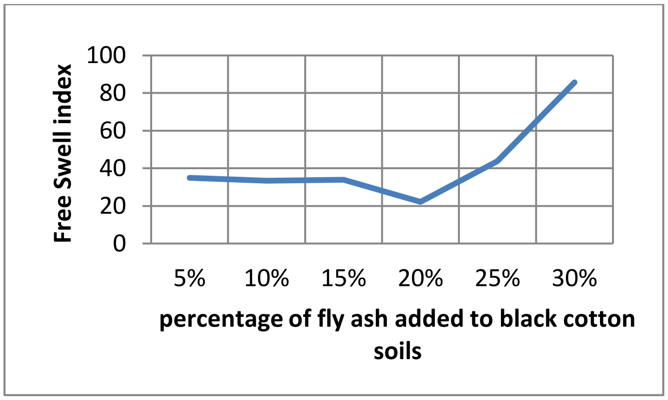
Fly ash collected from VTPS,kondapalli,Vijayawada was used in this investigation.The physical and chemical properties of Indian Fly ash are presented as follows

Freeswell index for fly ash:

We had conducted free swell index test with various proportions to added with black cotton soils

S.No.	% of Fly ash added	Free swell Index
1.	0	40
2.	5	35
3.	10	33.33
4.	15	33.33
5.	20	22.2
6.	25	43.75
7.	30	85.7

Graph:



Engineering properties:

S.No.	Description of property	Value(%)
1.	Color	Grey
2.	Liquid limit	44
3.	Plastic limit	Non plastic
4.	Shrinkage limit	42
5.	Specific gravity	2.03
6.	Fine sand size fraction	4
7.	Silt size fraction	89

8.	Clay size fraction	7
9	Optimum moisture content	41.9
10	Maximum dry density	1.00

Black cotton soils:

In this observation both for blak cotton soils and percentage offlyash added to black cotton soils are tabulated below**:**

Index properties:

S.No.	**Description of Property**	**Black cotton soil(%)**	**Black cotton added with 20% of flyash**
1.	Gravel size fraction(%)	0	0
2.	Coarse sand size fraction(%)	0	0
3.	Medium sand size fraction (%)	10.7	10.7
4.	Fine sand size fraction (%)	14	14
5.	Silt & Clayfraction (%)	86.6	75.3
6.	Liquid Limit(%)	72	29.5
7.	Plastic limit(%)	23.07	25
8	Plasticity index	17.25	4.5
8.	Shrinkage limit(%)	48.93	57.485
9.	Specific Gravity	2.45	2.34
10.	Optimum moisture content(%)	23	21.73
11.	Maximum Dry Density(t/cu.m)	1.64	1.589
12	Free swell index	40	20

Conclusion:

- The free swell index value has decreased to 22.2% from 40% after the addition of 20% fly ash to the soil which shows that the swelling is moderate.
- The plasticity index value has also decreased which shows that the stabilization done is helpful for reducing the problem in the soil to some extent when 20% fly ash is added to it.
- The optimum moisture content has decreased when 20% fly ash is added to it.
- The shrinkage limit when 20% fly ash is added to the soil which makes the soil stable

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