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Stabilization of Black Cotton Soil Using Flyash

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Abstract

Using expansive soil at construction sites poses significant challenges due to its tendency to shrink and swell. To mitigate these issues and make expansive soil suitable for construction, proper treatment is necessary. Black cotton soils, which are expansive and have low bearing capacity, contain Montmorillonite clay mineral responsible for their shrinkage and swelling properties. Changes in moisture content can exacerbate the swelling behavior of black cotton soil. The goal of stabilization is to enhance the usability of black cotton soil for construction by adding Fly Ash (FA). Soil is a unique material, and by incorporating certain admixtures, it can be stabilized with varying percentages of Fly Ash (5%, 10%, 15%, 20%).

Keywords: Black cotton soil, flyash, stabilization, admixture

1. INTRODUCTION

Soil is defined as unconsolidated material, composed of solid particles, produced by physical and chemical disintegration of soil.

Stabilization is a process of changing the soil properties by gradation by mixing with other soil, changing the density of soil by compaction or replacing soil with granular materials.

Now a day, population of world is rapidly increasing which indeed resulting into reduction of good land availability of construction purposes. Generally black cotton soil contains clay or very fine silts which have special typical property for volume change such as swelling, softening, and shrinkage, dry cracks, which depends on the saturation moisture content in black cotton soil. The movement caused by swelling and shrinking in expansive soil has previously undergone number of problems because of unexpected movements structures upward and downwards and thus it results into cracks in pavements, which are resulting on them. The property of swelling and shrinkage of soil creates depression cracks and swelling of construction on it. Therefore, there is requirement to upgrade or improve the engineering properties of such soils in advance to put the respective soil in construction.

The term soil improvement is use for the techniques which improve the index properties and other engineering characteristics of weak soils. Indian expansive soil covers about 0.8x106km² area which is approximately $1/5^{th}$ of its surface area .These soils contain montmorillonite mineral due to this they swell and shrink excessively with change of water content. Such tendency of soil is due to presence of fine clay particles which swell, when they come in contact with water, resulting in alternate swelling and shrinking of soil due to which differential settlement of structure takes place. Expansive soil can be stabilized by the addition of small percentage of admixtures. These techniques have been used for many construction purposes, preferably highway, and railroad and airport construction to improve sub grades and sub bases.

1.1 Problem Statement:

Black cotton soils are the major form of soil groups found in India, and cover approximately 20% of the total area and found in the most of the places, most commonly found on central and Western parts of India. It is characterized by low strength and high compressibility. This soil shows swell and shrink behaviour upon wetting and drying and is problematic. The black cotton soil shows collapse behaviour on soaking and therefore the strength of the soil needs to be improved. The characteristics of soil can be improved from various ground improvement techniques and one of the effective method is Soil Stabilization.

To overcome this behaviour, it has to be stabilized. The fly ash is freely available, for projects in the vicinity of a thermal power plants, it can be used for stabilization of expansive soils for various use and improve the properties of expansive soil with fly ash in varying percentages.

1.2 Objective of the study

In view of the above, the present aim is to study the effect of flyash as a material in improving the characteristics of black cotton soil.

The work has been planned with following objectives:

- To determine the effect of fly ash with varying percentage on MDD and OMC of black cotton soil.
- To know the UCS value of black cotton soil by the addition of fly ash.
- To determine the changes in the CBR values of soil with varying percentage of fly ash.
- To know the optimum percentage of adding fly ash to black cotton soil to stabilize.

2. MATERIALS AND METHODOLOGY

2.1 Black Cotton Soil:

Black cotton soil is considered as a very poor type of soil having a black colour with very fine grain. This type of soil contains pure clay particles with about 85-10 percentages passing through 75micron sieve. These soils are the major form of soil groups in India, and cover approximately 20% of the total are and found in most of the places. Most commonly found in the central and western parts India this includes, Maharashtra, Madhya Pradesh, Gujarat, AndraPradesh and some part of Karnataka.

Advantages:

- The enrich agro-friendly contents make black cotton soil fertile.
- These are enriched with calcium carbonate, magnesium potash and lime which are all nutrients.

Disadvantages:

- Cracking when dry and swelling when wet makes them difficult to manage unless they are cultivated at appropriate soil moisture levels. This make black cotton soil difficult to manage.
- Poor drainage and logging during rainfall and it is having low fertility.

Fig.1.1BlackCottonSoil

Black cotton soil is also known as expansive soil or swelling soils or shrink-swell soils are the terms applied to those soils, which have a tendency to swell and shrink with the variation in moisture content. As a result of which significant distress in the soil occurs, causing severe damage to the overlying structure. During monsoon, these soils imbibe water, swell, become soft and their capacity to bear water is reduced, while in drier seasons, these soils shrinks and become harder due to evaporation of water.

The types of soils are generally found in arid and semi-arid regions of the world and are considered as a potential natural hazard, which if not treated well can cause extensive damages to not only to the structures built upon them but also can cause loss of human life. Soils containing the clay minerals montomorillonite generally exhibit these properties. The annual cost of damage to the civil engineering structures caused by these soils are estimated to be ₹ 150 million in the U.K., $ 1,000 million in the U.S. and many billions of dollars worldwide.

Expansive soils also called as Black soils or Black cotton soils and Regular soils are mainly found over the Deccan lava tract (Deccan Trap) including Maharashtra, Madhya Pradesh, Gujarat, Andhra Pradesh and in some parts of Odessa, in the Indian sub-continent. Black cotton soils are also found in river valley of Tape, Krishna, Godavari and Narmada. In the north western part of Deccan Plateau and in the upper parts of Krishna and Godavari, the depth of black soil is very large. Basically these soils are residual soils left at the place of their formation after chemical decomposition of the rocks such as basalt and trap. Also these type of soils are formed due to the weathering of igneous rocks and the cooling of lava after a volcanic eruption.

These soils are rich in lime, iron, magnesia and alumina but lack in the phosphorus, nitrogen and organic matter. Their colour varies from black to chestnut brown, and basically consists of high percentage of clay sized particles. On an average, 20% of the total land area of our country's covered with expansive soils. Because of their moisture retentiveness, these soils are suitable for dry farmingand are suitable for growing cottons, cereals ,rice ,wheat, jawed, oilseeds, citrusfruits and vegetables, tobacco and sugarcane. During the last few decades damage due to swelling action has been clearly observed in the semiarid regions in the form of cracking and breakup of pavements, roadways, building foundations, slab-on-grade members, channel and reservoir linings, irrigation systems, water lines, and sewer lines.

2.2 Formation of black cotton soil:

Due to disintegration of a black lava i.e. Basalt Rock by Sun, wind and rain formation of Black cotton soil occurs, It is important to discuss the characteristics of black cotton soil because of which the troubles comes in the construction of different projects, mainly in Maharashtra, Gujarat, South Uttar Pradesh, East area of Madhya Pradesh and some of the part of Andhra Pradesh and Karnataka posses the black cotton soil in more area. Which is about 20 % of land area of India? The average depth of this Black cotton soil is 3.7 metres approximately.

Black cotton soils are made of varying Properties of minerals like Montmorinolite and kaolinite, chemicals like Iron Oxide and Calcium Carbonate and organic matter like humus. Montmorinolite is a predominant mineral of black cotton soils. The swelling and Shrinkage behavior of black cotton soils originate mainly from this mineral. Clay minerals are hydra silicate of aluminium and magnesium. They are made of sheets of silica and aluminium stacked are above the other forming sheet like structure with expanding lattice. The structure of some aluminium is by magnesium ions and the minerals becomes chemically active. They attract water molecules (dipoles) and various types of hydrated cat ions to the surface causing the soil to increase the volume. Abundance of calcium in black cotton soils has another

feature, it may be present in the form of saturating ions or as molecules of CaCo3 (kantar). Treatment with the Sodium aboutBaseExchangeandthesoilsbecomessofterandmoreplastic.Organicmatterinthe form of humus makes these soils more plastic and compressible .The dark colour of the black cotton soils is believed to be either due to humus or titanium oxide.

2.3 FlyAsh:

Fly ash is a finally divided by-product resulting from the combination of coal in power plants. It contains the large amount of silica, alumina and small amount of unburned carbon, which pollutes environment. It is grey in colour and alkaline in nature. The particle size ranges between 1-100microns.The specific gravity of fly ash is lies between 1.9-2.8.

Fig.1.2 FlyAsh

Fly ash is a waste material, which is extracted from the flue gases of a coal fired furnace. These have close resemblance with the volcanic ashes, which were used as hydraulic cements in ancient ages. These volcanic ashes were considered as one of the best pozzolona used till now in the world.

Now a day due to rapid urbanization and industrialization the demand of power supply has been grown up, these results in setting up of a numerous number of thermal powerplants. These thermal power plants use coal to produce electricity and after coal is burnt, whatever mineral residue is left is called as Fly ashes. These fly ashes are collected from the Electro static precipitator (ESPs) of the plants.

Safe disposal and management of fly ash are the two major issues concernedwith the production of fly ash. Generally the wastes which are generated from the industries possess very complex characteristics and are very hazardous, therefore it is necessary to safely and effectively dispose these wastes, so that it will not disturb the ecological system and will not cause any catastrophe to natural and human life. There should be provision of pre-treatment of these industrial wastes before its disposal and storage; otherwise it will cause environmental pollution.

Generally the fly ashes are micro sized particles which essentially consist of alumina, silica and iron. These particles are generally spherical in size, which makes them easy to flow and blend, to make a suitable mixture.

The fly ash contains both amorphous and crystalline nature of minerals. Its composition varies according to the nature of the coal burned and basically is a no plastic fine silt. At present, the generation of fly ash is far in excess of its utilization. Fly ash is also a potential material for waste liners. In combination with lime and betonies, fly ash can also be used as a barrier material.

2.4 Flyash Generation and Disposal:

For generation of steams, generally coal is used as a fuel in thermal power plants. In the past coal in the forms of lumps were used to generate steam from the furnaces of boilers, but that method proves to be

non-energy efficient. Hence to optimize the energy from coal mass, the thermal power plants use pulverized coal mass. Firstly the pulverized coal mass is injected into combustion chamber, where it burns efficiently and instantly. The output ash is known as fly ash, which consists of molten minerals.
When the coal ash moves along with the flue gases, the air stream around the molten mass makes the fly ash particle spherical in shape. The economizer is subjected, which recovers the heat from fly ash and stream gases. During this process, the temperature of fly ashes reduced suddenly. If the temperature falls rapidly, the fly ashes are resulting amorphous or glassy material and if the cooling process occurs gradually, the hot fly ashes becomes more crystalline in nature. It shows that the implements of economizer, improves its reactivity process.
When fly ash is not subjected to economizer, it forms 4.3% soluble matter and pozzolonic activity index becomes 94%. When it subjected to economizer, it forms8.8% soluble matter and pozzolonic activity index becomes 103%. Finally, the flyashes are removed from the flue gases by mechanical dust collector, commonly referred to electrostatic precipitator (ESPs) or scrubbers. The flue gases which are almost free from fly ashes are subjected to chimney into the atmosphere.

2.5 Fly Ash Utilization

Utilization of flyash in particular, can be broadly grouped into three categories.

- The Low Value Utilizations includes, Road construction, Embankment and dam construction, backfilling, Minefilling, Structuralfills, Soil stabilization , Ash dykes etc.
- The Medium Value Utilizations includes Pozzolana cement,Cellular cement, Bricks/Blocks, Grouting, Fly ash concrete, Prefabricated building blocks, Light weight aggregate, Grouting, Soil amendment agents etc.
- The high value utilization includes Metal recovery, Extraction of magnetite, Acid refractory bricks, Ceramic industry, Floor and wall tiles, Fly ash Paints and distempers etc.

Instead of these, there is large wastage of fly ash material, so large number of technologies developed for well management of fly ashes. This utilization of fly ash increased to 73 MT up to the year 2012. Fly ash has gained acceptance from the year 2010-12.
The present production of fly ashes in the country India are about 130 MT per year and expected to increase by 400MT by year 2016-17 by 2nd annual international summit for FLYASH Utilization 2012 scheduled on 17th & 18th January 2013 at NDCC II Convention Centre, NDMC Complex, New Delhi.

Table1.1 Production & Utilization of flyashes in different countries

Country	Annualashproduction, MT	Ash utilizationin percentage
India	131	56
China	100	45
Germany	40	85
Australia	10	85
France	3	85
Italy	2	100
USA	75	65
UK	15	50
Canada	6	75
Denmark	2	100
Netherland	2	100

2.6 Classification of FlyAsh

After Pulverizations, the fuel ash extract from flue gases, by electrostatic precipitator is called fly ash. It is finest particles among Pond ash, Bottom ash and Fly ash. The fly ashes are extracted from, high stack chimney. Fly ash contains non- combustible particulate matter, with some of unburned carbon. Fly ashes are generally contains silt size particles. Based on lime reactivity test,

Fly ashes are classified in four different types, as follows:

- Cementations fly ash
- Cementations and pozzolanic flyash
- Pozzolanic flyash
- Non-pozzolanic flyash

3. RESULTS AND DISCUSSION

The study of variations of different parameters viz. liquid limit, plastic limit, plasticity index, shrinkage limit, maximum dry density, optimum moisture content, unconfined compressive strength and California bearing ratio with the addition of fly ash suggest that, for each parameter of the study soil samples, there exists an optimum fly ash percentage for mixing with the soil under consideration; at which the respective parameter attains its most desirable value from geotechnical point of view.

Following laboratory test have been carried out as per IS: 2720. Tests are conducted to determine different properties of soil sample, fly ash sample, soil-flyash mixture and their test results are tabulated and presented in below tables.

Table 4.1Tests results on black cotton soil

SI.No	Laboratory Test	Result	Relevant IS Codes
1	Specific Gravity (G)	2.68	IS2720 Part3
2	Liquid Limit(WL)	70%	IS2720 Part5
3	Shrinkage limit	21%	IS2720 Part6
4	Plastic Limit(WP)	35%	IS2720 Part5
5	e or plasticity chart	CH	ISSCS
6	)ptimum Moisture Con-tent(O.M.C)	22%	IS2720 Part8
7	Maximum Dry Density(M.D.D)	12.17KN/m^3	IS2720 Part8
8	Unconfined Compressive Strength (U.C.S)	97.02KN/m^2	IS2720 Part10
9	lifornia Bearing Ratio(C.B.R)	2.65%	IS2720 Part16

Based on the data and results obtained from the experimental investigation on soil stability using different percentages of fly ash (0%, 5%, 10%, 20%), the following tables have been created to illustrate the strength properties of natural black cotton soil when fly ash is used as stabilizing agent..

Table.4.2 Test results on flyash

SI.No	Laboratory Test	Result
1	Specific Gravity (G)	2.25
2	Liquid Limit(WL)	45.5%

3	Plastic Limit(WP)	Non Plastic
4	e or plasticity chart	CI
5	Shrinkage limit(WS)	13%
6	ptimum Moisture Content(O.M.C)	20.79%
7	Maximum Dry Density(M.D.D)	12.17KN/m^3
8	Unconfined Compressive Strength (U.C.S) at OMC	12 2 KN/m^2
9	California Bearing Ratio(C.B.R) at OMC	2.9%

Table.4.3 Tests results of soil-flyash mixture

Sl.No	Particulars	BCSoli	Soil+5% Flyash	Soil+10% Flyash	Soil+15% Flyash	Soil+20% Flyash
1	O.M.C. (%)	22	20.79	20.75	19.56	20.39
2	MDD(KN/m^3)	12.17	11.63	11.96	12.18	11.62
3	UCS (KN/m^2)	122	122.6	122.9	123.4	122
4	CBR(%)	2.9	3.33	5.55	7.48	6.82

4. CONCLUSION

Based on the experimental analysis the following conclusions are drawn. As the locally available borrow soil has generally high plasticity (LL> 50) it was difficult to construction on it.

- Unconfined compressive strength of black cotton soil without fly ash which was 122KN/m² increased to 123KN/m² at 15% of fly ash in black cotton soil showing 1% improvement.
- The inclusion of different percentage of fly ash in natural soil generally resulted in some increasing in unconfined compressive stress.
- Maximum dry density was increase with increases in percentage of fly ash up to 15% in the black cotton soil was 12.17kN/m³, increases to 12.69kN/m³ at 21.67% OMC.
- CBR value of black cotton soil without fly ash which was 2.55% increased to 7.48% at 15% of fly ash in black cotton soil showing 4.93% improvement.

5. SOCIAL RELEVANCES

- Black cotton soil gives the good strength to the buildings due to the addition of Fly Ash.
- Flyash is better fill material for road embankments and concrete roads.
- It will help in environmental protection and saved soil excavation. It will also make a raw material available for construction at low cost to help governments ‘Housing for all’ projects.
- It is readily available and economical in construction.

6. SCOPE FOR FURTHER STUDY

- Efforts should be made to reduce the cost of operation, by searching other natural alkaline materials.
- Field application of this method, by using suitable technology.
- Use of other industrial wastes like bagasse ash, quarry dust and red mud with black cotton soil.
- Other Geotechnical properties such as permeability characteristic can also be studied.

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