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Study on Effect of Fly Ash on Strength Characteristics of Black Cotton Soil

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Abstract - *Urbanization and growth in the economy of cities of India have led to the steep increase in the building construction activities and has necessitated the implementation of infrastructure projects such as highways, railways, air strips, water tanks, reclamation etc. These projects invariably require quality earth in massive quantity. In urban areas, borrow earth is not easily available which has to be hauled from a long distance. Quite often, large areas are covered with highly plastic and expansive soil, which is not suitable for such purpose. The wide spread of the black cotton soil in the cities has posed challenges and problems to the construction activities. Therefore this study intends to investigate and improve the engineering properties of the black cotton soils so that, a better understanding is facilitated for the civil engineering practitioners, while dealing with these soils. In this study, fly-ash is used as a stabilizing material to stabilize the expansive soil dealing with engineering characteristics as the parameter for it. Present paper describes a study carried out to check the improvement in the properties of expansive soil with fly-ash in varying percentages. Fly-ash is added in 10%, 20%, 30%, 40%, 50% and the change in index properties and engineering characteristics is examined. The results of this study are analyzed to illustrate the influence of the treatment of fly ash on the properties of Black Cotton soil.*

Key Words: Black Cotton Soil, Engineering Properties, Fly-Ash, Index Properties

1. INTRODUCTION

Expansive soil:

Expansive soils are identified by significant volume changes with changes in moisture content, causing major structural failure and collapse, especially for light structures and pavements constructed on them. Different forms of soils are used in structural engineering structures; however, certain soil formations in their normal states are ideal for building purposes, and others, such as problematic soils, are unsuitable without treatment. Expansive soil is also known as problematic soil [1]. Typically, they are distinguished by a high plasticity, swelling potential and shrinkage potential, and low permeability and strength in wet areas. Due to the above properties, they are volumetrically unstable [2]. For improvement purposes, expansive soil is replaced, or the properties are changed by adding additional material to the soil [3]. As the moisture content increases, volumetric changes happen to expansive soil; this can be minimized by adding lime, fly ash, bitumen, cement, and other chemicals [4,5]. Expansive soil is considered one of the worst soils for civil construction, as engineers have to pay extra attention during the construction of structures using it. Black cotton soil is composed of fine-grained soil or decomposed rocks that show huge volume changes when subjected to variability in moisture content. Expansive soil shows swell-shrink behavior near the ground surface due to the land covered by expansive soil [6,7]. These soils occupy approximately 8.9×10 km2 in India; approximately one-fifth of their surface area covers the states of Maharashtra, Gujarat, Uttar Pradesh, Madhya Pradesh, Rajasthan, Andhra Pradesh, Telangana and Tamil Nadu [8,9]. Black cotton soil is composed of fine-grained soil or decomposed rocks that show huge volume change when subjected to variability in moisture content; expansive soil shows swell shrink behaviour near the ground surface due to direct contact with variation in seasons and environment [10,11]. Under drying or warm settings, soil moisture content reduces, and overall volume shrinks. The subsequent incremental development of desiccation cracks creates detrimental consequences on expansive soil's mechanical and hydraulic behaviors [12]. Expansive soil consists of hydrophilic minerals, such as Illite and montmorillonite, and is a generally troublesome expansive soil conceived in natural geological processes. Expansive soil is distinguished by shrinkage and expansion[13]. In India, 20 % of the land is covered by expansive soil [6].

1.1 Fly ash:

The material, which is the byproduct of the thermal power station and coal industries, was collected from fly ash gases. This is composed of very fine silt particles which are dumped into landfills. The production of fly ash is very high as compared to its consumption in India [14]. Fly ash is a good water absorbent; it can be used to increase the strength of the soil. Fly ash contains macro and micro nutrients that can support agriculture growth; 40 % of fly ash is suitable for agriculture use [15]. Due to urbanization, the demand for power supply increases, resulting in increasing numbers of power plants, which after combustion of coal generates fly ash as a residue [16]. The disposal of ash with safety towards the environment is also important. The utilization of fly ash alternative should be determined. The bulk use of fly ash can be done in geotechnical fields for embankments, retaining walls, soil replacement, etc. [17,18]. Fly ash is now used for making bricks, and it is added in different proportions to soil to improve its strength. This results in a fast hydration mechanism and a concurrent cation exchange, as lime and fly ash are added into a soil that flocculates the soil into larger lumps [2]. Murmu et al. studied the use of fly ash for the stabilization of expansive soil [19]. The objective of the research is to determine the effect of fly ash content on expansive soil. The standard proctor test is used, and specific gravity is determined. The maximum dry density and optimum moisture content of the different proportions of soil were analyzed. This analysis helps in selecting good soil-ash composition for field work. The results obtained from this research showed how expansive soil behaves after adding fly ash. Particle size distribution analysis was performed to determine the sizes of particles present in the samples [20]. Nalbantoğlu studied particle size increases with increase in curing time [21].

2. LITERATURE REVIEW

Many researchers have worked on use of industrial waste for soil stabilization.

1) Zala Yashwantsinh et.al, (2021): The authors had worked on Stabilization of black cotton soil using fly ash in various proportions (5%,10%,15%). These were the observations and conclusions made from the study. Liquid limit was decreasing with increase in percentage of fly ash and Plastic limit was decreasing with increase in percentage of fly ash.

2) Saxena Anil Kumar (2021)- Effect of fly ash and lime on engineering properties of BC soil. A liquid limit & Plastic limit was increases with increases in percentage of fly ash & lime. Compaction characters of soil increase with increasing % of fly ash & lime. CBR value of BC soil increases with increase in % of fly ash & lime.

3) Phanikumar and Sharma (2020): A similar study was carried out by Phanikumar and Sharmaand the effect of fly ash on engineering properties of expansive soil through an experimental programme. The effect on parameters like free swell index (FSI), swell potential, swelling pressure, plasticity, compaction, strength and hydraulic conductivity of expansive soil was studied. The ash blended expansive soil with fly ash contents of 0, 5, 10, 15 and 20% on a dry weight basis and they inferred that increase in fly ash content reduces plasticity characteristics and the FSI was reduced by about 50% by the addition of 20% fly ash. The hydraulic conductivity of expansive soils mixed with fly ash decreases with an increase in fly ash content, due to the increase in maximum dry unit weight with an increase in fly ash content..

Fly-ash is an industrial waste obtained from thermal power plants by burning of coal. The test result showed a significant improvement in compaction and CBR characteristics. And fly-ash is found to be an effective waste material for the stabilization of expansive soil.

3. METHODOLOGY

In this study, black cotton soil (BCS) was used for testing purposes, and fly ash (FA) was collected from the Thermal Power Plant. Different proportions of BCS, yellow soil, and moorum were taken and mixed with fly ash to determine the standard proctor test result, specific gravity, and particle size distribution. To stabilize BCS economically, only 10 to 15 % of class F fly ash was required [22,23]. The different samples were tested to determine index properties. The different samples were then collected in different proportions to determine stable compositions. The soil collected was dried and crushed into the appropriate sizes and checked according to IS:2720 for its physical characteristics, such as gradation, compaction, and strength.The black-cotton soil used in this study was mixed with fly-ash in different proportions and a series of laboratory tests were conducted on samples containing various percentages of fly-ash i.e. 0%, 10%, 20%, 30%, 40% and 50% by dry weight of the soil. The following tests were conducted on black cotton soil and fly-ash mixes as per relevant IS codes of practice:

- Liquid limit.
- Plastic limit
- Plasticity index.
- Compaction characteristics.
- Differential free swell (DFS) test.
- California bearing ratio (CBR) test.

3.1 METHODS

To determine the different properties of soil, the IS code was referred to, and with accordance to the code book, the different tests are performed. The standard proctor test was performed following IS: 2720 (Part 7) - 1980, liquid and plastic limit test - IS 2720 (Part 5) - 1985, free swell index test - IS 2720 (Part 40) - 1977, specific gravity - IS 2720 (Part 3/Sec 1) - 1980, MDD and OMC - IS 2720 (Part 7) - 1980, water content-IS 2720 (Part 2) - 1973. The samples for different tests were collected from different locations, and were preserved from atmospheric moisture.

A. Fly-Ash

Fly-ash is used as stabilization material in this research. Fly-ash was obtained from, Kothagudam thermal power plant , district khammam, Telangana.

B. Black Cotton Soil

Black cotton soil used in this study was brought from outskirts of Hyderabad city near to ramoji film city. The expansive soil is classified as Inorganic clay of high plasticity (CH) with expansive behavior. A physical characteristic of clay sample is listed in table-1.

Table -1: Index Properties of black cotton soil

S.No.	Parameters	Test Values
1.	Soil classification	CH (Inorganic clay of high plasticity)
2.	Liquid limit % (LL)	55.2
3.	Plastic limit %(PL)	28.1
4.	Plasticity index%(PI)	27.1
5.	Differential Free Swell%(DFS)	52
6.	Optimum moisture content (OMC)	19.3%
7.	Maximum dry density (MDD)	1.63g/cc
8.	California bearing ratio (CBR)	1.8

C Test Result:

Particle size distribution
For proper understanding of particle sizes in soil samples, particle size analysis should be performed. From particle size distribution (PSD), particles of different sizes present in a soil mass can be easily determined, and their distribution with accordance to size can also be found. The studies suggest that soil particle size increases with curing time (2 m - 0.075 mm). The different sizes of particles are plotted in Figure , and the data of analysis is given in Table.

The particle sizes were finer than 10, 30, and 60 % were determined as D10 = 0.30 mm, D30 = 0.40 mm, and D60 = 0.55 mm. The coefficient of curvature Cc = 1.83 and the coefficient of uniformity Cu = 0.97.

Cu = D60/D10 = 0.55/0.30 = 0.97 (1)
CC = D302/D60D10 = (0.30)2/0.55×0.30 = 1.83 (2)

As we know, when Cu is less than 4, it is classified as poorly graded or uniformly graded soil. Uniformly graded soil has identical particles, with Cu value approximately equal to 1. Here, it is less than 1, i.e., = 0.97. For the soil to be well-graded, the value of Cc must range between 1 and 3. Here, it is between 1 and 3, i.e., = 1.83
Particle size distribution (PSD).

Particle-diameter-(mm)	Percentage-finer-(%)
2.36	99.85
1.18	86.295
0.600	62.790
0.425	31.56
0.300	10.00
0.250	5.810
0.150	0.190
0.088	0.050
0.075	0.012

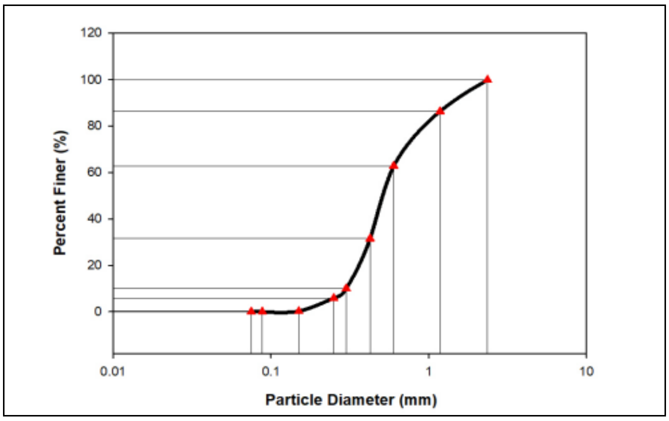

Fig -1: Particle size distribution curve of BCS

Various tests were conducted on black cotton soil mixed with fly-ash in the different proportions as per IS code of the

practice. Test results are summarized in Table-2.

Table -2: Test result of BCS with Fly-Ash (%)

S.No.	Tests	CF 0	CF 10	CF 20	CF 30	CF 40	CF 50
1.	Liquid limit(LL)%	55.2	51.3	48.1	44.3	40.5	36.3
2.	Plastic limit(PL)%	28.1	26.4	24.2	22.6	20.7	18.2
3.	Plasticity index(PI)%	27.1	24.9	23.9	21.7	19.8	18.1
4.	Differential free swell (DFS)%	52	41	32	25	18	14
5.	Optimum moisture content (OMC)	19.3	21.1	23.0	24.1	23.5	22.1
6.	Maximum dry density (MDD)	1.63	1.61	1.58	1.56	1.53	1.52
7.	California bearing ratio (CBR)	1.8	2.5	5.1	4.6	2.2	2.0

Where:CF0=BCsoil+0%fly-ash,CF10=BCsoil+10%fly-ash,CF20=BCsoil+20%fly-ash,CF30=BCsoil+30%fly ash,CF40=BCsoil+40%fly-ash,CF50=BCsoil+50%fly-ash.,FA= Fly-ash content

4. RESULTS AND DISCUSSION

Test results variations of LL, PL, PI, DFS , OMC, MDD and CBR with the addition of fly-ash up to 50% by dry weight of soil are shown in figure . The LL decreased from 55.2% to 36.3% as fly-ash content increased from 0% to 50% similarly, Plasticity index decreased from 27.1% to18.1% and DFS decreased from 52% to 14% respectively. And optimum moisture content increased from 19.3% to 24.1% and maximum dry density decreased from 1.63% to 1.52% and maximum CBR value obtained at 20% fly-ash. These test results indicates that the swelling behavior of the soil is considerably reduced.

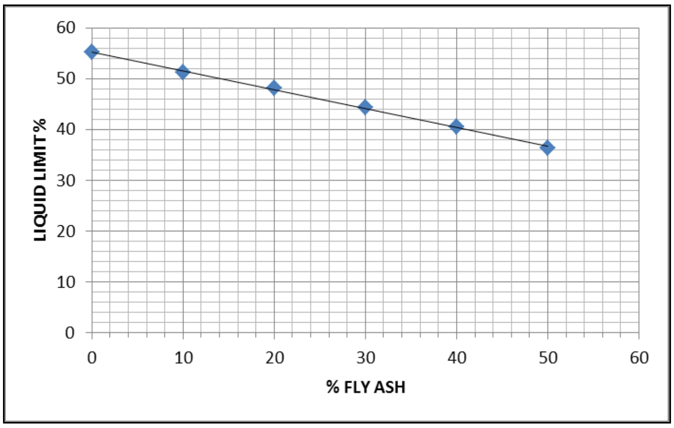

Fig -2: Variation of LL for BCS mixed with Fly-ash

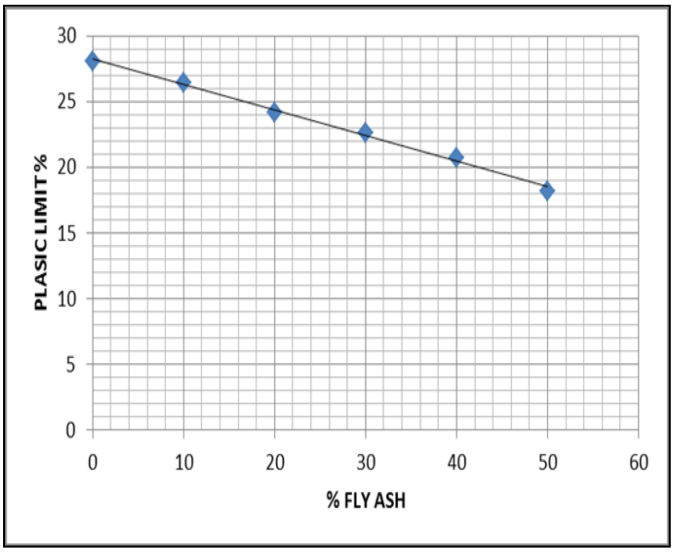

Fig -3: Variation of PL for BCS mixed with Fly-ash

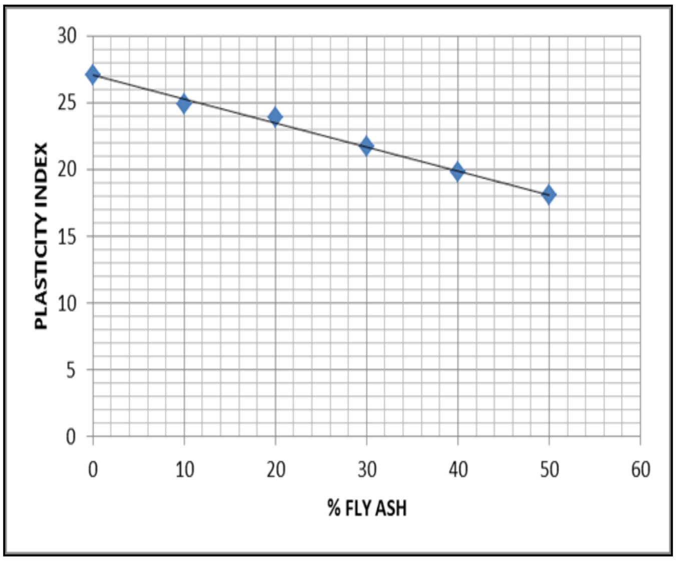

Fig -4: Variation of PI for BCS mixed with Fly-ash

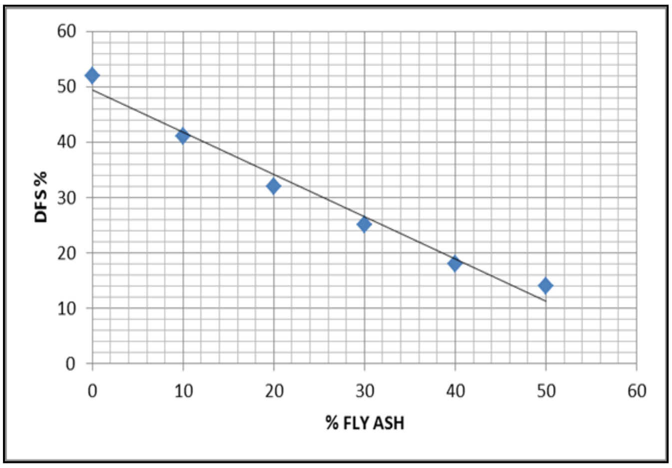

Fig -5: Variation of DFS for BCS mixed with Fly-ash

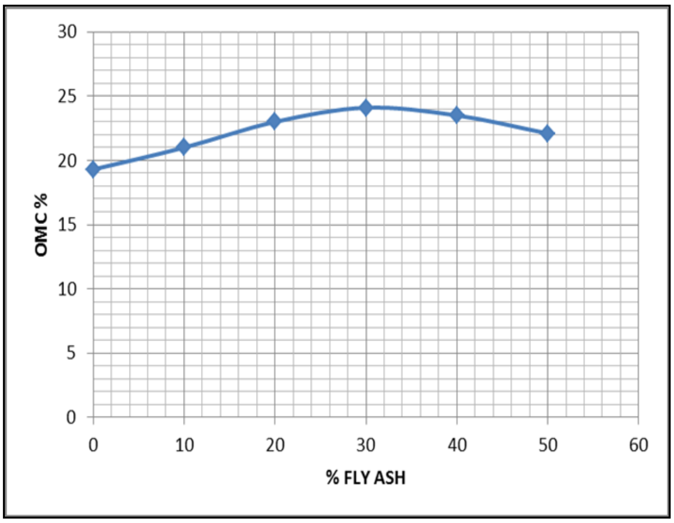

Fig -6: Variation of OMC for BCS mixed with Fly-ash

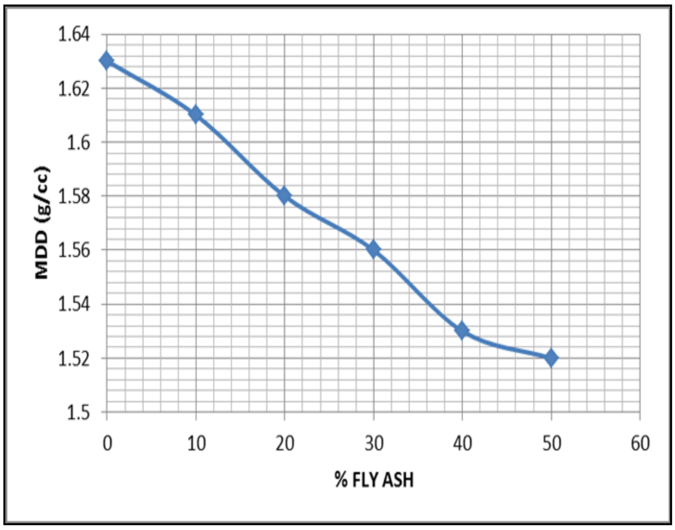

Fig -7: Variation of MDD for BCS mixed with fly-ash

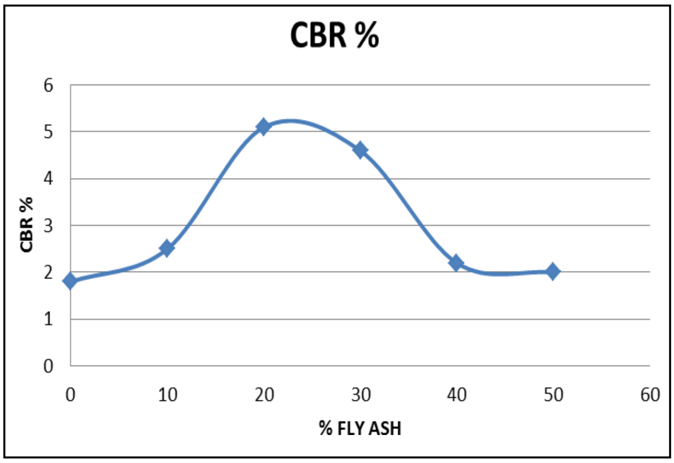

Fig -8: Variation Of Cbr For Bcs Mixed With Fly-Ash

5. CONCLUSION

The different tests performed on fly ash and expansive soil explains the behavior of soil for the different compositions used for testing. Some important conclusions which the author has emphasized are given below. Fly ash can decrease the maximum dry density of soil and increase the optimum moisture content, as fly ash has a property of absorbing water, resulting in decreased strength.

Based on the laboratory tests conducted on black cotton soil mixed with the fly-ash from 0% to 50% by dry weight of the soil. Following conclusions can be drawn:

- Liquid limit of samples are decreasing with the increasing of fly-ash into the Black soil. It has been found that the liquid limit decreased from the (55.2% to 36.3%).
- Plasticity index decreased from 27.1% to 18.2%.
- Differential free swell index has reduced from 52% to 14%.
- Optimum moisture content increased from 19.3 % to 23 %.
- Maximum dry density has reduced from 1.63% to 1.52%.
- Maximum CBR value obtained at 20% fly-ash.

Above results indicates that the degree of expansiveness reduced to low. From this research it can be concluded that fly-ash has a potential to modify the characteristics of expansive clay like black cotton soil and to make it suitable in many civil applications.

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