RESEARCH ARTICLE

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# CBR Characteristics and Swelling Behaviour of Black Cotton Soil Mixing with Fly Ash and Silica Fume

Beerendra Kumar[1], Ashish Gupta[2*], Adarsh Kasaudhan[3]

Department of Civil Engineering, Bundelkhand Institute of Engineering and Technology, Jhansi, Uttar Pradesh, India

## Abstract

Today's rapid growing world produces waste that is very difficult to handle eco-friendly. Soil contamination is also one of the major geo-environmental issues by pouring industrial wastes directly over soil without treating it like caustic soda, fly ash, etc. Fly ash reaches ground water through percolation and pollutes the ground water. The main reason behind the soil contamination is due to rapid urbanization. This innovative and non-traditional research on waste utilization is gaining importance nowadays. Geotechnical engineers are adopting soil properties remolding and monitoring techniques by using waste material like fly ash Slag, Silica fume etc. This research aims to find the suitability of by-product silica fume and fly ash for Black cotton soil. In this research number of laboratory test are performed on black cotton soil using silica fume & fly ash as admixture in varying percentage. The outcome of the research shows the enhancement in properties of black cotton soil also significant decrease in free swelling index is observed. This expansive soil has very high swelling and shrinkage characteristics due to the clay mineral montemorillonite. It is found in abundant quantity in southern region of India and due to its poor characteristic, it is also termed as poor soil. Building any structure, road, bridge, embankment etc is so risky, and the solution is to replace this poor soil with good natural soil. Hence in this thesis work, emphasis is given on the use of black cotton soil by mixing stabilizers like silica fume and fly ash. Both increase the maximum dry density of black soil, and also CBR %value is increased. On adding silica fume, it also possesses a very low free swell value; hence, using both additives simultaneously will be a better solution to the problem of black cotton soil.

**Keywords:** Fly Ash, Silica Fume, Expansion of BCS, CBR, Black cotton soil.

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## Introduction

The inbuilt nature and varying geological processes and overburden stress history in soils is responsible for varieties of soils on earth. Geological process and stress history brought the following changes soil like (i) their composition- mineralogy, fabric and particle size distribution etc (ii) the chemical composition. Initially, the swelling behavior can be seen in black cotton soil, which swells at a higher rate due to montemorillonite mineral's presence. However, recent investigations have proved that heaving characteristics also occur in some non-swelling soils due to chemical reaction between soil and strong alkaline pollutants resultingin zeolite formation.[1]

Black cotton soil (BC Soil) has always been a challenge for civil engineers for foundation design. High volume change and swelling happen due to change in water content of these soils. The structure founded on such soil undergoes excessive settlement. About 20% of the land cover of India is affected by Black cotton soil mainly coastal regions. Before going for construction this soil need stabilization either in mechanical or chemical form by adding fly ash and silica fume.[2] In this research behavior of black cotton soil is enhanced by adding fly ash obtained from a thermal power plan and silica fume in varying percentage.

**Corresponding Author:** Ashish Gupta, Department of Civil Engineering, Bundelkhand Institute of Engineering and Technology, Jhansi, Uttar Pradesh, India, e-mail: email

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## Materials Used

### Normal Soil

The Normal or uncontaminated soil representing the non-expansive soil was taken from Jhansi, Uttar Pradesh. These soil samples are obtained from the construction site at a depth of 3 to 6 m under the ground level near the railway station area at Jhansi.

**Table 1:** Particle size distribution of normal soil and BC soil

| *S. no.* | *Soil description* | *Percentage in normal soil* | *Percentage in BC soil* |
|---|---|---|---|
| 1. | Gravel | 21 | 17.7 |
| 2. | Sand | 85 | 81 |
| 3. | Fine | 9 | 14.5 |

**Table 2:** Atterberg limits of normal soil and BC soil

| *S. no.* | *Soil description* | *Normal soil* | *BC soil* |
|---|---|---|---|
| 1. | Liquid Limit (%) | 31.2 | 48.3 |
| 2. | Plastic Limit (%) | 29.1 | 26.89 |
| 3. | Shrinkage Limit (%) | 23 | 15.9 |
| 4. | Plasticity Index (%) | 2.1 | 21.41 |
| 5. | Classification | SM-ML | SC |

**Table 3:** Specific gravity of various combinations of soil

| *S. no.* | *Soil description* | *Specific gravity* |
|---|---|---|
| 1. | Normal Soil | 2.41 |
| 2. | BCS | 2.49 |
| 3. | Fly Ash | 1.94 |
| 4. | Silica Fume | 2.358 |
| 5. | BCS + 5% FA | 2.46 |
| 6. | BCS + 25% FA | 2.39 |
| 7. | BCS + 5% SF | 2.32 |
| 8. | BCS + 25% SF | 2.23 |

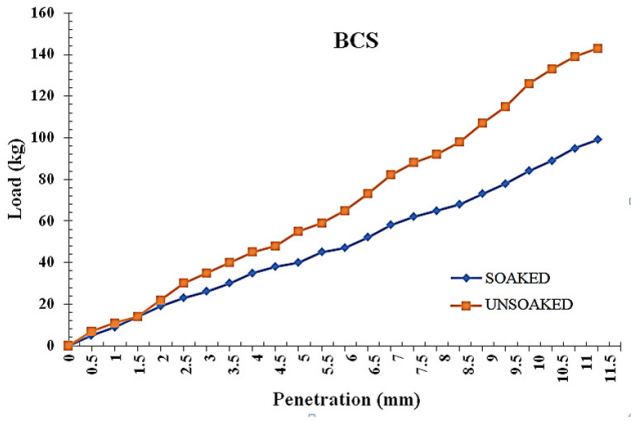


**Figure 1:** Variation of load vs. penetration of BCS.

## Black Cotton Soil

Uncontaminated black cotton soil is considered similar to expansive soil. The Black soil is sampled from Shivpuri located in Madhya Pradesh in the Bundelkhand region.

## Fly Ash

It is produced in very large quantities as a byproduct due burning coal for generating electricity in thermal power plant industries. Its dumping is so difficult in the present time due to its production in large quantity. Fly ash used for stabilizing expansive soil was obtained from the Parichha Thermal Power Station in Jhansi. It is obtained from dry pumps of the plant so that there should not be any loss in pozzolonic nature of fly ash due to moisture available in the atmosphere. Silica and aluminium are major chemical

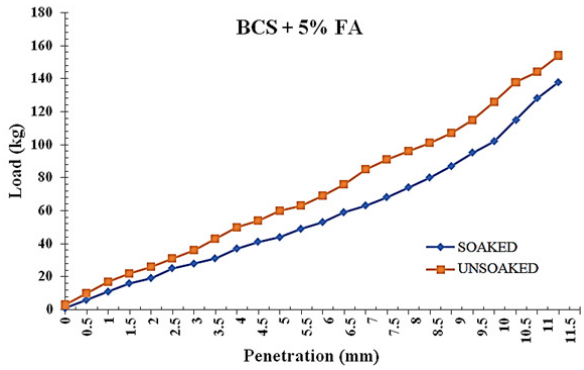


**Figure 2:** Variation of load vs. penetration of BCS + 5% FA.

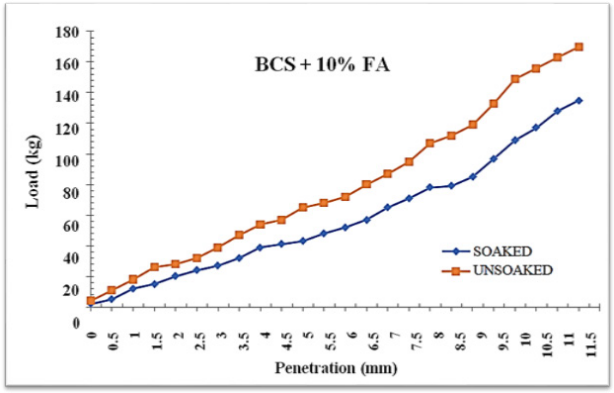


**Figure 3:** Variation of load vs. penetration of BCS + 10% FA.

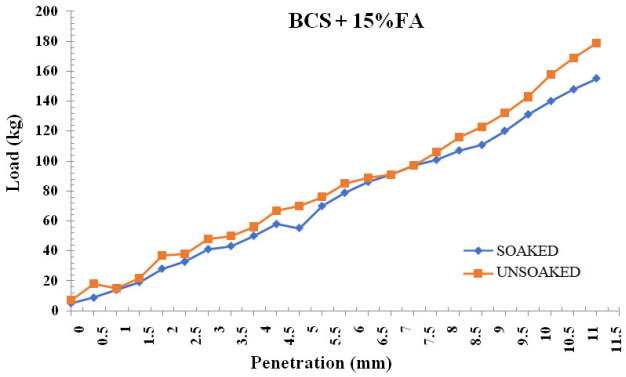


**Figure 4:** Variation of load vs. penetration of BCS + 15% FA.

**Table 4:** Permeability of normal soil and BC soil

| *S. no.* | *Soil Description* | *Permeability, k (cm/sec)* |
|---|---|---|
| 1. | Normal Soil | $1.85 \times 10^{-7}$ |
| 2. | BCS | $2.6 \times 10^{-7}$ |

**Table 5:** OMC and MDD of various combinations of soil

| *S. no.* | *Soil description* | *OMC (%)* | *MDD (g/cc)* |
|---|---|---|---|
| 1. | BCS | 18.2 | 1.717 |
| 2. | FA | 28.6 | 1.69 |
| 3. | SF | 32.4 | 1.21 |
| 4. | BCS + 5% SF | 16.9 | 1.63 |
| 5. | BCS + 10% SF | 19.5 | 1.60 |
| 6. | BCS + 15% SF | 24.1 | 1.59 |
| 7. | BCS + 25% SF | 27.8 | 1.58 |
| 8. | BCS + 5% FA | 14.5 | 1.72 |
| 9. | BCS + 10% FA | 17.2 | 1.69 |
| 10. | BCS + 15% FA | 18.6 | 1.70 |
| 11. | BCS + 25% FA | 20.90 | 1.73 |
| 12. | BCS + 5% SF + 5% FA | 19.1 | 1.69 |
| 13. | BCS + 15% SF + 15% FA | 17.5 | 1.725 |
| 14. | BCS + 25% SF + 25% FA | 16.8 | 1.741 |

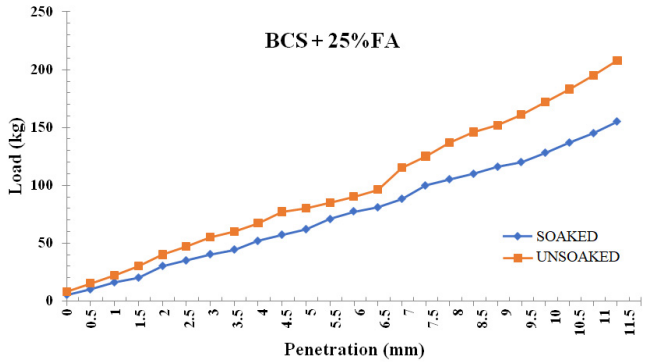


**Figure 5:** Variation of load vs. penetration of BCS + 25% FA.

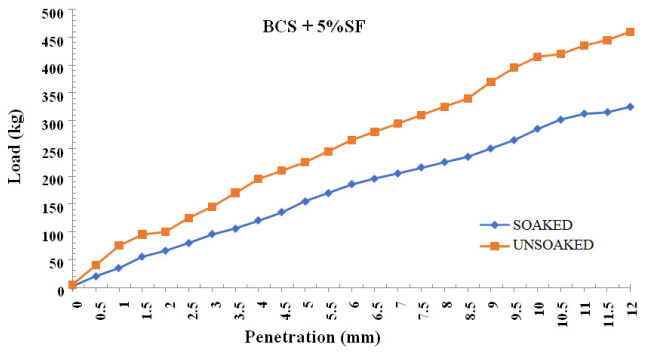


**Figure 6:** Variation of load vs. penetration of BCS + 5% SF.

composition of fly ash with some other elements in very small percentage.[3,4]

## Silica Fume

Silica fume is generated as byproduct in the production of silicon-based alloy and other important products. It creates

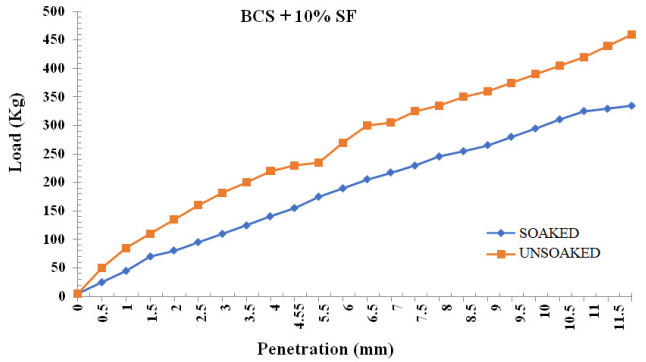


**Figure 7:** Variation of load vs. penetration of BCS + 10% SF.

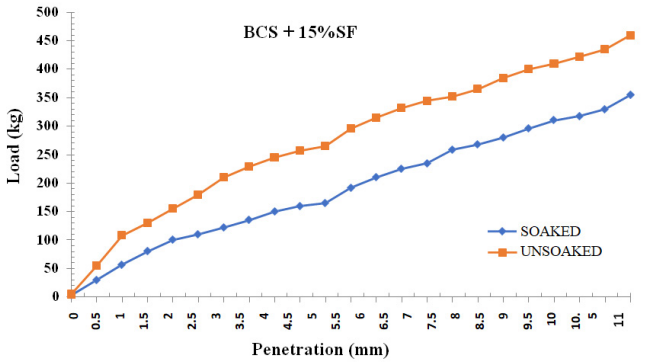


**Figure 8:** Variation of load vs. penetration of BCS + 15% SF.

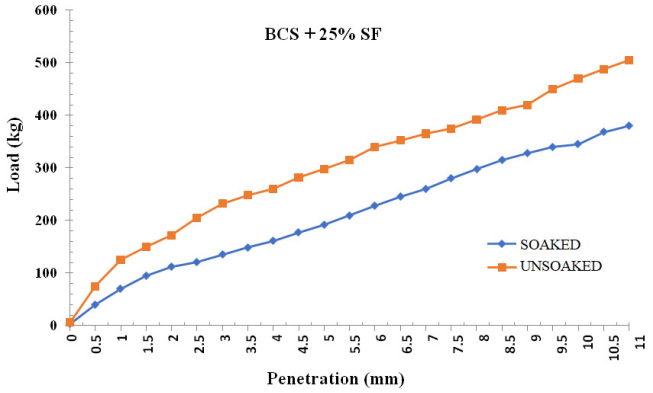


**Figure 9:** Variation of load vs. penetration of BCS + 25% SF.

various kinds of pollution problems and health hazards. Silicafume is used for increasing the strength of soil and also used in reduction of heaving property in roads.[5,6] Silica fume is obtained from a company named Sri Durga mines and minerals located in Kandukur Hyderabad. Silica fume is used as admixture for cement and soils to improve their engineering characteristics.[5,6]

# Experimental Results and Discussion

This chapter discusses the geotechnical behaviour in uncontaminated soils or normal soil of both expansive soil

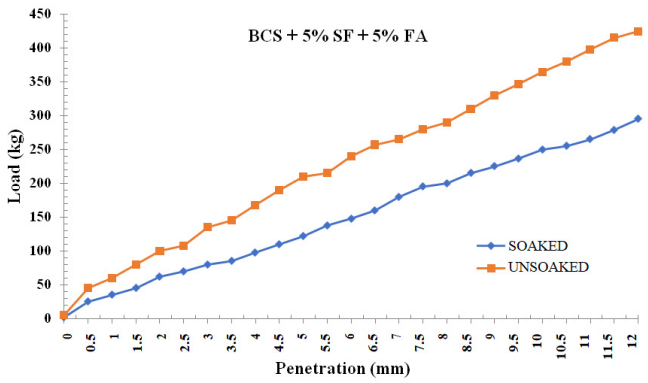


**Figure 10:** Variation of load vs. penetration of BCS + 5% SF + 5% FA.

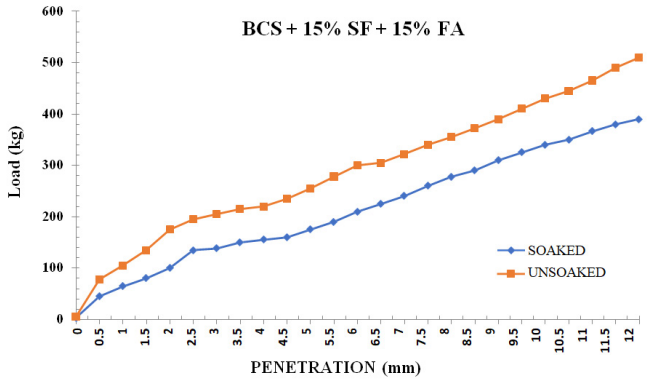


**Figure 11:** Variation of load vs. penetration of BCS + 15% SF + 15% FA.

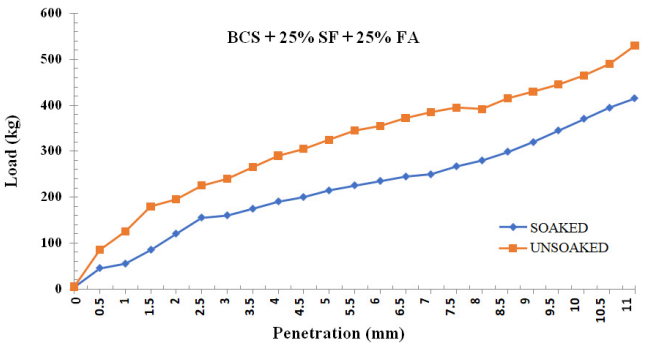


**Figure 12:** Variation of load vs. penetration of BCS + 25% SF + 25% FA.

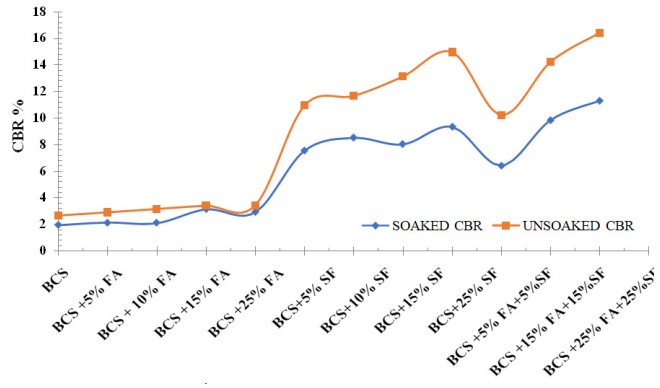


**Figure 13:** Variation of CBR (%) with various combination of soil mix (%).

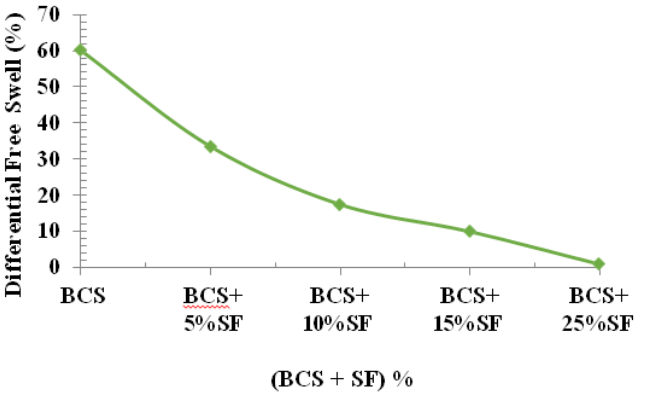


**Figure 14:** Variation of differential free swell with (BCS + SF) mix content.

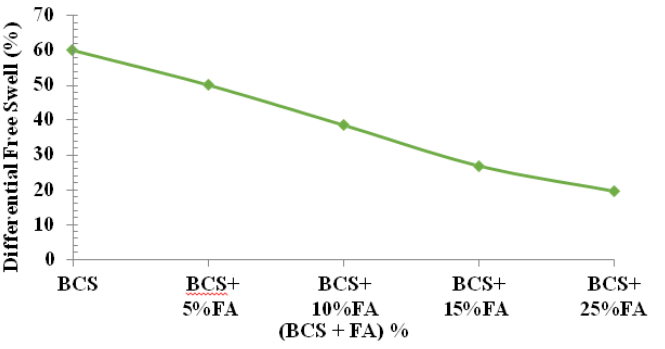


**Figure 15:** Variation of differential free swell with (BCS + FA) mix content.

and non-expansive soil and the geotechnical behaviour of the stabilized soil. It shows the changes in the soil due to mixing of various kind of additives viz. fly ashand silica fume. Expansive soil like black cotton soils are subjected to high swelling and shrinkage properties so keeping its properties efforts have been made towards increasing the strength characteristics of the soil and analyzing the swelling nature and minimizing with the use pozzolonic materials. Grain size distribution and the atterberg limits are done for both expansive and non-expansive soil (Normal Soil) and are represented in Tables 1 and 2. The results of the specific gravity of the various combinations used in the present study are shownin Table 3. Specific gravity in the virgin soil and after stabilizing the soil with fly ash and silica Fume. It is found that the soil stabilized with silica fume gives a lower specific gravity compared to the other mix like soil stabilized with fly ash and silica fume. The soil becomes lighter than the natural soil by adding fly ash and silica fume. To understand thepermeable nature of the soil, the falling head permeability method is used and the results are shown in Table 4. Proctor

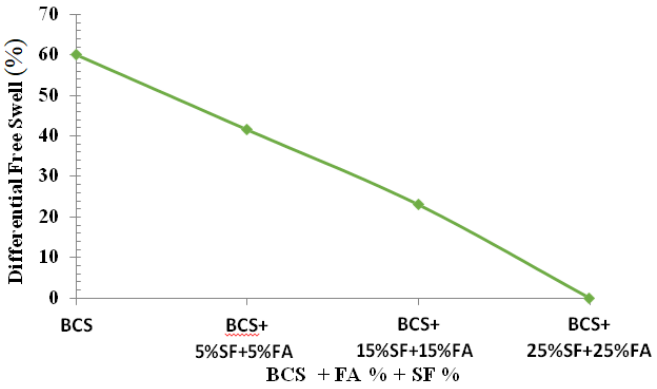


**Figure 16:** Variation of differential free swell with (BCS + SF + FA) mix content.

compaction tests to find the optimum moisture content (OMC) and maximum dry density (
MDD) for various combinations of soils are shown in Table 5.

Maximum dry density of black soil increases on the addition of fly ash and little increase on the addition of silica fume to the black cotton soil. This may be due to filling up the pores in the soil with fly ash and silica fume. The study also shows that the soils without the stabilizing agent have a lower CaO/ Na2O ratio and the alkali migration rate is higher in this case. With the addition of fly ash and silica fume in the soils, the CaO/ Na2O ratio is higher and the alkali migration rate becomes less. This proves that fly ash and silica fume are good additives to be used in alkali-contaminated areas, which will resist the heaving behavior of the soil.Hence to get MDD value higher both mixes should be mix simultaneously to black cotton soil.The California Bearing Ratio (CBR) test is a penetration test used to evaluate the subgrade strength of roads and pavements. The results obtained by these tests are used with the empirical curves to determine pavement thickness and its component layers. CBR tests done on the various combinations of soil are shown in Figures (1 to 13).

As the percentage of Silica fume and fly ash both in Black cotton soil increases in equal proportions like 5, 15 and 25%, then the value of soaked CBR and unsoaked CBR both increases and in the range of 6.4% to 11.3% for soaked CBR test and high increase from 10.2 to 16.4% for unsoaked CBR test. This high value of CBR are more than other when only Silica fume mix and fly ash mix CBR test is carried out. So it is better to mix both additives simultaneously in black cotton soil to increase its pavement characteristics.

Differential free swell (Free swell Index) of various combinations of soil are shown in Figures (14 to 16). It can be seen that silica fume additive is more effective in decreasing the free swell value of Black cotton soil. As the SF% increases in BCS mixfrom 5 to 25% then the free swell index value decreases from 60 to 1%. At 25% SF mix the soil have low degree of expansiveness; hence Silica fume is most effective in minimizing the swelling behavior of Black cotton soil due to its fine particles of pozzolonic nature. As the fly ash mix % increases in Black cotton soil the free swell value decreases at slower rate from 60% to 19.5%. As the both additives, Fly ash and silica fume is mixed simultaneously in equal proportion in black cotton soil as 5, 15 and 25%, then FSI value decreases to 0%.

## Conclusions

Based on the results of different combination of the soil following results can be concluded:

- The soil can be stabilized with fly ash and silica fume for the suppression of the heaving behavior of the soil. It is concluded that silica fume is the best additive of two, which arrest the heaving totally with 0% swelling in the soil. Usage of fly ash also reduces the heaving. The more the fly ash used, the lesser heaving can be expected but silica fume mix reduce the swelling to greater extent. When both additives mixed simultaneously with black cotton soil the swell index value reduces to 0% at higher rate at about 25% FA + 25% SF + BCS Mix. The degree of expansiveness reduces from High to Low.
- The strength characteristics of the stabilized soil have been calculated through the shear strength parameter. Both fly ash and silica fume, when added to the soil these additives increases the strength of the soil through higher shear strength parameter hence CBR% increases to higher % upto 20% at about 25% FA + 25% SF + BCS Mix.
- The sample of fly ash and silica fume mixed with BCS shows decrease in OMC and increase in maximum dry density, respectively on varying the percentages of 5, 15 and 25% of both combinations of fly ash and silica fume simultaneously. Hence the combination FA + SF + BCS is best from proctor test mainly at 25% mix.
- A significant increase in OMC and decrease in maximum dry density is observed when only micro silica is added to the black cotton soil but addition of fly results in initial decrease in dry density at low percentage about 5% and then an increase in dry density athigher percentage about 25%.
- Adding silica fume to the black cotton soil improves both the soaked and unsoaked CBR% considerably at a higher rate. The addition of 25% silica fume to the black cotton soil increases the CBR strength by 350% around in the soaked test and 450% around in the unsoaked CBR test.
- The CBR value of both additive combinations in black cotton soil is more than anyone mainly maximum at 25% FA and 25% SF mix in Black cotton soil.

## References

[1] Ramesh, H.N. and Mohan, S.V., 2013. Index properties of alkalis treated expansive and non-expansive soil contaminated with acids. IOSR J. Mech. Civ. Eng, 6(5), pp.1-9.

[2] Laguros, J.G. and Cokca, E., 2002. Use of class c fly ashes for the stabilization of an expansive soil. Discussion and closure. Journal of Geotechnical and Geoenvironmental Engineering, 128(11).

[3] Nalbantoğlu, Z., 2004. Effectiveness of class C fly ash as an expansive soil stabilizer. Construction and Building Materials, 18(6), pp.377-381.
[4] Abd El-Aziz, M.A., Abo-Hashema, M.A. and El-Shourbagy, M., 2004, April. The effect of lime-silica fume stabilizer on engineering properties of clayey subgrade. In Engineering Conference, Faculty of Engineering, Mansoura University, Paper (No. 96, pp. 1-18).
[5] Transforming Diagnostics Manufacturing at Cepheid: Migration from Paper-Based Processes to Digital Manufacturing using Opcenter MES. (2022). International Journal of Research and Applied Innovations, 5(1), 9451-9456. https://doi.org/10.15662/IJRAI.2022.0501005
[6] Abbawi, Z.W.S., 2013. Geotechnical properties of expansive soil treated with silica fume. Eng Technol J, 31(17), pp. 2458-2470.
[7] Kawther, A.S., 2018. Improvement of expansive soil by using silica fume. Kufa Journal of Engineering, 9(1), pp.222-239.