Open access Journal International Journal of Emerging Trends in Science and Technology
IC Value: 76.89 (Index Copernicus) Impact Factor: 4.219 DOI: https://dx.doi.org/10.18535/ijetst/v4i9.37

A Study on Swelling Characteristics of Black Cotton Soil by Using Sugarcane Baggage Ash and Phosphogypsum

Authors
P Siva[1], Dr. D S V Prasad[2]
[1]PG Student, Department of Civil Engineering, BVC Engineering College, Odalarevu, AP, India.
[2]Professor and Principal, Department of Civil Engineering, BVC Engineering College, Odalarevu, AP, India.

Abstract
In developing countries like India, due to remarkable development in road infrastructure , soil stabilization has become major issue in constructional activity, stabilization is not only a method of altering or modifying of one or more soil properties to improve the engineering . Characteristics and performance of a soil ,but also processing available materials for the production of low –cost design and construction

Black cotton soils which expand when moisture content of soils is increased the clay mineral montmorillonite is main responsible for expansive characteristics of soil. the expansive soils called swelling of soils or black cotton soils a large part of south India is covered with expansive soil another problem with this soil is strength is decreases with increases of degree of saturation heavy damages may occur buildings roads runways pipe lines and other structures built on such soils if proper preventive measures are not method. The damages can be prevented to an large extent if characteristics of expansive soil properly assessed suitable measures taken in design construction and maintenance of structures built on soils. This presents experimental investigation to study the effect of sugarcane baggage ash & phosphogypsum on swelling and shrinkage and mechanical properties of a soil. After finding out the experimental results in lab to know the evaluation and performance of baggage ash on the black cotton soil in the laboratory

Black cotton soil and baggage ash & phosphogypsum mixture has prepared by varying of different proportions with respect to dry the density

Keywords-*Black Cotton Soil, Sugarcane Baggage Ash (SCBA) , Phosphogypsum(PG)*

1. Introduction

In today's world due to rapid growth of urbanization and modernization leads to scarcity of land for construction. Everywhere land is being utilized for various structures from an ordinary house to sky scrapers, from bridges to airports and from village road to highways or expressway. Owing to this, construction of structures these days is being carried on land having weak or soft soil. The increasing value of land and due to limited availability of site for constriction of structures and roads are done on the land having expansive clays. The stability of structure or road depends on soil properties on which it has built. The construction can be economical if the soils is good a shallow depth below the ground surface. In this case shallow foundations such as raft foundations or footings can be used. However if the soil available on top surface is weak and strong stratum is available at greater depth foundations such as pile foundations, deep foundation, caisson and well foundations can be used. Such foundations are not economical for small structures. In some cases soil conditions are so poor even at greater depths. As the soils suitable for construction are limited, the weak soils need to be strengthened beforehand. This led to the development of various ground improvement techniques like soil stabilization, compaction and reinforcement.

Soil improvement is of major concern in the construction activities due to rapid growth of urbanization and industrialization. The term soil improvement is used for the techniques which improve the index properties and other engineering characteristic of expansive soils. Expansive soils are worldwide problematic soil which is associated with large volume change behaviour when it undergoes a change in the water content. When expansive soils are exposed to high water content, they exhibit high selling characteristics. And when the presence of low water content, then it shows low shear strength. These soils pose several problems to the structures due to their volume changes. Among those, black cotton soil is one type of expansive soils and they show high swell shrinkage behaviour owing to fluctuating water content. In India, black cotton soil covers as high as 20% of the total land area and majorly in central and south India. They are predominant in the states of Gujarat, Maharashtra, Madhya Pradesh, Andhra Pradesh, Karnataka and Tamil Nadu. These soils have high swelling and shrinkage characteristics and extremely low CBR value and shear strength. if it should be used as foundation material, Improvement of soil has need to be done by adopting various techniques like soil stabilization, reinforcement etc. One method of controlling volume changes is to stabilize the soils with admixtures that prevent volume changes are adequately modifies the volume change characteristics of soft clayey soil (KEHEW 1995)

2. Literature Review

Soils with significant plasticity it may swell and shrink actions caused due to changes in moisture content. Changes in volume it causes decreases in strength and dry density by using soil stabilization methods by adding of admixtures. Like fly ash, Phosphogypsum, Wood ash, Lime, CCR we can change the index properties black cotton soil. FA and PG are effectively used in stabilizing of soil.

The use of PG results in reduction in cement content and suggested economic stabilization technique and to use waste products effectively, Cement can be replaced by PG & FA increases the volume stability and it has max value at 5% fly ash and 6% PG

The use of PG and Wood ash these are effectively in increasing strength of weak expansive soils. The strength gained by a soil depends upon the admixtures proportions as well as Time allowed for curing. 4% PG and 12% Wood ash was found max percentage proportion of admixtures which yielded max strength of soil

Mainly study to improve the properties of a soil by adding waste material baggage ash & CCR which are the waste product of acetylene gas factories and steel plant addition to the black cotton soil. Various test investigations performed on black cotton soil using different percentages of Fly Ash at 2%, 10%, 6%, 8% & 2%, 10%, 6%, 8 % of calcium carbide residue by dry weight of soil.

Mainly studied on stabilization of soil using fly ash Extensive laboratory / field trials have been carried out by various researchers and have shown promising results for application of such expansive soil after stabilization with additives such as sand, silt, lime, fly ash, etc. As 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 uses. The present paper describes a study carried out to check the improvements in the properties of expansive soil with fly ash in varying percentages. Both laboratory trials and field tests have been carried out and results are reported in this paper.

3. Materials, Methodology

. Different types of materials used in this study are Black Cotton Soil, Sugarcane Baggage ash, Phosphogypsum and their details along with properties are explained in below sections.

a. Black Cotton Soil

The Black Cotton Soil used in this study was collected at a depth of 1 to 1.5 m from Thummalapalli Village, Allavaram Mandal, East Godavari District of Andhra Pradesh, India. The collected soil was subjected to air dried for further experimentation. And the properties of Black Cotton Soil were determined and those are detailed in Table –1

b. Sugarcane Baggage Ash

Use With the ever increasing demand and consumption of cement and in the backdrop of waste management, scientists and researchers all over the world are always in quest for developing alternate binders that are environment friendly and contribute towards sustainable management. Sugarcane baggage (SCB) which is a voluminous by-product in

the sugar mills when juice is extracted from the cane. It is, however, generally used as a fuel to fire furnaces in the same sugar mill that yields about 8-10% ashes containing high amounts of un-burnt matter, silicon, aluminum, iron and calcium oxides. But the ashes obtained directly from the mill are not reactive because of these are burnt under uncontrolled conditions and at very high temperatures. The ash, therefore, becomes an industrial waste and poses disposal problems. For obtaining amorphous and reactive sugarcane baggage ash (SCBA), several trials were conducted to define optimum burning time and temperatures. SCBA used in this study was obtained by burning SCB at 600^{0C} at 5 hours (James and Rao, 1986) under controlled conditions and its physical, chemical, and mineralogical characterization was done to evaluate the possibility of its use as binder partially replacing cement in the mortar applications.it can be shown on Fig. 1

c. Phosphogypsum

Refers to hydrate formed as a by-product of the production of fertilizer phosphate rock It is mainly composed of gypsum ($CaSO4•2H2O$). Although gypsum is a widely used material in the construction industry Phosphogypsum is usually not used, but is stored indefinitely because of its weak radioactivity the long-range storage is controversial

Phosphogypsum stand for the chemical origin gypsum generated in fertilizers production, in which phosphate rock is attacked by sulphuric acid resulting in phosphoric acid ($H3PO4$) and phosphate fertilizers, according the chemical equation represented on (1). It can be shown in Fig. 2

$Ca_{10}(PO_4)6F_2 + 10\ H_2SO_4 + 20\ H_2O \rightarrow 10\ CaSO_4.2H_2O + 6\ H_3PO_4 + 2\ HF$ → (1)

Fluor apatite Phosphogypsum

d. Methodology

Black Cotton Soil was collected and it was subjected to air dried to carry further experiments on it. The total study was carried in 3 phases.

In phase 1, preliminary tests like Specific gravity, Liquid limit, Plastic limit, differential free swell were conducted on existed soil.

In phase 2, SCBA was added to Black cotton Soil at 5%, 10%, 15% and 20%. Modified Compaction Test was conducted to these samples and OMC, MDD were obtained. Maximum values are obtained for the proportion having 10% SCBA.

In phase 3, at 10% SCBA, PG was added by 0%, 2%, 4%, 6% and 8% in random inclusion manner. Total 6 samples were prepared and those are presented in Table – 2. Several tests like, Modified Compaction, CBR, UCS and Consolidation were carried on these samples.

4. Testing Methods

In order to determine the effect of SCBA and PG in Black Cotton Soil, different tests were conducted on the samples which were mentioned in Table – 1. And the testing procedure followed is explained in below sections.

a. Index Properties:

Liquid Limit, Plastic Limit, Specific Gravity, and Differential Free Swell (DFS) tests were carried on collected soil by following IS standard procedures. IS: 2720 - Part 5 (1985) was used to determine the Liquid and Plastic limits. By using these and plasticity chart, the type of soil was classified. Pycnometer method described in IS: 2720 – Part 3 (1980) was used to determine the Specific gravity. DFS was measured as per IS 2720 – Part 11 (1977).

b. Compaction Characteristics*:*

The Compaction Characteristics of soil samples with different percentages of SCBA and PG were determined by using Modified (Heavy) Compaction method as per IS: 2720 – Part 8 (1983). By using this test, the relationship between the OMC and MDD for different samples was evaluated.

c. California Bearing Ratio:

The standard procedure mentioned in IS: 2720 – Part 16 (1979) was followed to determine the CBR value. The CBR test was conducted on Black Cotton Soil with different percentages of SCBA and PG in both Unsoaked and Soaked conditions. In order to calculate the soaked CBR, sample was immersed in water for 96hrs.

d. Unconfined Compressive Strength:

UCS Test was carried on cylindrical soil samples with different percentages of SCBA and PG Split Mould was used to prepare the sample, and test was conducted on samples as per IS: 2720 – Part 10 (1991). UCS was

calculated on samples at 0, 3, 7, 14, 28 days curing periods

e. Consolidation Characteristics*:*

Consolidation Characteristics of soil samples were determined as per IS: 2720 – Part 15 (1986). The pressure applied on consolidometer assembly are 0.1, 0.2, 0.4, 0.8, 1.6 kg/cm^2. From this test, Coefficient of Compressibility (a_v), Compression Index (C_c) and Coefficient of Volume Change (m_v) were calculated and their variation with different percentages of SCBA and PG in black cotton soil was analysed.

The above mentioned tests were carried on different types of soil samples (as mentioned in Table – 2) and their test results were presented in below section.

5. RESULTS AND DISCUSSIONS

a. Index Properties:

The basic index properties of collected soil are, Liquid Limit is 52%, Plastic Limit is 25.15% and Plasticity Index is 26.85%. Based on these, the soil was classified as CH (Clay with High Plasticity). Specific gravity obtained is 2.67. And Differential Free Swell is 50%. From DFS, the soil was classified as High Expansive Soil.

b. Compaction Characteristics:

The MDD and OMC obtained for untreated soil are 20% and 1.50g/cc. OMC was increased with the addition of PG. The variation of OMC and MDD with different percentages of SCBA and PG was shown in Chart – 1.

c. California Bearing Ratio:

The variation of Load with Penetration graphs for Black Cotton Soil along with different percentages of SCBA and PG in both Unsoaked and soaked condition were shown in Chart – 2 and Chart – 3 respectively

d. Unconfined Compressive Strength:

UCS at 0, 3, 7, 14, and 28 days curing periods was calculated. And the variation of UCS with Curing Days was shown in Chart – 5. The UCS values are increased when SCBA and PG were added to Black Cotton Soil. 0, 3, 7, 14 and 28 days.

e. Consolidation Characteristics:

Total 3 coefficients, Coefficient of Compressibility (a_v), Compression Index (C_C) and Coefficient of Volume Change (m_v) are calculated from consolidation test and the values re resulted and their variation with different percentages of SCBA and PG are shown in Chart – 6, Chart – 7 and Chart – 8. When compared with black cotton soil, all three coefficients were decreased i.e., Consolidation characteristics were improved when SCBA and PG were added to Black Cotton Soil. The Sample Type mentioned in below graphs is as per samples represented in Table – 2.

f. Figures, Tables and Graphs

Fig. 1 Sugar Cane Baggage Ash

Fig. 2 Phosphogypsum

TABLE 1 INDEX PROPERTIES OF BLACK COTTON SOIL

Characteristics	Value
Color	Black

Specific Gravity	2.67
Liquid Limit (%)	52
Plastic Limit (%)	25.15
Plasticity Index (%)	26.85
Classification	CH
Optimum Moisture Content (%)	20
Maximum Dry Density (g/cc)	1.58
Unsoaked CBR	2.2
Soaked CBR	1.4
Unconfined Compressive Strength (kg/cm^2)	0.9
Differential Free Swell (%)	50
Coefficient of Compressibility (cm^2/kg)	0.039
Compression Index (cm^2/kg)	0.051
Coefficient of Volume Change (cm^2/kg)	0.025

TABLE 2 TYPES OF SAMPLES PREPARED AND TESTED

Notation	Sample
BC	Black Cotton Soil
SCBA10-PG0	BC + 10%SCBA
SCBA10 –PG 2	BC + 10%SCBA+2%PG
SCBA10-PG 4	BC + 10%SCBA+10%PG
SCBA10-PG 6	BC +10%SCBA+6%PG
SCBA10-PG 8	BC+10%SCBA+8% PG

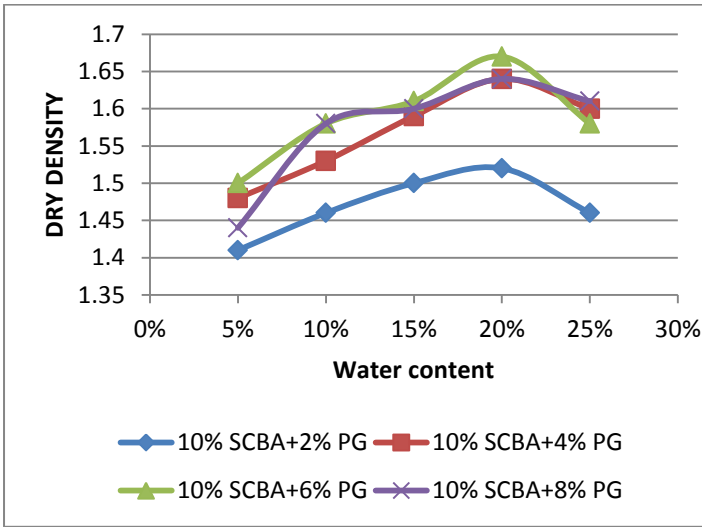

Chart 1: Compaction Curves

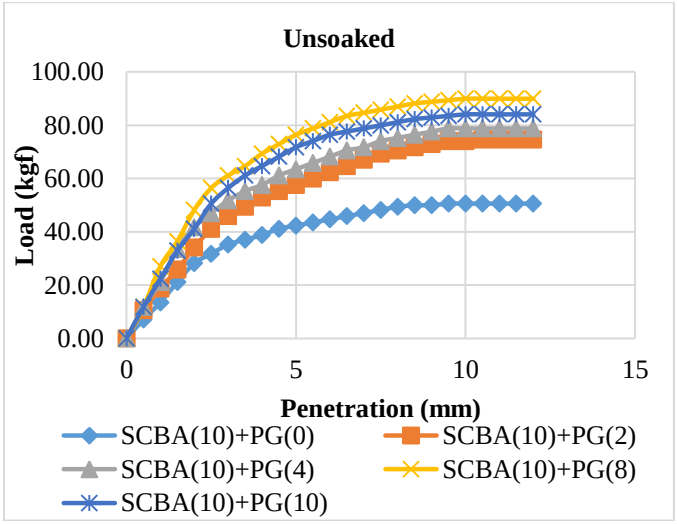

Chart 2: Load Vs Penetration graphs of Unsoaked CBR at different percentages of SCBA & PG

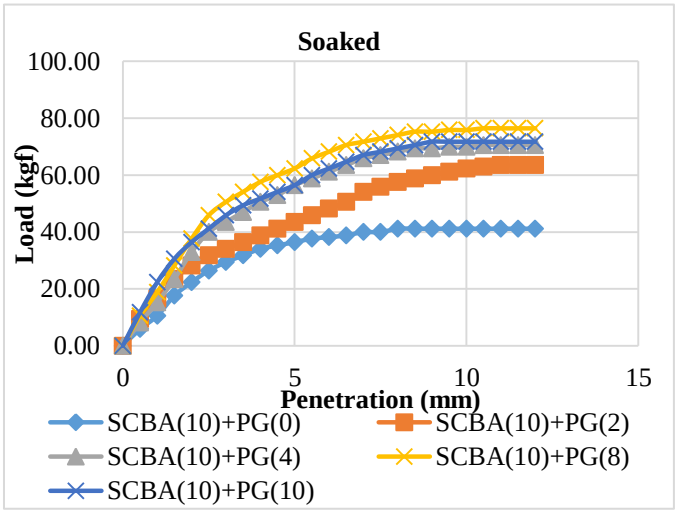

Chart 3: Load Vs Penetration graphs of Soaked CBR at different percentages of SCBA & PG

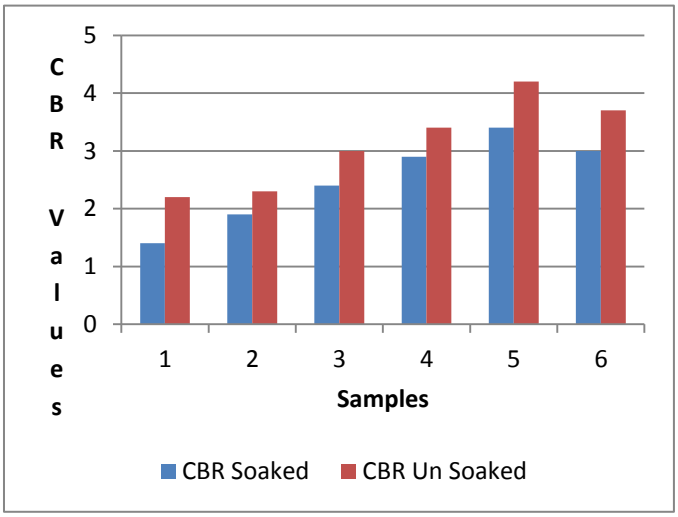

Chart 4: Unsoaked and Soaked CBR values at different percentages of PG & SCGBA

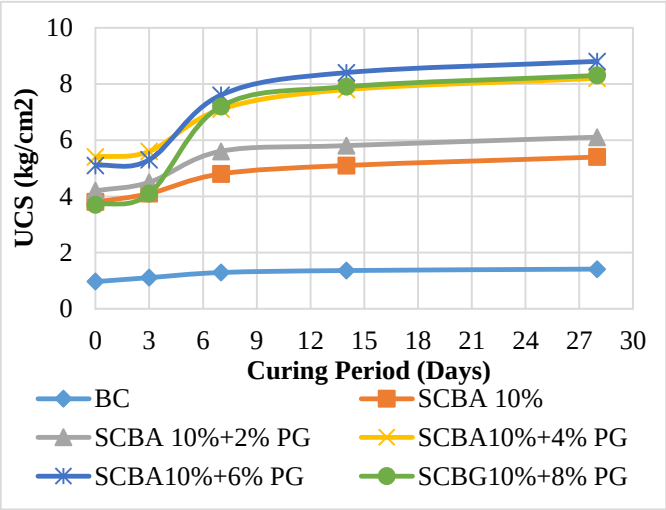

Chart 5: Variation of UCS at different curing periods

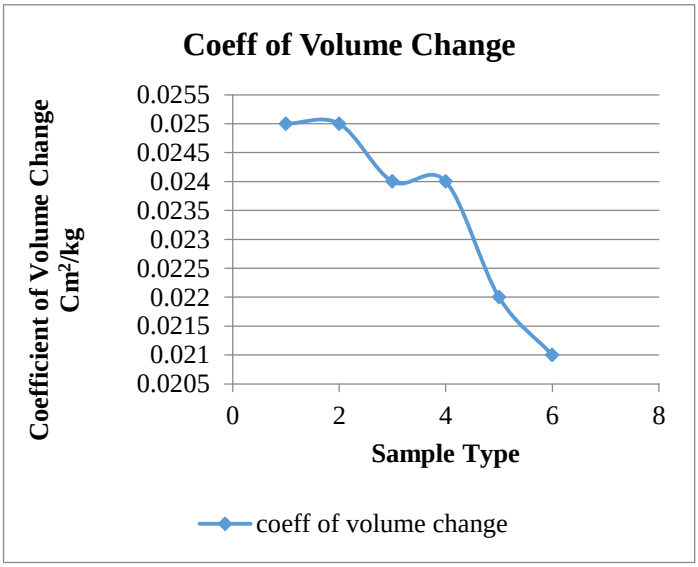

Chart 6: variation of coefficient of volume change with diff prop of SCBA& PG%

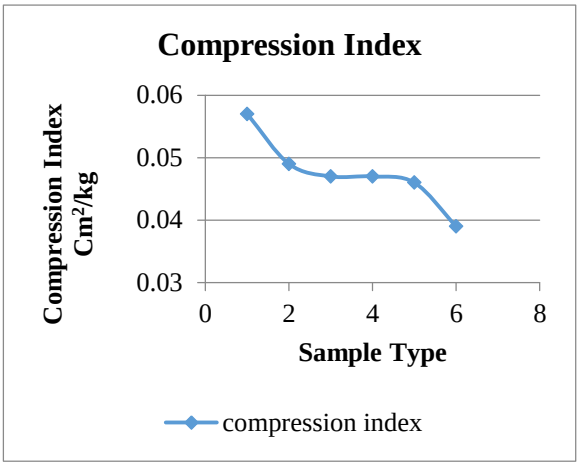

Chart 6: variation of compression index with diff prop of SCBA& PG%

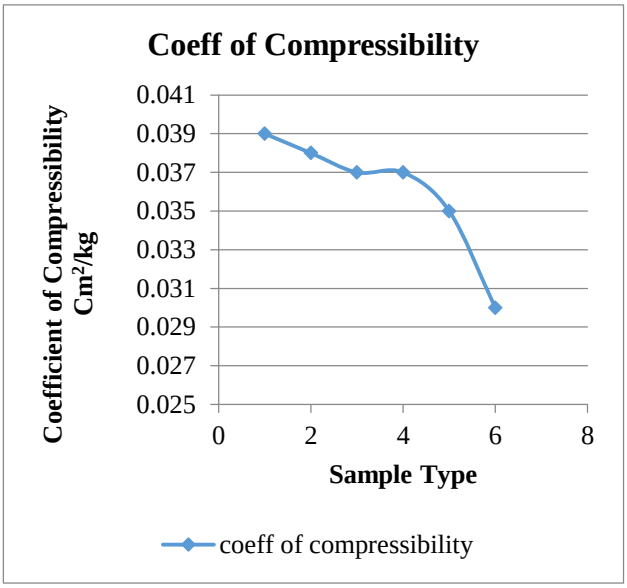

Chart 7: variation of coefficient of compressibility with diff prop of SCBA& PG%

Conclusions:

In this study, the major properties studied are OMC, MDD, CBR, UCS, and Consolidation. Based on the all investigations on all samples and when compared with normal soil, following conclusions were made

Compaction Test and CBR Test:

- Maximum dry density was increased with the addition of PG and SCBA
- When 5%,10%,15%,20% SCBA added, higher MDD observed for 10% of SCBA addition
- When PG added, MDD value was increased.
- Both the Unsoaked and soaked condition of CBR were studied and Peak value was obtained at 6% PG addition in both conditions.
- From 0 to 6% addition of PG, CBR value was gradually increased in both unsoaked and soaked condition.
- But, CBR value was decreased after 6% of PG addition (i.e., at 8%)

Unconfined compressive strength:

- UCS was calculated for 0, 3, 7, 14, 28 curing days.
- UCS values are gradually increased 0, 3, 7, 28 curing days for respective addition of PG and SCBA
- The Curing period of mix is a governing parameter as the chemical reaction of stabilizers is depends on it.so it can be

concluded that the strength will increase with increase in curing period.

- UCS of treated soils was higher than that of untreated soils.
- UCS value of sample is Increased from 0.97 to 8.8 kg/cm^2

Consolidation Characteristics:

Coefficient of Compressibility, Compression index, Coefficient of Volume change were calculated for all samples. And observed that, there is a decrement in all coefficients with addition of PG and SCBA. i.e., consolidation characteristics are improved through the addition of these additives.

- Addition of combination of PG with SCBA makes the soil mixes durable, low cost and effective for soil stabilization.
- DFS is greater than 35%, its expansiveness should be considered
- As per Holtz (1969) classified expansive soils based on clay content, based on plasticity Index (%) Swelling potential becomes "Medium"
- As per Chen (1988) classified on expansive soils based on plasticity index (%) Based on plasticity Index (%) Swelling potential becomes "High"

Compression Index (C_C) generally varies from 0.3 to 0.075 for clays we get the value of 0.043 that means "Low plastic clayey soil"

References

1. "Experimental Study on Stabilization of Black Cotton Soil by Fly Ash, Coconut Coir Fiber & Crushed Glass" by Amit Tiwan, H.K. Mahiyar, International Journal of Emerging Technology and Advanced Engineering – IJETAE, ISSN 2250-2459, Volume 4, Issue 11, November 2014, pg.330-333.
2. "Effect on Strength Characteristics of Expansive Soil Using Sisal Fibre and Waste Materials" by Amrutha Mathew, Dr.Raneesh.K.Y, International Journal of Science and Research – IJSR, ISSN: 2319-7064, Volume 5, Issue 9, September 2016, pg.1702-1707.
3. "Compressibility Behavior of Black Cotton Soil Admixed with Lime and Rice Husk Ash" by Dr. A. V. Narasimha rao, B. Penchalaiah, Dr.M. Chittranajan, Dr. P. Ramesh, International Journal of Innovative Research in Science, Engineering and Technology – IJIRSET, ISSN: 2319 – 8753, Volume 3, Issue 4, April 2014, pg. 11473 – 11480
4. "Consolidation Characteristics of Fly Ash and Lime Treated Black Cotton Soil" by Vijayakumar Sureban, Proc. Of International Conference on Recent Trends in Transportation, Environmental and Civil Engineering - TECE, 201, pg. 49 – 52.
5. Soil Stabilization by using Phospogypsum & Fly ash .Divavya Krishnan, V.Jannani, P.T.Ravichandran, R.Annadurai, Manisha gunturi - International journal of engineering trends and technology – volume 9 Nov 14-mar 14
6. "Experimental study on black cotton soil with calcium carbide residue & baggage ash" Neeraj kumrawat , S.K. ahirwar international journal of engineering sciences & management . ISNN : 2277- 5528
7. "Experimental study on strength behaviour of expansive soil treated with Phospogypsum and Wood ash"Roshini R, Divvya Krishnan K , P.T. Ravichandran) (International journal of Science & Research)
8. "Foundation on expansive soils" chen FH(1988) Elsevier sciences publishing company,NEWYORK
9. "Engineering properties of expansive clays"HOLTZ, WG and GIBBS,HJ ,TransASCE121
10. "Volumetric changes in expansive clay soils and control by lime Treatment," Holtz, WG,(1969) second international Research and engineering conferences on expansive clay soils,PP157-173,Texas A& M Press
11. "Consolidation Characteristics of Fly Ash and Lime Treated Black Cotton Soil"by Vijayakumar Sureban, Proc. Of International Conference on Recent Trends in Transportation, Environmental and Civil Engineering - TECE, 201, pg. 49 – 52
12. "Compressibility Behaviour of Black Cotton Soil Admixed with Lime and SAW dust Ash" by C.C.ikeagwuani ,Nigerian journal of technology vol 35, no 4 oct 2016
13. Compressibility Behaviour of Black Cotton Soil Admixed with Lime and Rice husk Ash

"by A.O. eberemu, H.sada ,Nigerian journal of technology vol 32, no 3 nov 2013

14. S.Srikanth. Swapan,k das" nature of fire side deposits in a baggage and ground nut shell ash",volume74
15. Is 2720 (part 8-1980),Indian standard, methods for test for soils" part 8,determination of water content dry density relation using heavy compaction.
16. Stabilization of expansive soils using fly ash S. Bhuvaneshwari R. G. Robinson S. R. Gandhi
17. Phosphogypsum analysis: total content and extractable element concentrations Roseli F.Gennari1, Isabella Garcia, Nilberto H. Medina, Marcilei A.G .Silveira 2011 International Nuclear Atlantic Conference - Inac 2011 Belo Horizonte, MG, Brazil, October 24-28 Cm^2/kg