*IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*
*e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 15, Issue 3 Ver. II (May. - June. 2018), PP 43-51*
*www.iosrjournals.org*

# Improvisation ofGeotechnical Properties ofBlack Cotton Soils withGranite Waste - An Environmental Approach

K.Anupama[1]K.Sai Kumar[2] A.Srinivas[3] Anjaneyula[4]AndDr.R.S.N.Sastry[5]
*1,2,3,4: B.Tech. final, Dept. of Civil Engineering, Anurag Group of Institutions,Venkatapur, GhatkesarMandal, Rangareddy District.*
*5: Professor of Enginering Geology, Anurag Group of Institutions,Venkatapur, GhatkesarMandal, RangareddyDistrict.Telangana*
*Corresponding Author:K.Anupama*

***Abstract:*** *Black cotton (BC)soils are known to be potential expansive soils. Pedagogicalclassification as Vertisols is used for long time in agricultural and engineering research in India and other countries. The BC soils are considered problematic and sometimes as natural potential hazard be as they result in extensive damage to civil structures because of excessive seasonal volumetric variations (swelling and shrinkage). The widespread ubiquitous black cotton soils around the world and their geotechnical challenges to structures require a clear knowledge of their peculiar properties to enable effective utilization of BC soils by suitable alterations for engineering purposes. In this context we made a small attempt in stabilization of black cotton soils with natural granite waste powder obtained from the building stones industry. We have chosen this topic to safeguard the environment by using natural material for stabilization of the expansive soils. The results regarding engineering and index properties of the BC soils are encouraging. We also propose to undertake the further research in this regard to experiment with various size fractions of the granite powder.*

***Key words**: Black Cotton (BC) soils, Engineering and Index properties, Granite Powder, Mineralogy, Montimorillonite Weathering**.***

---

Date of Submission:14-05-2018 Date of acceptance: 30-05-2018

---

## I. Introduction

The knowledge of geology, weathering, mineralogical and chemical composition is pre requisite for any researcher dealing with geotechnical research apart from civil engineering knowledge. Soil is a weathered product of rock. Soil is classified on the basis of grain size and color. The clay and silt particles are having lowest size fractions. The black cotton soils are black containing different clay mineral.. Black cotton soils are problematic soils of some tropical countries especially in Africa and India. They are poor materials by temperate zone standards and difficult to use for road and air field construction because they are often expansive due to the presence of large percentages of expansive clay minerals, i.e. montimorillonite. The soil deposits are usually extensive making it impossible to avoid or by pass during construction of engineering projects. Katti et al., (2002) reported that the black cotton soil deposits are formed under conditions where the slope of the terrain is less than $3^o$

According to Gidigasu& and Gawu, (2013) black cotton soils and other expansive soils have typical characteristics of shrinkage and swelling due to moisture movement through them. During rainy season, moisture penetrates into the soils, resulting in expansion. Most of the fine grained clays, including black cotton soils have their grains which are more or less in the form of platelets or sheets (just like leafs of a book), and their grains are not round. When moisture enters between the platelets under some hydrostatic pressure, the particles separate out, resulting in increase in the volume. This increase in volume is commonly known as swelling. If this swelling is checked or restricted (due to the construction of footings over it), high swelling pressure, acting in the upward direction, will be induced. This would result in severe cracks in the walls etc. and may sometimes damage the structural units, such as lintels, beams slabs etc. During summer season, moisture moves out of the soil and consequently, the soil shrinks. Shrinkage cracks are formed on the ground surface. These shrinkage cracks sometimes also known as tension cracks, may be 10 to 15 cm wide on the ground surface and may be ½ to 2 m deep.Many roads and foundations of light buildings have been reported distressed due to the seasonal volume change (i.e. swell and shrinkage) of these soils (Chen, 1988).

Black cotton soils (vertisols) have been reported all over the world and have been found to occupy about 2% (257 million hectares) of the total ice-free land area of the earth with 72million hectares occurring in India. In Soil Mechanics, if particle size of clay is less than 2 microns with plasticity will absorb water, and shrinks on withdrawal of water based on the mineralogical properties of the clay.

The important clay minerals in problematic soils are Kaolinite, Illite and Montimorillonite. Kaolinite Clays are more stable, Montimorillonite soils are highly expansive/ swelling clays, illitic clays possess characters between Kaolinite and Montimorillonite.

Clays having angle of internal friction Ø = 0, the depth z of tension cracks is found to be equal 2c/y, where c is the unit cohesion y is the unit weight of the soil. These cracks result in loss of support beneath the footings, resulting in high settlements. Some expansive and shrinkable soils stick to the footing base and pull the footing down when they shrink. This results in horizontal cracks in the walls and other flexible units of the structure.

Black cotton soils and other expansive soils are dangerous due to their shrinkage and swelling characteristics. In addition, these soils have very poor bearing capacity, ranging from $5t/m^2$ to $10t/m^2$. In designing footings on these soils, the following points should be kept in mind:

1. Estimation of safe bearing capacity based on the depth of the unweathered bed rock, w.r.t. the effect of sustained load. The continuous load results in slow consolidation. In absence of tests, the bearing capacity of these soils may be limited to 5 to 10t/m2.
2. The foundation to be placed minimum 50 cm lower than the depth of moisture movement (i.e. Just above the fresh bed rock and below the tension cracks).
3. If the thickness of black cotton soil layer is not more than1 to 1.5 m, the entire soil should be removed, and foundation should be laid.
4. If the soil depth is more, the contact between foundation or footing and soil should be prevented by wider and deeper excavationfor foundation trench below the footing till we reach unweathered rock formation.
5. Highly expansive soils should have minimum contact between the footing and soil by transmitting the loads through deep piles or piers. Supporting wall loads on capping beams, with 5 to 15 cmgap above the ground surface, gives scope for free expansion of the soil.
6. If the soil is very soft and having poor bearing capacity, the bed of the foundation trench to be hard and compact, ramming in completely weathered rock, and ballast is required.
7. The foundations to be laid during dry season with suitable plinth protection around the external wall on the ground surface with outward slope to avoid water reaching foundation.

### 1.1 Mineralogy of Black Cotton Soils

The mineralogy, chemical components and organic matter of Black cotton soil are given in table- 1

**Table 1.The Mineralogy, Chemical components and Organic Matter of BC soils**

| Clay minerals | Chemical Components | organic matter |
|---|---|---|
| Montimorillonite | iron oxide | Humus |
| Illite | calcium carbonate (in the form of kankars) | |
| Kaolinite | Magnesium carbonates | |
| | Alumina, Potash, Phosphates, Nitrogen | |

Montimorillonite is the predominant mineral of Black cotton soils. The swelling and shrinkage behavior of black cotton soil originate mainly from this mineral are hydrous silicates of aluminum and magnesium. They are made of sheets of silica (tetrahedral) and alumina (octahedral) stacked on above the other forming sheet like of flaky particle. Montimorillonite has a three sheeted structure (Fig 1.) with expanding lattices(Gidigasu&Gawu, 2014). The structure carries negative charge, due to isomorphic substitution of some aluminum ions by magnesium ions and minerals becomes chemically active. The structure of Kaolinite, illite, smectite is given in the fig.2. The chemical composition of BC soils is given in table -2.

**Table 2. Chemical composition of black cotton soils from India (1. Kattiet. al., 2002; T – Top soil)**

| Major Oxides | Concentration Weight % | Major Oxides | Concentration Weight % |
|---|---|---|---|
| $SiO_2$ | 49.3 | CaO | 6.9 |
| $TiO_2$ | 1.9 | $Na_2O$ | --- |
| $Al_2O_3$ | 13.7 | $K_2O$ | --- |
| $Fe_2O_3$ | 14.8 | $P_2O_5$ | --- |
| MnO | 0.13 | $SO_3$ | 1.6 |
| MgO | 4.00 | | |

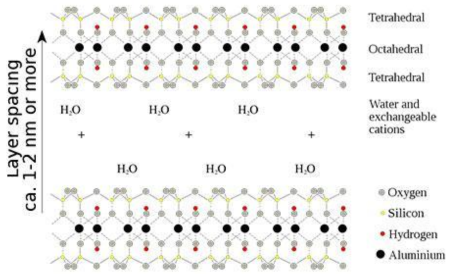


**Fig.1. Montmorillonite structure (After Gidigasu&Gawu, 2014)**

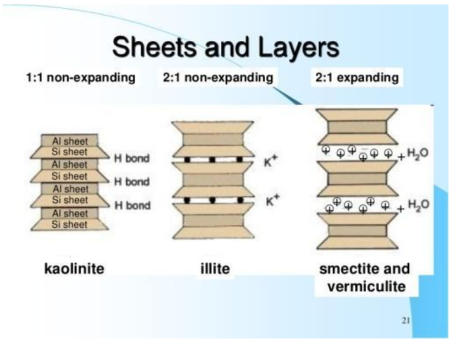


**Fig.1.1. Kaolinite, Illite and Smectite and vermiculite structures(After Gidigasu&Gawu, 2014)**

### 1.2 Parent material and weathering

Black cotton soils have been identified on igneous, sedimentary and metamorphic rocks. They are formed mainly by the chemical weathering of mafic (basic) igneous rocks such as basalt, norite, andesites, diabases, dolerites, gabbros and volcanic rocks and their metamorphic derivatives (e.g. gneisses) which are made up calcium rich feldspars and dark minerals which are high in the weathering order, in poorly drained areas with well-defined wet and dry seasons. All constituents weather to form amorphous hydrous oxides and under suitable conditions clay minerals develop. The absence of quartz leads to the formation of fine grained, mostly clay size, plastic soils which are highly impermeable and easily becomes waterlogged. In addition abundant magnesium and calcium present in the rock adds to the possibility of formation of black cotton soil with its attendant swelling problem (Ola, 1983). The black cotton soils have also formed over sedimentary materials such as shale, limestone, slates etc. (Ahmad 1983) found that although the parent materials are diverse, one striking feature which is common to all is the fact that the parent materials are rich in feldspar and ferromagnesian minerals which yield clay residue on weathering. He also noted that where the parent rock is not mafic (basic), alkali earth elements can be added through seepage or by flooding waters.

According to Gidigasu&Gawu (2014) Weathering is a pedogenic process by which soils are formed as a result of disintegration or decomposition of rocks. This process causes changes in rocks at and near the earth's surface by interaction between the rocks and the chemically active components of the earth's atmosphere, principally water, carbon dioxide and oxygen. The effects of weathering extend below the earth's surface by ground-water movement through or around grains or along joints and fissures. The depth of weathering is largely controlled by topography and the availability of channels of flow for surface water. In some regions where climatic, topographic, and structural conditions are appropriate, weathering caused by circulation of groundwater of surface origin extends tens to hundreds of meters underground and causes notable changes in originally fresh rocks.

### 1.3. Stabilization of soils

According to Githaiga Esther Nyakarura (2009), Removal of large volumes of unsatisfactory soils and replace them with suitable material is expensive. Hence it is inevitable to improve the soil. The improvement of the stability or bearing power of a poor soil and durability which are related to performance of the soil through mechanical, physico-mechanical and chemical methods is referred to as soil stabilization. This is achieved by use of controlled compaction, proportioning and addition of suitable admixture or stabilizer. The stabilization process involves excavation of the in-situ soil, treatment of the in-situ soil and compaction of the treated soil. Increase in strength is expressed quantitatively in terms of: Adsorption, softening and reduction in strength; Direct resistance to freezing and thawing; Compressive strength, shearing strength or measure of load deflection to indicate the load bearing quality

Stabilization process is ideal for improvement of soils in shallow depth such as pavements and light weight structures as the process essentially involve excavation of the in-situ soil. The most common type of stabilization are (Brijesh Mishra, 2015) Lime, Cement, Bitumen, Salt, Chemical stabilisation. However there are other methods of stabilization by using different types of waste materials.

Stabilsation of soils can be done in many ways. But the authors wanted to stabilize to safeguard the environment by using natural material for stabilization of the expansive soils. Many natural materials are available for stabilization. As the granite powder is easily available for us at low cost we have selected granite powder for stabilization. About 3000 metric ton of granite waste is produced per day as a by-product during manufacturing of granite tiles and slabs from the raw blocks. The granite cutting industries are dumping these wastes in nearby pits or open lands. This leads to serious environmental pollution and occupation of vast area of land. The cost of granite powder is about 375 rupees for metric ton. By using this granite powder for soil stabilization will be more economical and also environmental pollution decreases.

**Soil Stabilization Benefits (MIDWEST 2018): The following are the benefits of soil stabilization.**
- Improve the mechanical qualities of local road construction soils
- Increase loading capacity (CBR)
- Improve structural integrity
- Reduce harmful moisture penetration
- Provide longer economic life of the roadbed
- Reduce maintenance costs
- Lower road construction costs

### 1.4. Problem Associated with Black Cotton (B. C.) Soil

The peculiar nature of Black Cotton soils are challenge for engineers all over the world, and also in tropical countries like India because of wide variation in temperature and distinct dry and wet seasons, leading to wide variations in moisture content of soil. The following problems generally occur in black cotton soil – High Compressibility: Black Cotton soils are highly plastic and compressible, when they are saturated. Footing, resting on such soils under goes consolidation settlements of high magnitude. Swelling: A structure built in a dry season, when the natural water content is low shows differential movement as result of soils during subsequent wet season. This causes structures supported by such swelling soils to lift up and crack. Restrictions on developed swelling pressures making the structure suitable. Shrinkage: A structure built at the end of the wet season when the natural water content is high, shows settlement and shrinkage cracks during subsequent dry season.

### 1.5. Engineering Properties of B. C. Soil

The primary engineering properties of soil are permeability, plasticity, compaction, compressibility and shear strength.
Permeability, Plasticity, Compaction, Compressibility
Shear Strength.

### 1.5. Index Properties of B. C. Soil

The index properties of soil indicate engineering properties such as

i. Particle Size Analysis (Sieving)
ii. Specific Gravity
iii. Pycnometer (Density)
iv. Atterberg's limits
a. Liquid limit
b. Plastic limit
c. Plasticity Index
d. Shrinkage Index

## II. Materials and Methods

The different materials used for testing stabilization of black cotton soils with waste granite powder are Black Cotton soil, Granite powder, Kerosene and water. The tests performed on respective equipment are Consistency limits, Compaction test, Vane shear test, California Bearing ratio test, Differential free swell, Unconfined compression strength and Specific gravity.

**2.1. Soil Source& material**

Black Cotton Soil: The soil sample for the present investigations was collected from Venkatapur village, GhatkesarMandal, Hyderabad in India. About 45 Kg. of black cotton soil is used for conducting various experiments.

Granite Powder: Waste Granite powder generated was brought from Korremula village granite cutting shop, situated near Venkatapur village.Standard methods have been followed for conducting the geotechnical tests in the laboratories of Civil Engineering Dept. laboratories, Anurag Group of Institutions, Venkatapur.

## III. Results and Discussion

The standard limits of the test parameters

Consistency Limits as per the IS 2720 part - 4 (1970) given as follows:

1. For clayey soil liquid limit is in range from 68.04% to 39.24%.
2. After stabilization of black cotton soil liquid limit and plasticity should be less than 45%.

For proctor test, according to IS 2720 part-7(1974)

1. Maximum dry density > 1.76 for any type of soil.
2. Optimum moisture content in compaction test is used in finding CBR value.

For CBR test, according to IS 2720 part- 16 (1971)

1. Value of CBR should greater than or equal to 2%
2. The standard loads for 2.5mm and 5mm are 1370 Kgs and 2055Kgs.

CBR value is used in sub grade improvement during embankment construction

The following tests have been conducted on the mixed proportions varying from 0% to 30% of granite powder with black cotton soil

a. Consistency limits,
b. Proctor test,
c. CBR test,
d. Vane shear test,
e. Unconfined compression strength test,
f. Differential free swell test,
g. Specific gravity test and The results are tabulated and plotted on graph paper is as follows
h.

**3.1Liquid limit result analysis**

Combining all liquid limit values for all the mix proportions of black cotton soil and granite powder from 0% to 30% by taking replacement percentages of granite powder in X-axis and liquid limit values in Y-axis have been plotted (Fig1.2.) as follows.

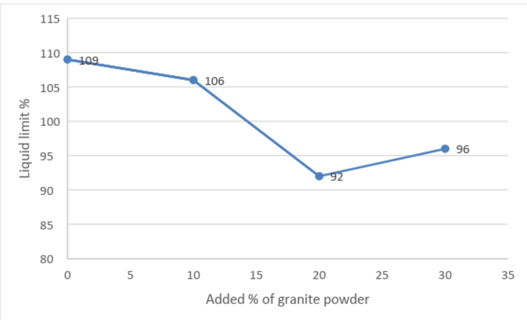


**Fig 1.2. The behavior of liquid limit as granite % increases**

The results show that the optimum Liquid limit value is obtained at 20% granite powder and 80% black cotton soil mixed proportions.

**3.2 Plastic Limit Result Analysis**

Combining all Plastic limit values for all the mix proportions of black cotton soil and granite powder from 0% to 30% by taking replacement percentages of granite powder in X-axis and liquid limit values in Y-axis have been plotted (Fig.1.3.) as follows

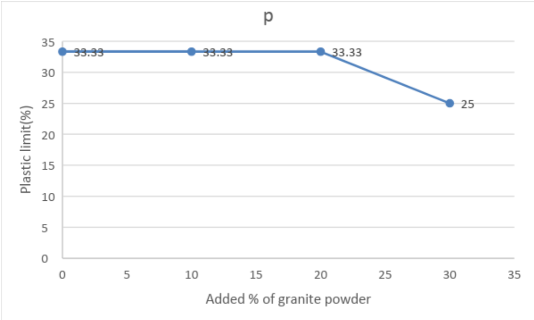


**Fig 1.3. The behavior of plastic limit as granite % increases**

The results show that the optimum Plastic limit value is obtained at 20% granite powder and 80% black cotton soil mixed proportions.

**3.3 Proctor test result analysis**

Proctor test the values of dry density is known from oven dry of the sample. Optimum moisture content is determined from graph (Fig 1.4.) by taking water percent added on X-axis and dry density on Y-axis

It was noted that dry density value is high for 90% black cotton soil + 10% granite powder compared to remaining mix proportions. The value of maximum dry density is 1.735 g/cc.

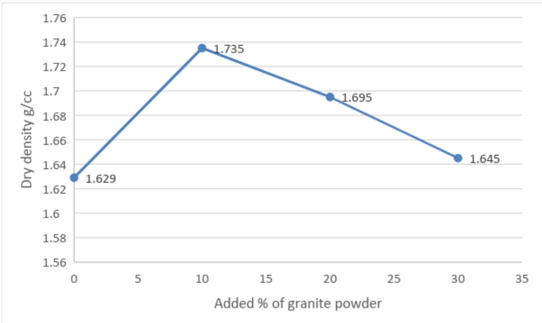


**Fig 1.4. The behavior of Dry density as granite % increases.**

**3.4 Vane shear test result analysis**

Shear strength test was conducted for different mix proportions from 0% to 30% granite powder and black cotton soil, by knowing angle of torque from vane shear apparatus and results are tabulated in table-3.

**Table 3. Vane shear test results showing shear strength as per granite powder % increases**

| Mix proportions of granite powder | Angle torque $\Theta = \Theta_2 \sim \Theta_1$ | Torque (T) T = Θ x K180(KN-m) | Shear strength C (Kg/cm$^2$) |
|---|---|---|---|
| 0% | 6 | 0.004 | 2.133 x $10^{-5}$ |
| 10% | 7 | 0.0047 | 2.49 x $10^{-5}$ |
| 20% | 13 | 0.0087 | 4.62 x $10^{-5}$ |
| 30% | 14 | 0.009 | 4.975 x $10^{-5}$ |

Values of shear strength from angle of torque by vane shear Apparatus for mix proportions of 0% to 30% granite powder and black cotton soil, indicating shear strength increases from 0% to 30% mix proportions of granite to black cotton soil.

**3.5 California bearing ratio (CBR) test result analysis**

CBR values for are determined for different mix proportions of granite powder (0% to 20%) and black cotton soil and results are tabulated in table-4. In all replacing percentages 2.5mm penetration CBR value is greater than 5mm penetration CBR value.

Variation of penetration and load values of replacing granite powder by different percentages in black cottonsoil. It was observed that from 0% to 10% mix proportions of granite powder the California bearing ratios are increasing while for the adding of granite powder about 20% the California bearing ratio was decreased. This variation was shown in graph by taking penetration in X-axis and load in Y- axis

**Table 1.2. CBR test values as per granite powder % variation**

| Mix proportions of granite powder | Load | | CBR values | |
|---|---|---|---|---|
| | penetration of 2.5 mm | penetration of 5.00 mm | penetration of 2.5 mm | penetration of 5.00 mm |
| 0% | 8.6 | 12.9 | 5.963 | 5.963 |
| 5% | 10.2 | 14.6 | 7.07 | 6.749 |
| 10% | 14.6 | 21 | 10.12 | 9.708 |
| 20% | 11 | 16.1 | 7.627 | 7.443 |

**3.6 Unconfined compressive strength test**

Unconfined shear strength test was conducted for different mix proportions from 0% to 30% granite powder and black cotton soil, by knowing compressive stress at different loads from unconfined compression strength test apparatus.

Unconfined compression strength values for different mix proportions of granite powder and black cotton soil are show in the above graph (Fig 1.5.). This also indicates that unconfinedcompression strength increases from granite 0% to 30% mix proportions with black cotton soil.

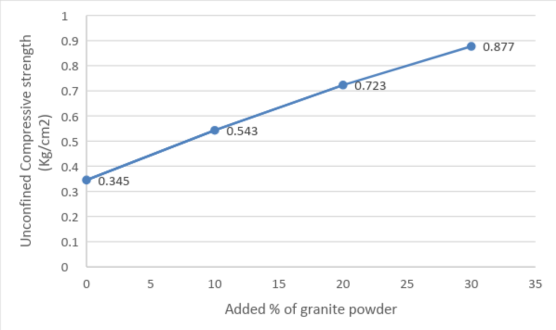


**Fig 1.5. The behavior of Compressive Strength as granite % increases.**

**3.7 Specific gravity test**

Specific gravity test was conducted for different mix proportions of granite from 0% to 30% with black cotton soil, by Pycnometer and results are plotted in a graph

The values of free swell index for mix proportions of 0% to 30% granite powder and black cotton. This also indicating that free swell index decreases from 0% to 30% mix proportions. (Fig 1.6.)

The values of specific gravity for mix proportions of 0% to 30% of granite powder with black cotton soil by Pycnometer. This also indicating that specific gravity increases from 0% to 30% mix proportions

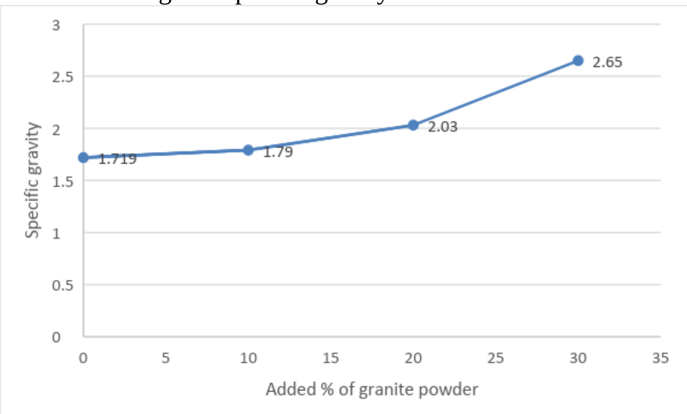


**Fig 1.6. The behavior of Specific Gravity as granite % increases.**

**3.8 Differential free swell test (DFST)**

Free swell index, this test was conducted for different mix proportions from 0% to 30% granite powder and black cotton soil and the results are tabulated in the table-1.4.

**Table 1.4. Free swell index values as per variation in granite powder %**

| S.NO | % of Additive | Swell index (soil +water) % | Swell index (soil+ kerosene) % |
|---|---|---|---|
| 1. | 0 | 66.6 | 11.11 |
| 2. | 10% | 22.22 | 0 |
| 3. | 20% | 20 | 0 |
| 4. | 30% | 18.18 | 0 |

**Table 1.5. Results of 0 % to 30 % black cotton soil and Granite powder proportions**

| Name of Test performed | 100%BC+ 0%GP | 90%BC+ 10%GP | 80%BC+ 20%GP | 70%BC+ 30%GP |
|---|---|---|---|---|
| Liquid limit | 109% | 106% | 92% | 96% |
| Plastic limit | 33.33% | 33.33% | 33.33% | 25% |
| Proctor test | 1.629g/cc | 1.735g/cc | 1.695g/cc | 1.645g/cc |
| Vane shear test | $2.133x10^{-5}$ $Kg/cm^2$ | $2.49x10^{-5}$ $Kg/cm^2$ | $4.62x\ 10^{-5}$ $Kg/cm^2$ | $4.975\ x\ 10^{-5}$ $Kg/cm^2$ |
| Unconfined compression test | 0.345 $Kg/cm^2$ | 0.543 $Kg/cm^2$ | 0.723 $Kg/cm^2$ | 0.877 $Kg/cm^2$ |
| Specific gravity | 1.719 | 1.79 | 2.03 | 2.65 |
| DFST (Soil+ water) | 66.66% | 22.22% | 20% | 18.18% |
| DFST (Soil+ kerosene) | 11.11% | 0% | 0% | 0% |

BC = Black Cotton Soil; GP = Granite Powder

**Table 1.6. Results of 0 % to 20 % black cotton soil and Granite powder proportions**

| Name of Test performed | 100%BC+ 0%GP | 95%BC+ 5%GP | 90%BC+ 10%GP | 80%BC+ 20%GP |
|---|---|---|---|---|
| CBR test | 5.963% | 7.07% | 10.12% | 7.627% |

### 3.9 Comprehensive test results are tabulated as follows:

The test results of Liquid Limit, Plastic Limit, Proctor test, Vane shear test, Unconfined Compression test, Specific Gravity, Differential Free Swell test have been tabulated for varying percentage of granite powder from 0% to 30% in mix proportion with BC soils are tabulated in table-6 and CBR test results are given in table-6.

The results are in agreement as compared to published work of Mishra etal (2014), Ogbonnaya and Illoabachie (2011) etc. The limit of granite powder addition to the BC soils for stabilization is at 20% is evident from the following table.

**Table 1.7. Index properties and DFS (After Jagmohan Mishra et al 2014)**

| Mix Proportions | LL (%) | PL (%) | PI (%) | SL (%) | DFS (%) |
|---|---|---|---|---|---|
| CL0G0 (0% granite dust) | 57 | 19.85 | 37.2 | 8.10 | 56.60 |
| CL5G0 (0% granite dust) | 38.5 | 22.96 | 15.5 | 10.40 | 20.0 |
| CL5G10 (10% granite dust) | 34.5 | 25.50 | 9.0 | 14.64 | 11.10 |
| CL5G20 (20% granite dust) | 33 | 26.20 | 6.80 | 16.50 | 5.26 |
| CL5G30 (30% granite dus) | 28 | 24.34 | 3.7 | 18 | 4.1 |

Note: L L – liquid Limit; P L- plastic limits; P I – plasticity Index; DFS – Differential Free Swell

## IV. Conclusions:

The BC soils can be developed on igneous, sedimentary and metamorphic terrains by prevalence of dry and wet seasons as a part of weathering process, further it also depends on the mineralogy of rock. The results and analysis of different tests regarding Index and Engineering properties performed on black cotton soil and mix proportions of black cotton soil & granite powder with varying percentages from 0% to 30%. The experimental results and their analysis, show that the values of 90% black cotton soil + 10% granite powder are in optimum permissible limits to be used in stabilization of BC soils prior to the construction. Further clarity in results may be achieved by the interested researchers by performing experiments, with different sieve size fractions from fine to coarse from 0% to 40% to be mixed with BC soils.

This natural process of soil stabilization will enhance the health of the sustainable environment and our future generations will also live happily. Thus every researcher should play his own role in safe guarding the environment in his every technological innovative work. Further research is warranted regarding the grain size comparison between the BC soils and different grain sizes of granite.

## Acknowledgements

The authors are thankful to the Anurag Group of Institutions for providing necessary laboratory facilities for our experimental studies during the course of their study. Further we are also grateful to the Dr. Vimala, HOD, Civil Department, Anurag Group of Institutions, Venkatapur, Ghatkesar for providing the guide (Dr. R.S.N. Sastry) to steer the work which lead to the successful completion of the project work. Finally we are indebted to our teachers who imparted knowledge and paved the way to carry out the project work. We also express our gratitude to the fellow students and of respective Lab Attenders. We offer special thanks to our parents who encouraged us with moral and financial support for the experimental work.

## References:

[1]. Ahmad N(1983).Vertisols. In L.P. Widding.N.E., Smeck N.E. and Hall G.F. (Eds).Pedogenesis and Soil Taxonomy, Vol.11, The soils orders, Elsevier, Amsterdam, pp: 91-123

[2]. Brajesh Mishra (2015): A Study on Engineering Behavior of Black Cotton Soil and its Stabilization by Use of Lime: International Journal of Science and Research (IJSR) ISSN (Online): Volume 4 Issue 11, November 2015 2319-7064

[3]. Chen FE(1988): Foundations on Expansive soils. Elsevier Scientific Publishing Company, Amsterdam

[4]. Gidigasu S. S. R and Gawu S. K. The Mode of Formation (2013) Nature and Geotechnical characteristics of Black Cotton Soils - A Review Y Department of Geological Engineering, Kwame Nkrumah University of Science and Technology, Kumasi-Ghana, Standard Scientific Research and Essays Vol1 (14): 377-390, December (ISSN: 2310-7502)

[5]. Gidigasu S. S. R and Gawu S. K. Y. (2014) The Mode of Formation, Nature and Geotechnical characteristics of Black Cotton Soils - A Review: Standard Scientific Research and Essays Vol-1 (14): 377-390, December (ISSN: 2310-7502) http://www.standresjournals.org/journals/SSRE

[6]. Githaiga Esther Nyakarura (2009): Project submitted on Stabilisation of black cotton soils- Cement stabilized black cotton soil for pavement subgrade construction; College of Architecture and engineering Department of Civil and construction engineering fce 590 final year civil engineering project. UNIVERSITY OF NAIROBI

[7]. Jagmohan Mishra, R K Yadav1 and A K Singhai (2014): Effect of granite dust on index properties of lime stabilized black cotton soilInt. J. Engg. Res. & Sci. & Tech. 2014: ISSN 2319-5991 www.ijerst.com Vol. 3, No. 1, February 2014.

[8]. Katti RK, Katti DR, KattiAR(2002). Behaviour of saturated expansive soils and control methods.A. A. Balkema Publishers. Pp. 1270

[9]. MIDWEST Green Pave Industrial Supply, Inc All Rights Reserved. 1101-3rd St. S.E., Canton, OH 44707

[10]. Mishra, J.,Yadav, R.k. and singhai, A.K.(2014) "Effect of granite dust on index properties of lime stabilized black cotton soil", International journal of Engineering research and science and technology,3(1),19-23.

[11]. Ogbonnaya, I. and Illoabachie , D.E. (2011): " The potential effect of granite dust on the geotechnical properties of clays ", continental journal of earth sciences,6(1),23-30.

[12]. Ola SA(1983**).** The geotechnical properties of the black cotton soil of Northeastern Nigeria. In Tropical soils of Nigeria in Engineering Practice, Ola S.A. (Ed).A. A. Balkema Publishers, Rotterdam. Pp.85-101

K.Anupama "Improvisation of Geotechnical Properties of Black Cotton Soils with Granite Waste - An Environmental Approach "IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) , vol. 15, no. 3, 2018, pp. 43-51