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Improvement of Stabilization Characteristics of Black Cotton Soil Using Ternary Blend for Flexible Pavement Construction

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Abstract: India is a country of differenttypes of soil, of which the black cotton soils (BC soil) are one of the major soil deposits. BC soils are seldom used to support buildings or pavements because of its complicated behavior. Generally, BC soils have a very low bearing capacity and high swelling and shrinkage characteristics when it is saturated and because of its higher degree of compressibility resulting in settlements, and subsequently leading to failure. But due to the lack of space for the growing population of our country make it necessary to build structures supported on BC soil. Hence in order to overcome this problem the alternate method to improve properties and characteristics of the BC soil practically was by stabilization. The main objective of soil stabilization is to improve the performance of soil by increasing its strength, Stabilization of BC soil by using industrial waste and convention stabilizer such as cement proved to be a sustainable option. This paper present the test results on study of BC soil stabilized by using Cement, Fly ash and Metakaolin to improve the engineering property of BC soil.

The BC soil was sampled from Belagavi region of Karnataka district and was mixed with Cement, Fly ash and Metakaolin with varying percentage i.e. 0% to 10%, 20% and 30% by dry weight of soil respectively. The aim of the investigation was to find the effects of stabilizers on various geotechnical properties of the BC soil. From experimental studies it was found that the maximum dry density was achieved at 30% of the ternary blend. The CBR value of the stabilized soil was also maximum at 30% of ternary blend. This study proved a significant enhancement in the engineering performance of waste-stabilized BC soil using the ternary blend of the mentioned stabilizers which can be employed in the structural applications such as highway construction work and also in the stabilization of existing BC soil for foundations.
Keywords: Stabilization, BC soil, Cement, Fly ash, Metakaolin. Ternary blend (BCS+C+FA+MK)

I. INTRODUCTION

The materials of the earth crust is divided into two, soil and rock in civil engineering. Soil is a natural mineral grains of the rock mass. It is a material supporting the vegetation depending upon their origin soil can be classified into different types, In general as sand, silt, clay, peat etc. Clay is an aggregate of microscopic and sub microscopic particle derived from chemical composition of rock. It is also a most complicated soil because when it comes in contact with water it swells and it shrinks when pore water expels out. Hence this behaviour makes the clay soil as the most complicated soil. All the clay minerals are crystalline hydrous which have lattice structure in which the atoms are arranged in several layers, this determines the type of clay mineral. The different important types of clay mineral are, Kaolinite, Illite and Montmorillonite. The presence of Montmorillonite mineral is the cause of high plasticity index and high frictional resistance.

Civil Engineers are interested in construction projects, As a result it is always not possible to have a good foundation soil for constructions. It may be some time inevitable to use the site consisting of clayey soil for construction. Therefore to utilise the site of low strength or the soil for pavement construction, it can be stabilised by using some chemicals or industrial wastes or by- productsso that it can satisfy the civil engineering requirements. Many authors suggest different materials, methods to stabilize the clayey soil.

II. LITERATURE REVIEW

Soil stabilization using cement hasPositiveimpact.

Andromalos et al. (2000): Studied the strength and mechanicalproperties of the cement stabilized soil. They are related with the effectives of the cement and with the mineralogical composition of a clayeysoil.

Koncagül et al. (1999): Studied on clayey soils which from montmorillonite(bentonite) or kaolinite (kaolin)mineral. They showed good performance under workingload. Moreover, impact of the mineralson hydration of cement and hardeningprocess are also different.

Bell (1978): Showed Kaolin had small impact on hardening process when compared to bentonite, which requireslarge amounts of cement to obtain proper Strength properties.

ErdalCokca (2001): Studied on effect of Flyash on expansive soil, Flyash consists of hollow spheres of silicon, aluminum and iron oxides and unoxidized carbon. There are two classes of flyash, they are class C and class F. The former is produced from burning anthracite or bituminous coal and the latter is produced from burning lignite and sub bituminous coal. Both theclasses of fly ash are having good cementatiuos property, which are defined as siliceous and aluminous materials. Thus Flyash can provide divalent and trivalent cations ($Ca^{2+,}$ Al^{3+}, Fe^{3+} etc) under ionized conditions that can promote flocculation of dispersed clay particles. Thus expansive soils can be stabilized effectively by cation exchange process using flyash. He carried out test using Soma Flyash and Tuncbilekflyash.He prepared a specimens of expansive soil treated with0-25%. After curing the specimens cured for 7days and 28 days, The Oedometer, free swell tests experimental findings confirmed that the plasticity index, activity and swelling potential of the samplesdecreased with increase in percentage of stabilizer and curing time. The optimum content of flyash indecreasing the swell potential was found to be 20%. He concluded that both high –calcium and low calcium class Cfly ashes can be recommended as effective stabilizing agents for improvement of expansive soil properties.

Pandian et.al. (2002): The CBR characteristics of the black cotton soil was studied using the effect of two types of fly ashes Raichur fly ash (Class F) andNeyveli fly ash (Class C). The fly ash content wasincreased from 0 to 100%. Generally the CBR/strength is contributed by its cohesion and friction. The low CBR of BC soil is attributed to the inherent low strength, which is due to thedominance of clay fraction. On addition of fly ash to BC soil increases the CBR of the mix up to thefirst optimum level due to the frictional resistance from fly ash in addition to the cohesion from BC soil. Thus the variation of CBR of fly ash-BC soil mixes can beattributed to the relative contribution of frictional or cohesive resistance from fly ash or BC soil,respectively.

Phanikumar and Sharma (2004): A similar study was carried out and the effect of fly ash on engineering properties of expansive soil through an experimentalprogramme was investigated. The effect on parameters such as free swell index (FSI), swell potential, swelling pressure, plasticity, compaction, strength and hydraulic conductivity of expansive soil was studied. The expansive soil was treated with flyash contents of 0, 5, 10, 15 and 20% by dry weight and theyinferred that increase in flyash content reduces plasticitycharacteristics and the FSI was reduced byabout 50% by the addition of 20% fly ash. The hydraulic conductivity of expansive soils mixed withflyash decreases with an increase in flyash content, due to the increase in maximum dry unit weightwith an increase in flyash content. When the flyash content increases there is a decrease in theoptimum moisture content and the maximum dry unit weight increases. Hence the expansive soil is rendered more stable. The undrainedshear strength of the expansive soil mixed with flyash increases with the increase in the ashcontent.

Salvado (1995); Zampieri, (1989): Stated Metakaoilin is a highly pozzolanic and reactive and supplementary cementatious material. It is unique in that it is neither the by-product of an industrialprocess nor is it entirely natural. Metakaolin is derived from naturally occurring mineral and is manufacturedspecially for cementing applications; it is refined kaolin clay that is fired (calcined) under carefully controlledconditions to create an amorphous aluminosilicate that is reactive in concrete and is obtained by calcination of
the kaolinitic clay at temperatures 600 – 800^{o}C which when used as stabilizer reduces the volume change.

III. MATERIALS AND METHODOLOGY

In most of the papers it is highlighted that through stabilisation process it is possible to improve the engineering properties of the soil either in the field or in construction where soil is used as construction material. In the present study the Black cotton soil was collected from Belagavi region of Karnataka state, and the initial tests on the black cotton soil was conducted to understand the geotechnical properties of the soil and studied for the improvement in engineering properties. The chemical composition obtained by X-ray fluorescence (XRF) of the stabilisers used in this study are,

Table: 1 Chemical composition of stabilisers

Property	Cement	Flyash	Metakaolin
SiO_2	21.9 %	59.94%	54.3%
Al_2O_3	6.9%	22.87%	38.3%
Fe_2O_3	3%	4.67%	4.28 %
CaO	63%	3.08%	0.39 %
MgO	2.5%	1.55%	0.08 %
SO_3	1.7%	0.35%	0.03 %

Atterberg limits and initial tests on BC soil were conducted in the laboratory and the soil classification was done using Casagrande Plasticity chart.

Table: 2 shows the different test on BC soil conducted in the laboratory to know the geotechnical properties of BC soil.

Table: 2 Properties of BC soil.

Sl No	Laboratory Tests	Results
1	Liquid Limit (%)	87.2
2	Plastic Limit (%)	52.06
3	Plasticity Index	35.14
4	Optimum Moisture content(OMC)%	23
5	Max Dry Density(MDD)KN/M^3	13.826
6	Cohesion (C) ,KN/M^2	29.418
7	Angle of internal friction(Φ)^o	13
8	UCS ,KN/M^2	127.478
9	CBR Value	
	Unsoaked 2.5mm	6.13%
	5.0mm	2.18%
	Soaked 2.5mm	3.65%
	5.0mm	2.06%
10	Classification of soil (Casagrande plasticity chart USCS)	CH

Knowing the behaviour of the soil, Different stabilisers were mixed with different percentage by dry weight of soil such as 10%, 20% and 30% and the test were conducted for the different mix proportions.
The procedure or the methodology adopted for determining the mix proportion and the steps to arrive for a ternary blend can be explained. In the following steps.

1. Tests were conducted on BC soil to determine the geotechnical properties.
2. Tests were conducted on BC soil blended with individual stabiliser with varying percentage such as 10%, 20%, 30% and optimum values for dry density were obtained.
3. From the test results the proportion which gave maximum MDD was considered for ternary blendi.e(BCS+C+FA+MK).
4. The total percentage of the stabilisers to be considered was the optimum value obtained from the above test results.

A. Laboratory test results for soil blended with individual stabilizers.

The BC soil was blended with different Stabilizers individually to know the optimum percentage value of the stabilizer used for ternary blend. The proctor test and CBR test were conducted on them to understand the behaviour of BC soil with different stabilizers.

Fig: 1 Chart showing Dry density and OMC for BCS+Cement.

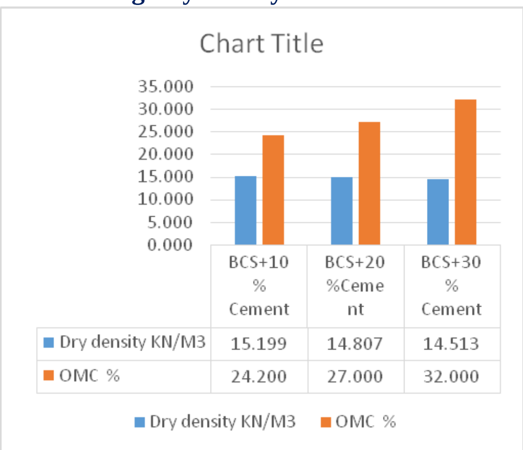
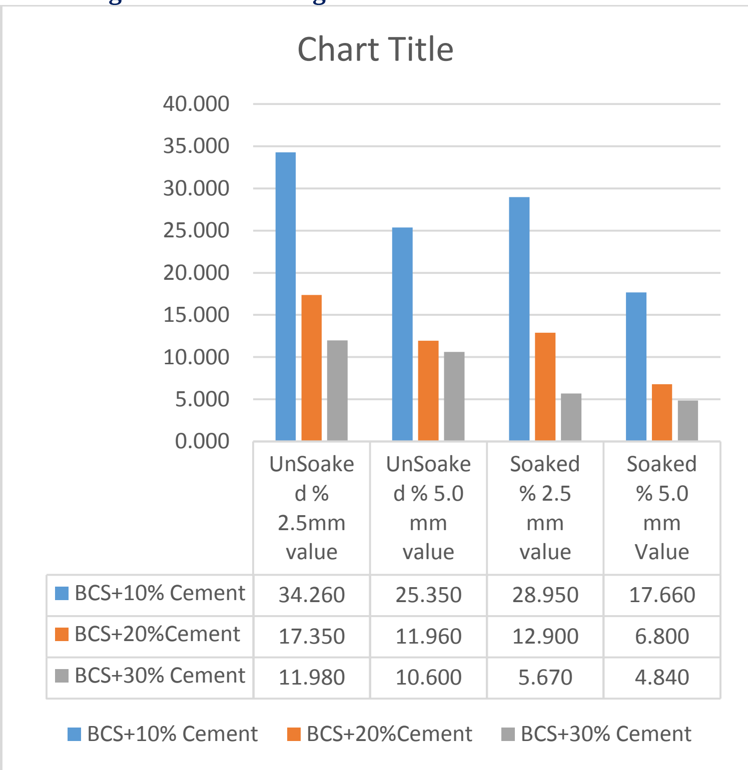


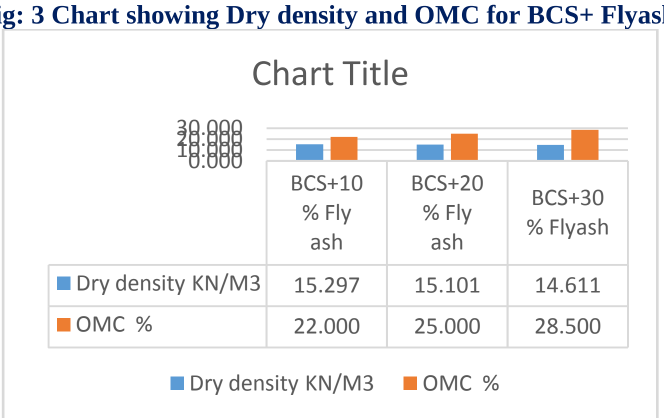
Fig:1 shows the value of Dry density and OMC for BC soil mixed with different percentages cement. It is understood that for BCS+ 10% of cement the dry density is maximum and with OMC of 24.2%.

Fig: 2 Chart showing CBR value for BCS+Cement.



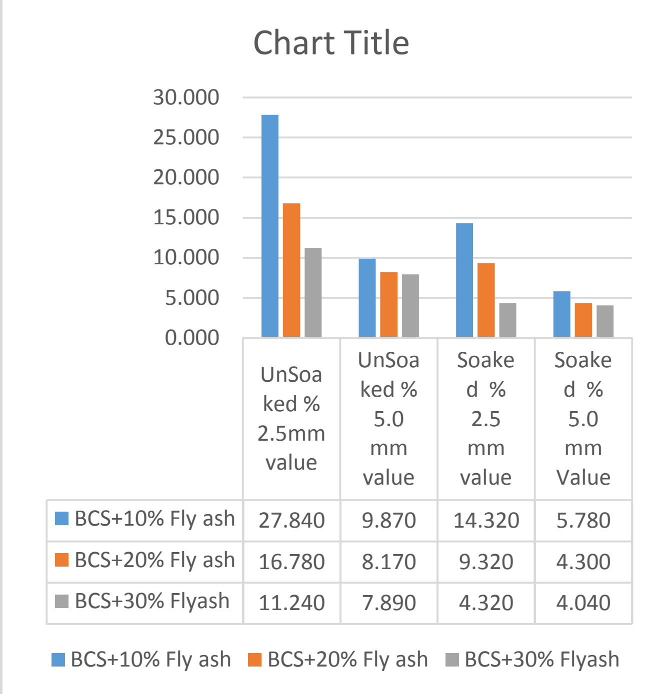
The above chart shows the CBR value for unsoaked and soaked condition for varying percentages of cement with BCsoil.As per the test result it is clear that the CBR value for BCS+10% cement is maximum both for unsoaked and soaked values.

Fig: 3 Chart showing Dry density and OMC for BCS+ Flyash.



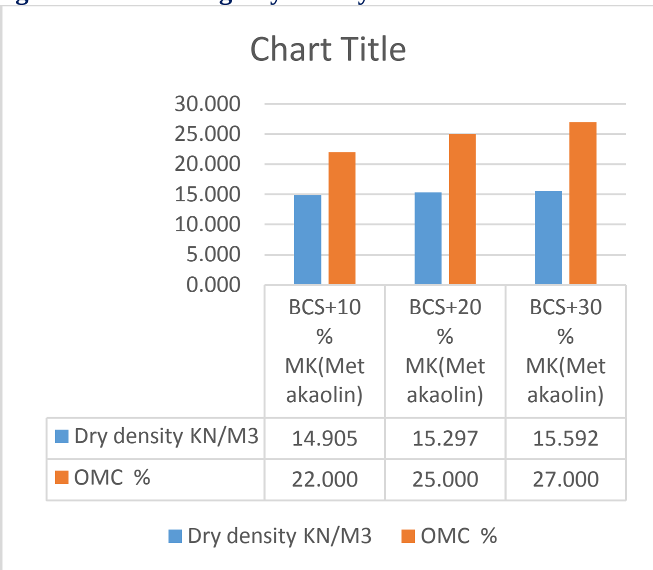
From fig:3 the dry density is maximum for BCS+10% flyash with OMC of 22 %.
Further the test was conducted on CBR using the MDD and OMC for different percentage of stabilizer. The test results are shown in fig: 4

Fig:4 Chart showing CBR value for BCS+ Flyash.



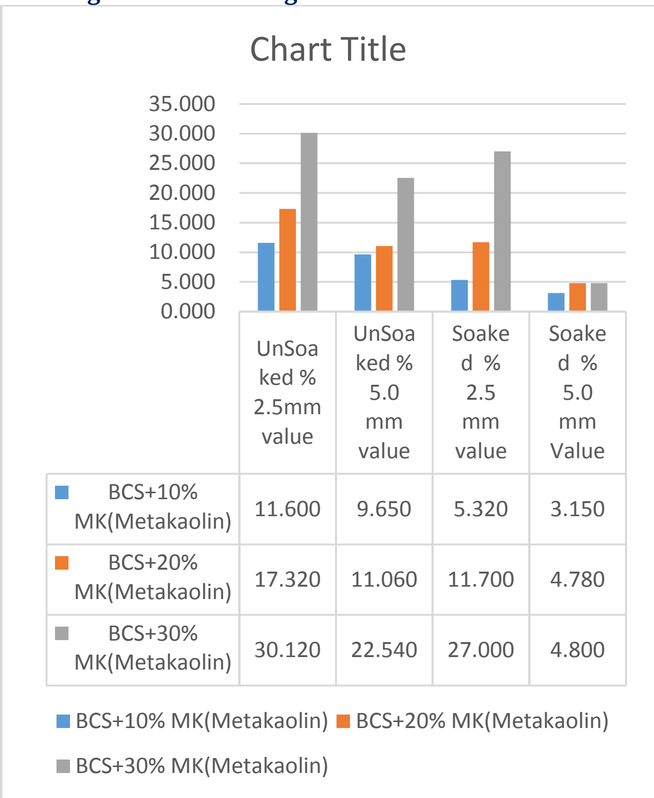
From the above fig it is seen that for BCS +10% flyash the CBR value is more both for unsoaked and soaked.

Fig: 5 Chart showing Dry density and OMC for BCS+MK .



The Dry density from above chart is maximum for BCS+30% MK with the OMC of 27% hence the optimum value to be considered is 30% for MK.

Fig:6 Chart showing CBR value for BCS+ MK



From the fig:6 it was observed that BCS+30% MK gave max value of CBR for both Unsoaked and soaked conditions.

From all the above figures it was understood that the behaviour of BC soil with different stabilisers with varying percentages shows maximum values for 10% for Cement and Flyash and 30% for Metakaolin. Hence for mix design of ternary blend the percentage variation considered was 10,20 and 30% of sum of stabilisers i.e (C+FA+MK) by dry weight of BC soil i.e when blended all together with BC soil the maximum percentage of individual stabilizer should not be more than 10%.

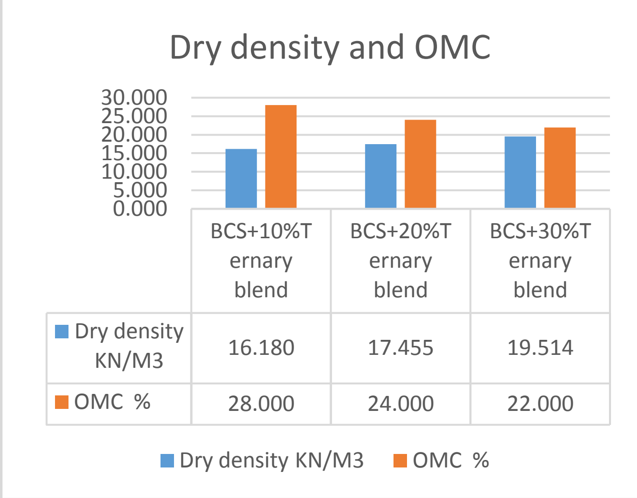
BCS was blended with of sum of Cement, fly ash and metakaolin with varying percentage that is 10%,20% and 30% in order to see the improvement in stabilization characteristics, so that it can be effectively utilised for structural applications such as stabilisation of foundation soil and in flexible pavement construction.

Hassnen M. Jafer et.al (2018) studied on ternery blend containing high calcium fly ash (HCFA), palm oil fuel ash (POFA), rice husk ash(RHA). A new, ternary blended cementitious binder (TBCB) producedfrom waste materials was developed from 66% HCFA, 17%POFA ,17% RHA, activated with 5% FGD gypsum, by total binder. This binder can be used for commercial cement replacement insoft soil stabilisation which, in turn, contributes to the reductionof the negative environmental footprint created by the manufactureof cement.[8]

B. Laboratory test results for soil blended with individual stabilizers.

In this particular study the blending of Cement +Flyash and Metakaolin was done for BC soil, the proctor tests and CBR tests was conducted with ternary blend treated BC soil.

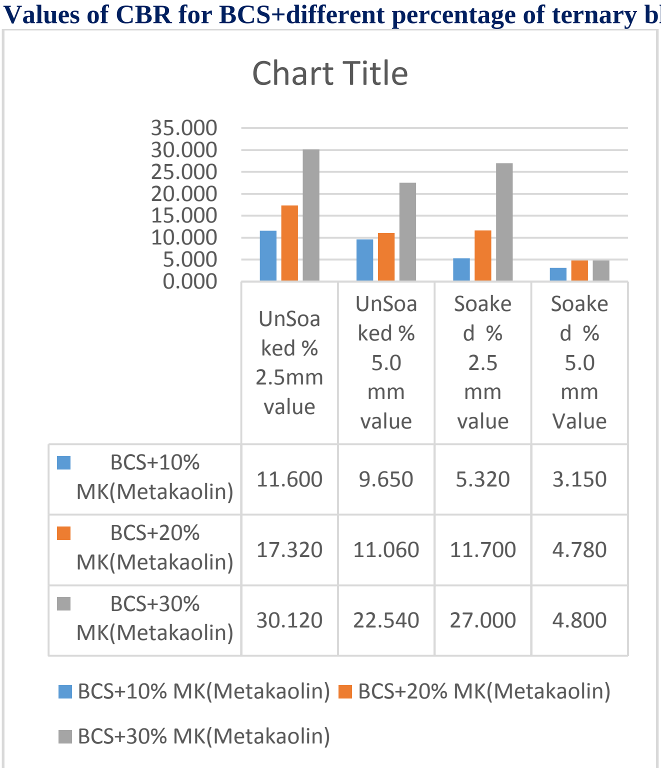
Fig: 7 Values of Dry density and OMC for BCS+different percentage of ternary blends.



The above fig shows the test result of BC soil blended with varying percentages of ternary blend, it was observed that the dry density achieved was more than that for individual stabiliser and the dry density was maximum for 30% ternary blend with OMC of 22%.

Similarly the CBR value was also optimum 30% ternary blend for both unsoaked and soaked conditions. This is illustrated in fig:8.

Fig:8 Values of CBR for BCS+different percentage of ternary blends.



IV. CONCLUSIONS:

1. From the test result on the BC soil it was clear that the soil is highly compressive clay whose liquid limit is very high.
2. When the BC soil was blended with Cement, FA and MK with varying percentage such as 10%, 20% and 30%, it showed that for 10% was optimum for cement and fly ash and 30% for metakaolin and further increase in percentage showed reduction in MDD.
3. Hence the mix design for ternary blend was decided that the sum of all the three stabilizers will be 30% as maximum variation.

4. Form the results it can be concluded that the ternary blend of 30% can be efficiently utilised for stabilisation process in construction of flexible pavements and also in stabilisation of foundation.
5. The CBR value obtained is such that it can be used in economical construction of roads.

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