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Suitability of bagasse ash-lime mixture for the stabilization of black cotton soil

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Abstract. Lime stabilization has conventionally been listed amid the key techniques of chemical stabilization. Replacing lime with sustainable agro-based by-products have gained prominence in recent decades. Bagasse ash (BA) is one such potential alternatives, an industrial waste with abundance in production, and industries exploring sustainable solutions for its safe disposal. Supplementing BA with lime could be an ideal approach to reduce lime consumption. However, suitability of BA and lime for the stabilization of expansive clays, such as black cotton (BC) soil is yet to be explored. This paper therefore aims to investigate the suitability of BA-lime mixtures to stabilize BC soil with emphasis to compaction behaviors and unconfined compressive strength (UCS) using standard laboratory procedures. Suitability of BA-lime mixture is then assessed against addition of calcium sulphate which, from previous experience, is detrimental with lime stabilization. Experimental outcomes nominate 15% BA as the optimum value observed from both compaction and UCS data, while addition of 4% lime to 15% BA showed the best results. Mineralogical and microstructural analysis show the presence of cementitious compounds with addition of lime and calcium sulphate with curing periods. While, formation of Ettringite needles were noted with the addition of calcium sulphate in BA-lime mixtures (at optimum values) after 90-day curing, and UCS results showed a decrease at this point. To this end, addition of BA in lime stabilization showed encouraging results as assessed from the compaction and UCS results. Nonetheless usage of calcium salts, with utmost emphasis on calcium sulphate and equivalent should be avoided.

Keywords: calcium sulphate; compaction behavior; expansive clay; unconfined compressive strength

1. Introduction

Black cotton (BC) soil has been well documented as problematic soil owing to its excessive volume change behavior subjected to varying moisture, typically referring to swell-shrink behavior. This behavior in BC soils is well related to the presence of Montmorillonite (Dif and Bluemel 1991, Day 1994), an expansive 2:1 phyllosilicate clay mineral. Nonetheless, infrastructure development and required construction activities such as road sub-layers, retaining structures, embankments on such expansive clay deposits leave us with very less-to-no option, but to employ soil stabilization strategies. This further becomes crucial accounting to the large extent or spread of such expansive soil – BC soil in this paper. As an estimate, the BC soil deposits in India covers the central and western regions extending to over 20% of India's land area (Oza and Gundaliya 2013), while the built infrastructure in these regions have a significant contribution to the nation's development. Literature presents various stabilization methods and stabilizers being experimented with utmost focus to improve the bearing capacity or shear resistance, and reduce compressibility or excessive volume change in expansive soils (Mohanty *et al.* 2017, Subramanian *et al.* 2017, Sriraam *et al.* 2019). Literature also evince notable use of lime stabilization to restrict this swell-shrink behavior of BC soil (Sivapullaiah *et al.* 2006, Dash and Hussain 2012). Supplementing lime in BC soils (expansive soil, in general) typically influences the diffused hydrous double layer of the clay particles, thereby changing the plasticity of the soil. Moreover, the pozzolanic activity of lime is also well known to significantly improve the long-term strength performance of the stabilized soil.

Efficiency of lime stabilization is typically influenced by the type and amount of clay mineral, dosage of lime, water content, and degree of compaction. Recent efforts to ensure and/or improve the economic and practical viability of the lime-stabilization process has led to adopting alternate materials to reduce the amount of lime usage. For example, literature present experimentation using various industrial wastes or by-products such as fly ash, rice husk ash, and mine tailings as admixture with lime (Consoli *et al.* 2001, Karatai *et al.* 2017, Ojuri *et al.* 2017) thereby reducing the usage of lime. Bagasse ash (BA), by-product from incineration of bagasse in sugar industries is another alternative material which has high potential to similarly

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Table 1 Procedure and geotechnical properties of the study material

Property	Test procedure	BC soil	Bagasse ash
Specific gravity	IS 2720-3(Sec1): 1980	2.65	1.71
Sand – 4.75 to 0.075 mm (%)	IS 2720-4: 1985	4	12
Silt – 0.075 to 0.002 mm (%)	IS 2720-4: 1985	36	66.4
Clay – less than 0.002 mm (%)	IS 2720-4: 1985	60	–
Liquid limit (%)	IS 2720-5:1985	91	61
Plastic limit (%)	IS 2720-5:1985	39	Non plastic
Plasticity index (%)	IS 2720-5:1985	52	–
Shrinkage limit (%)	IS 2720-6:1972	11	–
Optimum moisture content (%)	Sridharan and Sivapullaiah (2005)	32	43
Maximum dry unit weight (kN/m^3)	Sridharan and Sivapullaiah (2005)	12.95	10.34

replace lime, thereby making the lime stabilization process more economical. An estimated 10 million tonne of BA is collected for every 300 million tonnes of sugar produced (Modani and Vyawahare 2013). Moreover, BA when disposed without proper considerations may pose acute problems to human health and the environment – ranging to respiratory difficulties, and air and water contaminations respectively. It is for this reason; the sugar industries are exploring sustainable solutions and safe disposal procedures for BA. The pozzolanic activity of the BA due to the presence of reactive silica and traces of calcium oxide (Cordeiro *et al.* 2009) further contributes in improving the strength performance of the expansive clays. This pozzolanic activity is known to further enhance when heated in furnace to temperatures 800-1000°C for about 20 minutes (Villar-Cociña *et al.* 2008). Though literature note small amounts of lime content in BA, this small amount is typically insignificant to achieve desired post-stabilization geotechnical properties of clays (Hausmann 1990, Little and Nair 2009). Thus, the utilization of BA as admixture in lime stabilization is a potentially sustainable alternative to warrant the process more economic and environmentally feasible. Nevertheless, literature presenting detailed research assessing the suitability of BA-lime mixture to stabilize BC soils were seldom/not encountered in the search conducted for this study. The work presented in this paper therefore focus on addressing this research gap.

The main aim of this paper is to investigate the suitability of utilizing BA and lime (Lm) mixture for stabilizing compacted BC soil and deliberate on quantitative assessment of the compaction and strength behavior of the thus stabilized BC soil samples. The suitability of BA-lime mixture is further analyzed against some of the commonly used stabilizing chemicals - calcium chloride and calcium sulphates. It is deemed critical to assess the suitability against the calcium salts owing to our previous rough experiences – formation of highly expansive Ettringite and Thaumasite with the addition of calcium sulphate demonstrating severe distress/problems related to pavement soil layers (Hunter 1988, Mitchell and Dermatas 1992, Latifi *et al.* 2016). An increased amount of sulphates induces high swelling pressures, increased water absorption and expansion (Wild *et al.* 1993). Therefore, the analysis and discussion in this paper also focuses on assessing the suitability of calcium salts with BA-lime mixtures at optimum values for the stabilization of BC soils. The data to facilitate the proposed suitability assessment are gathered using a series of carefully planned laboratory experimentation conducted following standard procedures as detailed in this paper henceforth.

2. Material and methodology

The laboratory investigation in this paper was designed to determine the compaction and strength properties of BC soil samples supplemented with BA-lime mixtures at different contents and curing periods. The BC soil used in this study was procured from a construction site in the Hosakatti village located 25 kms from Hubli, Karnataka state, India. Disturbed soil samples were excavated at a depth of 2 m below the ground level and carefully transported to laboratory at the University Visvesvaraya College of Engineering (UVCE), Bengaluru, Karnataka state, India. The soil samples were then dried (as per IS 2720-1:1983) and pulverized using ball mill before testing for geotechnical properties. Table 1 summarizes the laboratory procedure and geotechnical properties of the representative BC soil used in this study. Tests were conducted in triplicates and the results showed fewer variation; thus, the averaged values of the properties are presented here. Fig. 1 shows the grain size distribution curve for the BC soil used in this study. The BC soil is classified as the “clays of high plasticity (CH)” in accordance with the Indian standard classification system for soils (IS 1498: 1970). The BC soil used in this study was also classified as “clay of high plasticity (CH)” using the Unified Soil Classification System (as per ASTM D 2487–17).

Bagasse ash (BA) samples in this study were procured from a sugar industry located in Mandya district, Karnataka state, India. BA samples collected from the conveyor belt in the sugar industry were initially processed to remove the organic content by burning the samples in an oil-fired furnace at temperatures of 600°C for a duration of 8 hours. The properties of the BA samples were also measured in-

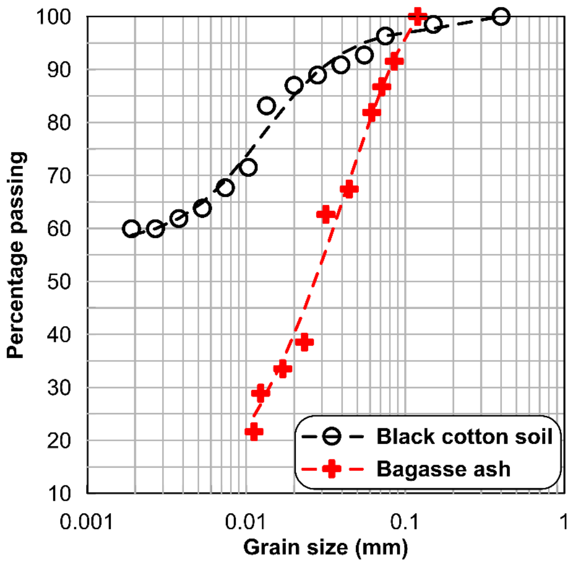

Fig. 1 Grain size distribution of the study material

Table 2 Chemical composition of the study material

Chemical composition	Bagasse ash	Black cotton soil
Silica (SiO_2)	65.9%	60.4%
Alumina (Al_2O_3)	11.9%	15.1%
Ferric oxide (Fe_2O_3)	2.9%	6.6%
Calcium oxide (CaO)	5.6%	6.9%
Magnesium oxide (MgO)	4.0%	1.7%
Sodium oxide (Na_2O)	1.8%	0.3%
Potassium oxide (K_2O)	3.2%	0.4%
Loss on ignition	16.2%	8.4%

line with the geotechnical properties of BC soil samples – shown in Table 1, and the grain size distribution information in Fig. 1. Table 2 summarizes the chemical composition of the BA samples used in this study. Understanding the chemical composition of the study materials were deemed equally important to the geotechnical properties, and are used later in this paper in analyzing the physicochemical interaction of BA with BC samples. Table 2 also tabulates the chemical compositions of the BC samples. The other admixtures used in this study include the hydrated lime (Lm), calcium sulphate (CS), and calcium chloride (CC) which were procured commercially. Literature entrusts that the application in high amounts of calcium sulphate is detrimental to the lime treated soil (Wild *et al.* 1993). While various researchers show values of CS and CC ranging to 1% as the optimum dosage (Sharma *et al.* 2008). Therefore 1% of CS and CC is chosen as the optimum dosage and used in the experimental program of this study.

The mini compactor testing apparatus and procedure proposed by Sridharan and Sivapullaiah (2005) was used in this study for the compaction tests. In brief, the mini-compactor consists of a steel mold with inner diameter of 38.1 mm and height of 100 mm. The hammer used for compaction weighs 2.5 kg and dropped from a free fall of 160 mm. The soil samples were prepared by mixing water at predetermined water contents using hand kneading method to ensure proper mixing. The samples were stored over-night in sealed polythene bags to allow for moisture equilibrium. The samples were then kneaded again before measuring the water content (IS 2720-2:1973, reaffirmed 1990) and used for compaction testing. The sample mold was first cleaned and lubricated using grease to avoid difficulty while extruding the compacted sample. The soil samples were compacted in 3 layers by applying 36 blows at each layer. The remaining procedure and calculations were conducted in accordance with IS 2720-7:1980.

Unconfined compressive strength (UCS) tests were performed to measure the UCS values using cylindrical shaped compacted soil samples of 76 mm height and 38 mm diameter. The samples for this purpose were compacted to their respective maximum dry unit weights and corresponding optimum moisture contents. The compacted soil samples were carefully wrapped in polyethylene bags and stored in air tight desiccator for predetermined durations – overnight curing was practiced for uncured samples, while other samples were allowed to stand in the desiccator over predetermined number of days for curing. The sample weight was monitored before and after curing periods to ensure minimal or no moisture variation. Samples with more than 0.5% variation in water content measured by the weight were discarded. UCS tests were performed as per the procedure in IS 2720-10:1991, using a constant strain rate of 1.25 mm/minute throughout the testing program. The samples were tested in triplicates and the peak stress was noted from the stress-strain curve. The UCS values presented henceforth are the average values of the peak stresses, while the sample/test was discarded when the variation in the peak stress values were observed to be more that 10%. Tests were terminated with observations of decreasing and/or steady trend in the load measurement or at strains of 20%, whichever reached earlier.

The x-ray diffraction (XRD) analysis in this study was conducted on randomly oriented dry powered samples. A Rigaku Miniflex 600 advance model diffractometer was used for this purpose with CuKα radiations. A speed of 1°/minute and Bragg's angle ranging 3°–130° was used, and a commercially available software was used to analyze the data. The surface microstructure analysis of the soil samples in this study was conducted using the scanning electron microscope (SEM). Soil samples with and without admixtures were prepared by cutting them to 10 mm x 10 mm x 10 mm cubes and air-dried before subjecting to gold coating. Coating included an approximate 100Å thick gold palladium coated for a period of about 38 seconds using a sputter coater before microstructural examination.

3. Results and discussion

The consistency limits of soils are typically used as the key indicator in assessing the effect of chemical admixtures or stabilizers. The basic characteristics of the stabilizer and/or admixture is likely to influence the plasticity of the

Table 3 Consistency limits of the BC soil samples with selected compositions of bagasse ash, lime and calcium salts (after Ramesh and Kulkarni 2018)

Combination	**Liquid limit (%)**		**Plastic limit (%)**		**Shrinkage limit (%)**		**Plasticity Index**	
Curing period (days)	**0**	**7**	**0**	**7**	**0**	**7**	**0**	**7**
BC alone	91	-	39	-	11	-	52	-
BA alone	61	-	Non-plastic		-	-	-	-
BC + 15%BA	83	83	52	51	15	15	31	32
BC + 15% BA + 4% Lm	90	91	79	86	50	52	11	5
BC + 15% BA + 4% Lm + 1% CS	88	89	79	79	55	56	9	10
BC + 15% BA + 4% Lm + 1% CC	88	89	79	79	55	56	9	10

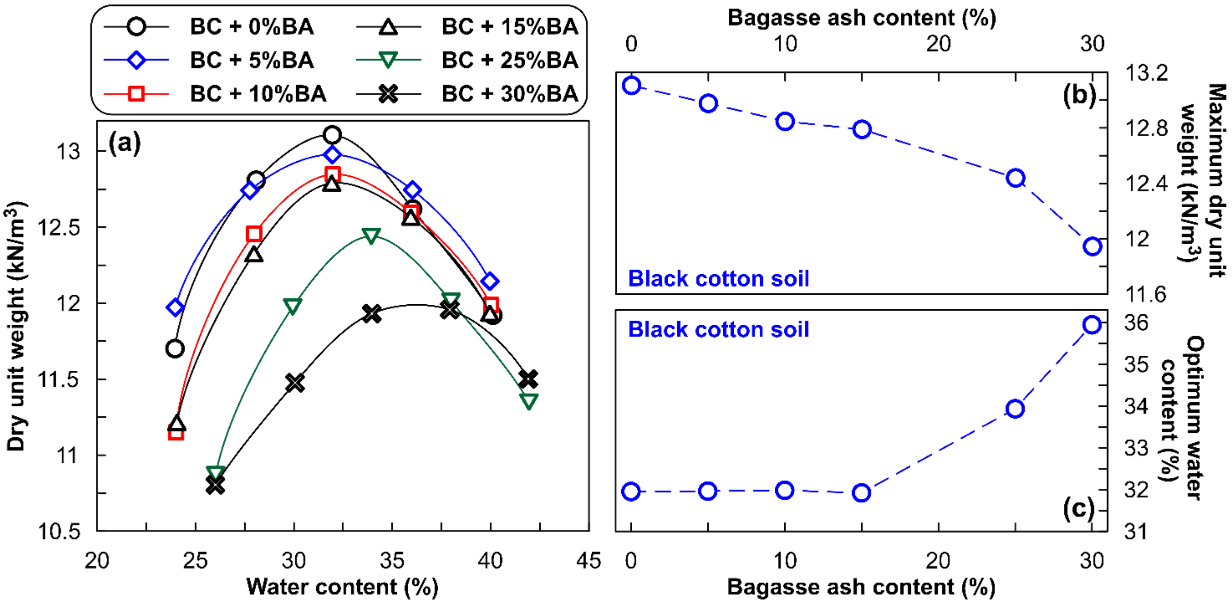

Fig. 2(a)-(c) Effect of bagasse ash content on the compaction behavior of BC soil, (a) compaction curves, (b) variation of maximum dry unit weight with BA, and (c) variation of optimum water content with BA

soil, and the other behavior - compaction and unconfined compressive strengths eventually. In this study, the consistency limits of BC soil stabilized with BA, Lm, CC, and CS were evaluated using standard procedures (refer Table 1 for the details). The results and discussion of these consistency limits are presented in detail at Ramesh and Kulkarni (2018) Nonetheless, Table 3 summarizes the consistency limits of the BC soil treated with selected compositions of the stabilizers which are used in this study – that includes 15% of BA, 4% of Lm, and 1% of CS and 1% CC combinations at 0- and 7-days curing periods. These composition of BA, Lm, CC and CS are basically the optimum contents of the admixtures based on the consistency limits as discussed in (Ramesh and Kulkarni 2018). As evident from the consistency limits, adding a non-plastic BA to BC reduces the plasticity of the stabilized material (evident from the decreasing plasticity index values). While the consistency limits increased with the addition of lime, and show minor fluctuations with CS and CC. The curing period however has no effect with BA alone, while the presence of Lm, CC and CS show time-dependent changes in the consistency limits of the stabilized BC samples.

Fig. 2 shows the compaction test results for the BC soil samples with increasing BA content. Fig. 2(a) shows the variation of dry unit weight (γ_d) at every trial water content (w). The curves compare well with the standard compaction curves – γ_d increasing with w up to a certain value, followed with a decreasing trend. Maximum γ_d and the corresponding w (optimum) values are noted. Figs. 2(b) and 2(c) shows the variation in maximum γ_d and the optimum w values with increasing BA contents respectively. Fig. 2(a) shows a gradual decrease in maximum γ_d values up to 15% BA content followed with steeper decrease thereafter. The decrease in the maximum γ_d overall attributes to low specific gravity of BA in comparison to BC. In addition to this, further increase in BA content is likely to flocculate and agglomerate the clay particles, thereby increasing the volume of the compacted soil, thus decreasing γ_d (Sivapullaiah and Jha 2014, Xu et al. 2009, Brito *et al.* 2018). The increasing w values are mainly related to the additional amount of water required to facilitate hydration process of BA (Eberemu 2013). Thus, 15% BA content can be nominated as the optimum content for compaction purposes, as any higher BA content are likely to result in

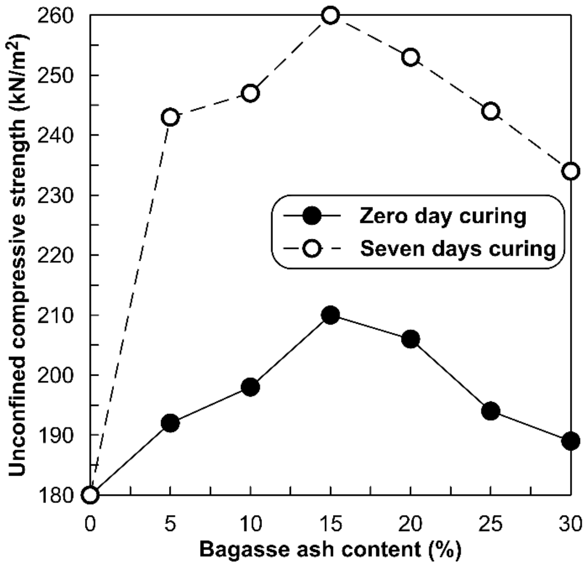

Fig. 3 Effect of bagasse ash content on the unconfined compressive strength of BC soil

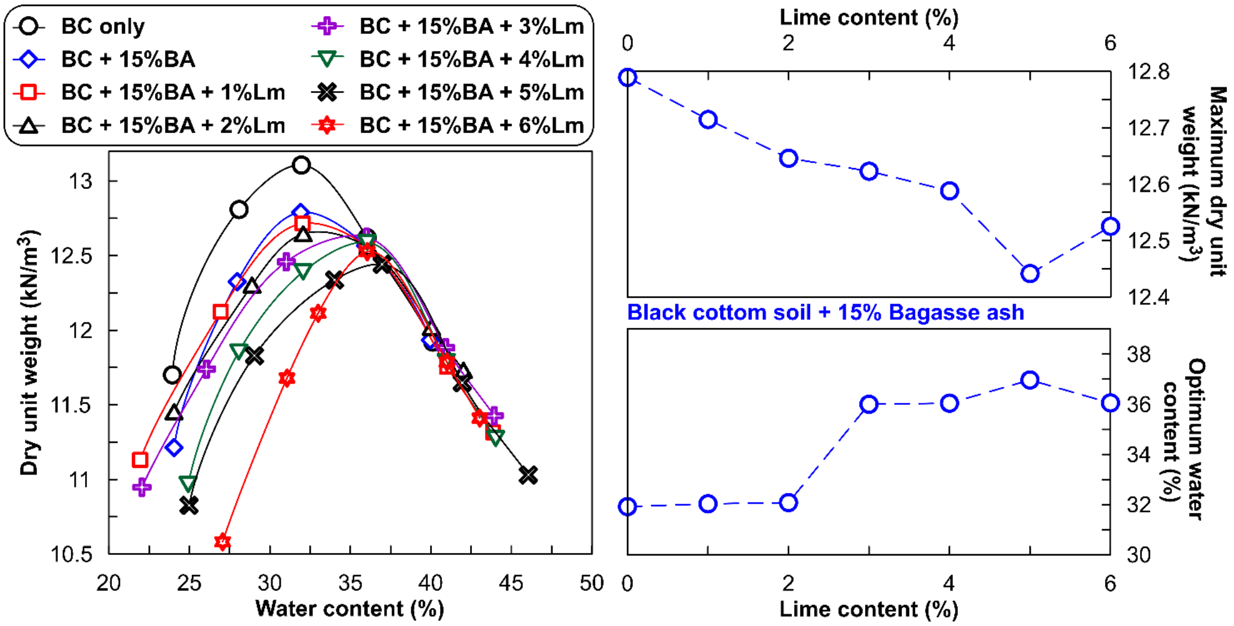

Fig. 4(a)-(c) Effect of lime content on the compaction behavior of BC soil with 15% BA content, (a) compaction curves, (b) variation of maximum dry unit weight with lime, and (c) variation of optimum water content with lime

flocs induced compacted BC soil layers. Moreover, optimum water content (see Fig. 2(c)) also support this consideration, because the amount of water in BC soil with BA contents >15% starts to increase at higher rates compared to BC soil with BA ≤15%. The increased *w* attributes to the water occupying the voids encompassed by the flocs. Usage of BA contents >15% thus proves to cause issues during compaction of BC soil and its post-construction performance.

Fig. 3 shows the unconfined compressive strength (UCS) of BC soil supplemented with varying BA content. Observations show gradual increase in the UCS values for BA content up to 15%, and decreased with further increase in the BA content. This trend was observed in all the samples irrespective of the curing process and/or period.

The initial increase in UCS relates to the addition of non-plastic BA particles in to BC – an expansive clay, thereby improving the resistance of samples to the applied compressive force. However, further increase in BA content impart the reducing clay content, cohesion to be specific, thereby making the sample less cohesive (Dang *et al.* 2016) which eventually reduces the resistance to the applied compressive forces. These observations clearly justify the selection of 15% BA content as the optimum value to stabilize BC soil, which will be used in this paper for further discussions hereafter. In addition, the samples tested after 7 days of curing showed an encouraging increase in the UCS values, which ranged to 22-27% increment. These observations clearly highlight the pozzolanic action of the BA-lime mixtures.

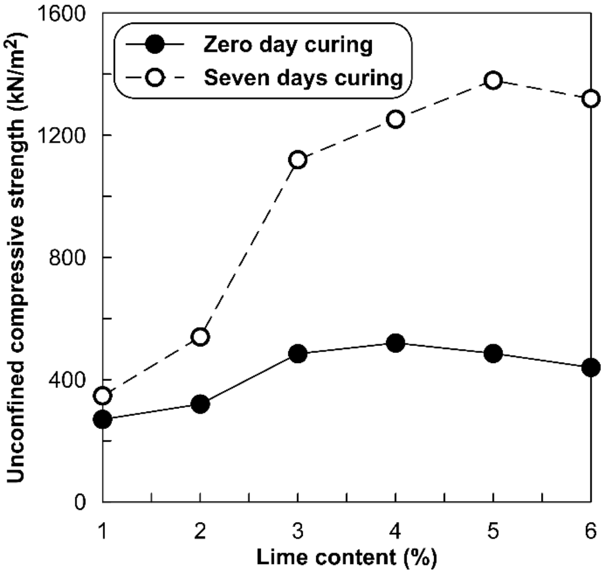

Fig. 5 Effect of bagasse ash content on the unconfined compressive strength of BC soil

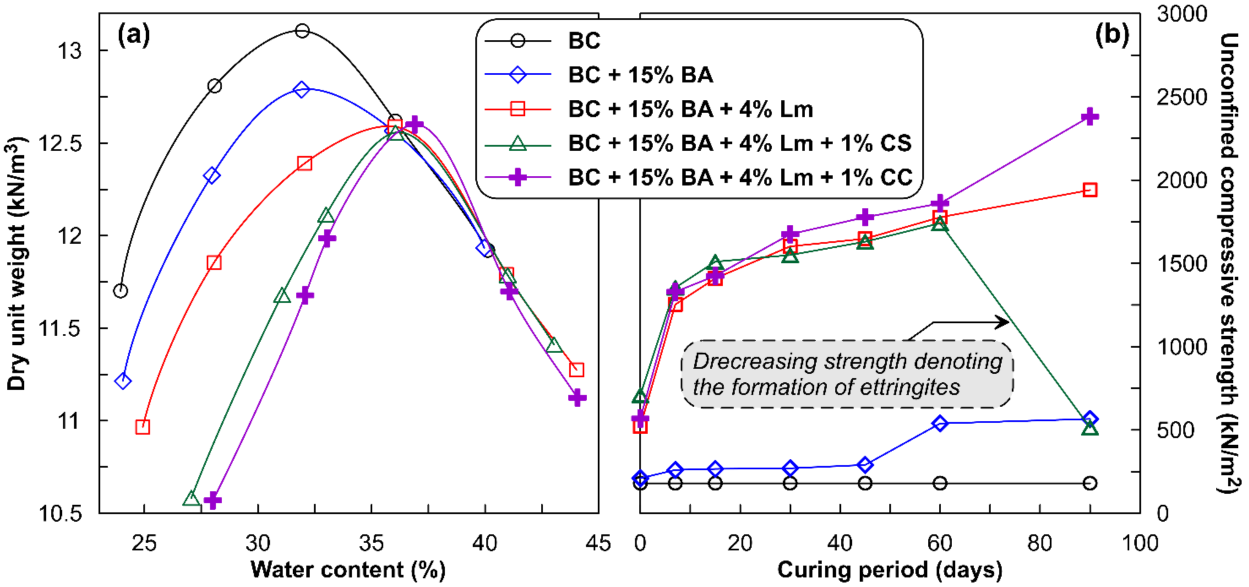

Fig. 6(a)-(b) Effect of calcium sulphate and calcium chloride on the BC soil supplemented with optimum contents of BA and lime, (a) compaction curves, and (b) UCS values at different curing periods

Fig. 4 shows the compaction test results of the BC soil supplemented with 15% BA content with increasing lime (Lm) contents. Fig. 4(a) shows the set of standard compaction curves for all the trials. Figs. 4(b) and 4(c) shows the maximum γ_d and the optimum w values with increasing lime contents respectively. Observation from the figures show a gradual decrease in the maximum γ_d values with lime content. While the optimum w values are steady up to 2%, followed by a jump at 3% lime content and stayed steady thereafter. To this observations, 4% lime content encouragingly are perceived as the optimum value owing to higher decrease after 4% lime (see Fig. 4(b)). However, it is deemed appropriate to confirm the optimum lime content mainly basing on the strength with lime content and curing periods – to the fact that the pozzolanic action of lime is the key criterion dictating the strength.

Lime has been conventionally used for stabilization owing to its ability to react with silica and alumina of clays and form the cementitious calcium silicate hydrate and calcium aluminate hydrates, thereby improving the strength. Fig. 5 shows the UCS values of BC soil supplemented with 15% BA at varying lime contents. Observation in this study also show similar results, with increasing UCS values following the addition of lime. Nonetheless, the increase in UCS values reached a peak before declining at 4% and 5% lime contents for samples with zero and 7 days curing respectively. The increasing UCS with lime relates to formation of the cementitious compounds – calcium silicate hydrates and calcium aluminate hydrate. While the UCS is well known to decrease after a certain optimum lime content – lime content at which formation of cementitious compound ceases (Sivapullaiah *et al.* 2000). Thus, this is

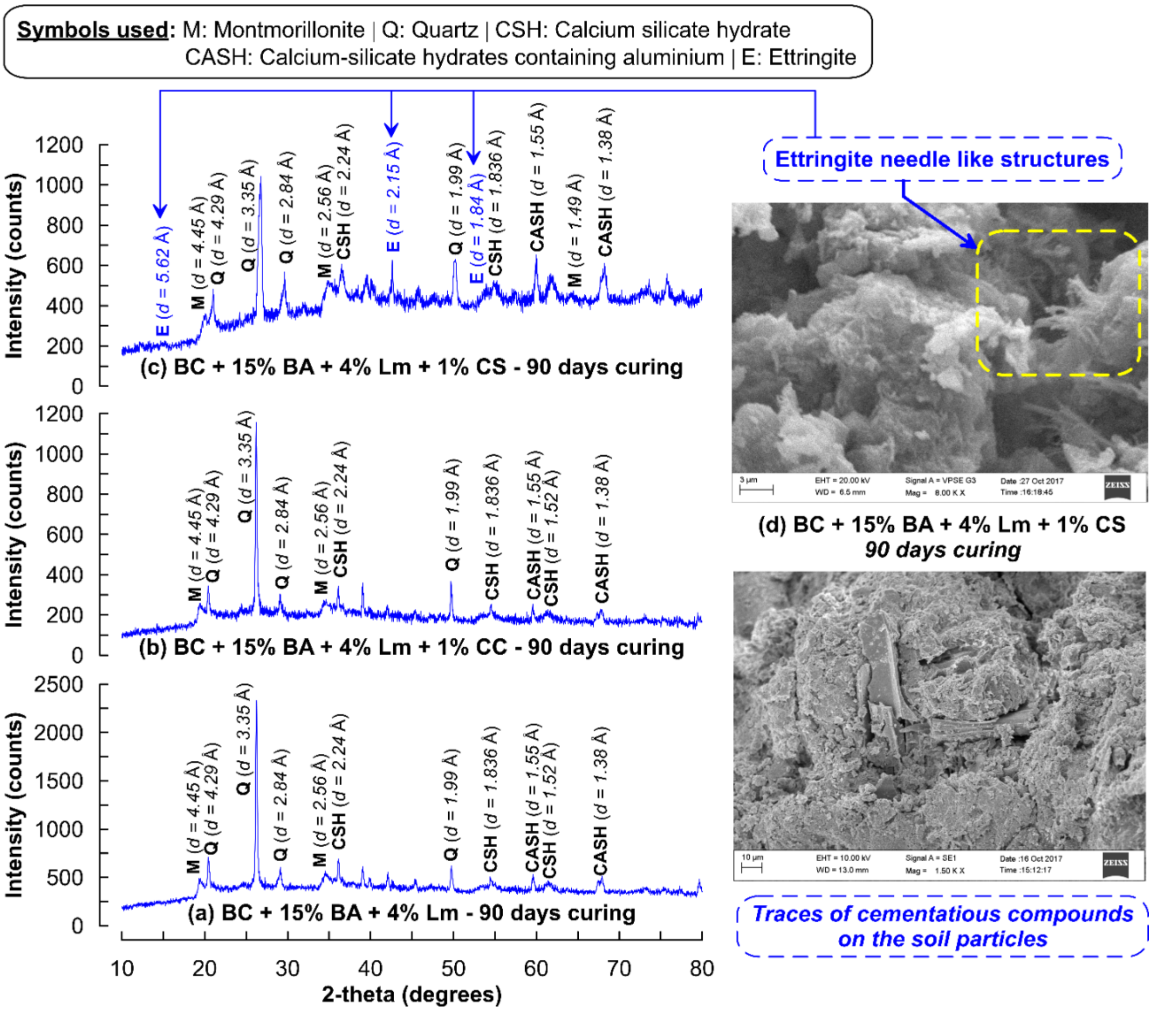

Fig. 7 Comparison of the XRD patterns and SEM micrographs of the BC soil with 15% BA and 4% Lm with addition of 1% CC and 1% CS

clearly evident to restrict the lime content to 4%, which can be termed as the optimum lime content for stabilizing BC soils supplemented with 15% BA content. This trend and observations also agree well with the test records obtained for samples processed after 7 days of curing periods.

Fig. 6 shows and compares the effect of calcium sulphate and calcium chloride salts on the compaction behavior and UCS values of the BC soil supplemented with optimum values of BA (15%) and lime (4%). Literature evince that high amounts of calcium sulphate is detrimental to the lime treated expansive soil (Wild *et al.* 1993), thus it was deemed important to study the effect of CS and CC on the BC soil with admixtures. Observations from Fig. 6(a) explains that the compaction behavior was not significantly affected due to the addition of either CS or CC salts. Except that the optimum *w* for the samples with CS and CC was marginally higher than for the samples – BC + 15% BA + 4% Lm. This marginal increase in *w* relates to addition of calcium salts (McCarthy *et al.* 2012). On the other hand, the UCS results (Fig. 6(b)) overall show similar observations with gradual increase in UCS values with curing period for both CC and CS. The increasing UCS for samples mixed with CC are due to the formation of cluster in presence of water, reducing the voids in soil's matrix and stronger bonding, thus improving the strength (Manoj Krishna 2012). However, one obvious observation is the sudden decrease in the UCS for BC samples with 15% BA, 4% Lm and 1% CS. The initial gain in UCS attributes to the formation of Ettringites – hydrous calcium aluminum sulphate minerals, which facilitates with interlocking of the crystal structure within the soil's matrix. Ettringites are formed when sulphate ion reacts with the calcium from lime and alumina from the BC soil (Hunter 1988). The decrease in UCS with curing up to 90 days, corresponds to increased growth of Ettringite needles which further is likely to reduce the strength of the test sample (Sivapullaiah *et al.* 2000, Sivapullaiah and Jha 2014). The presence of Ettringites most likely causes expansion in the clay matrix – they absorb water and cause inter-particle repulsion, thereby resulting in expansion of the clay matrix (Little *et al.* 2010). Thus decrease in strength due to the expanding soil is the most relevant explanation for sudden drop in the unconfined compressive strength of the BC soil when supplemented with 15% BA, 4% lime and 1% CS. Similar results or behavior was also observed in the literature (Sivapullaiah *et al.* 2000, Sivapullaiah and Jha 2014).

Fig. 7 presents visuals of the mineralogical (XRD) and microstructural (SEM) analysis of the 90 days cured BC samples mixed with 15% BA, 4% Lm and 1% CS/CC to identify and support the above discussions of Ettringite formation in the samples. Formation of Ettringite typically appear as needle like structures in the soil matrix. Figs. 7(a)-(c) presents the XRD patters of the BC + 15% BA + 4% Lm, BC + 15% BA + 4% Lm + 1% CC, and BC + 15% BA + 4% Lm + 1% CS respectively. Fig. 7(c) clearly highlights the broad peaks of the Ettringite needles appearing at d-spacing of 5.62 Å, 2.15 Å and 1.84 Å with Bragg's angles of 16°, 42°, and 52° respectively (Sivapullaiah and Jha 2014). Fig. 7(d) demonstrates visuals of such needle like structures of the Ettringite mineral formed within the matrix of the 90 days cured BC samples mixed with 15% BA, 4% Lm and 1% CS, as observed under scanning electron microscope (SEM). The SEM micrograph also shows the traces of cementitious compounds (white shaded fluffy or spongy appearance) on the soil particles highlighting the products related to pozzolanic activity of the BA, Lm and calcium salt combinations. These observations clearly highlight the formation of Ettringite minerals with CS added to lime and BA stabilized BC soils, thereby limiting the possibility of using calcium sulphate in the lime stabilization of BC soils with or without the addition of BA. Nonetheless, addition of CC did not show any such ill-effects, nor did it show any significant improvement in the compaction behavior or the UCS strength. Though an increase in UCS (of approximately 400 kN/m^2) may be observed at 90 days curing (see Fig. 6(b)), adding CC also marginally increased the optimum *w* value (see Fig. 6(a)). Thus, it is perceived that the increase in UCS in contrast to the additional amount of water and the chemical (CC) itself will add-on to the construction cost, thereby making the process less economic. Moreover, using chemicals on natural ground may also raise questions regarding the environmental impacts, if any, and the sustainability of the stabilization process.

5. Conclusions

This study investigates the suitability of bagasse ash (BA) as admixture with lime for the stabilization of black cotton (BC) soil, with emphasis on the compaction and unconfined compressive strength (UCS) behaviors of the stabilized soil. The effect of increasing BA contents (0 to 30% at 5% increments) on the compaction and UCS values are evaluated to ascertain the optimum BA content. This optimum content was then used to determine the optimum lime content which was experimented starting 0 to 5% at 1% increments. Observations from the laboratory experiments evince 15% BA and 4% lime to produce the best acceptable compaction and UCS behaviors of the stabilized BC soils. The long-term performance of thus stabilized BC soil samples was crucial to evaluate the suitability of adopting BA in practice. For this purpose, calcium sulphate (CS) which have previously been noted as detrimental with lime was also used in this study. Experimental observations show both CC and CS to facilitate the formation of cementitious compounds with lime and BA as anticipated. However, an in-depth mineralogical and microstructural analysis reveal the formation of Ettringite mineral for the sample with 15% BA, 4% lime, and 1% CS composition cured to 90 days. The sample also showed a decrease in the UCS value, thereby signifying the effect of excessive Ettringite formations.

To this end, adoption of BA in lime stabilization show convincing results, with the pozzolanic activity of BA complimenting the expected pozzolanic reaction in lime stabilization. At the same time, incorporation of BA reduces the amount of lime required for this purpose, and provide a convenient disposal opportunity for the BA – a waste or by-product. Contrarily, addition of calcium salts, CS particularly, is strongly discouraged owing to the formation of the detrimental Ettringite minerals with curing period. Though increase in UCS was observed with CC, the additional amount of water (due to higher optimum *w*) and the chemical (CC) itself will add-on to the construction cost, thereby deemed to making the process less economic. Further studies focusing on the compaction and strength behaviors is recommended using different expansive clay samples to further strengthen the understanding and interaction of BA-lime mixtures with such clays. This study forms the preliminary attempts assessing the suitability of BA-lime mixtures for soil stabilization and possible adoption in field.

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