# Statistical Evaluation of the Effect of Elapse time on the Strength Properties of Lime-Bagasse Ash Treated Black Cotton Soil

Ochepo, J.[1] and Osinubi, K. J.[1], J. A. Sadeeq[1]

[1]Department of Civil Engineering, Ahmadu Bello University, Zaria, Nigeria

A laboratory study of the effect of elapse time on compaction, UCS and durability of black cotton soil treated with 4 % lime and 0 to 8 % bagasse ash was carried out. Compaction and unconfined compressive strength tests were carried out to determine the effect of elapse time on maximum dry density, MDD, optimum moisture content, OMC and unconfined compressive strength, UCS, of the mixes. The results obtained show a decrease in MDD, OMC, UCS and resistance to loss in strength, RLS (Durability), as elapse time increased. A statistical analysis of the results carried out to determine the effect of elapse time, curing period and bagasse ash content on MDD, OMC, UCS and RLS shows that the effect of elapse time and bagasse ash content on MDD are statistically significant at 5 % level. The effect of elapse time on OMC is statistically significant while the effect of bagasse ash content is not, the *p*-value being greater than α = 0.05. The relative contribution of bagasse ash, curing period and elapse time on UCS and RLS was statistically significant at α = 0.05. Of the three variables, the contribution of curing period was observed to be comparably more significant. From the combine results of the UCS and RLS, it can be concluded that elapse time exceeding 1 hour could result in significant strength lost for all practical purposes.

*Key words:* Elapse time; Compaction; Durability; Bagasse ash; Statistical significant; unconfined compressive Strength

## 1.0 INTRODUCTION

Black cotton soils are expansive soil by nature, exhibiting the dual characteristic of swell-shrinkage during wetting-drying seasons. These characteristics of the soil results in significant volume change causing excessive swelling pressure when wet and shrinking extremely when dried, developing cracks, often measuring 70 mm wide and 1.0 m deep (Adeniji,1991), and may extend up to 3.0 m in case of deep deposit. When wet, the index properties of the soil are high, the bearing value and strength are low.

The soil is found in large deposit in the North-eastern part of Nigeria occupying an area of some 10.4 x 10 $km^2$ (i.e., 400000 sq miles) in the North Eastern fringe of the country (Klinkenberg and Higgins, 1972). Near Maiduguri, the Chad formation is known to be about 550 m (1800 ft) thick. The characteristic features of the soil behaviors which are majorly extensive cracks are obvious on road pavements and building structures constructed on the soil in this part of the country. The distress caused on structures founded on this type of soil world wide amount to billion of dollars (Gourley et al., 1993).



Modifications of black cotton soils by chemical admixtures are a common method for stabilizing the swell-shrink tendency and increasing the strength properties of the soils.

Lime is widely used for treatment of cohesive soils with expansive properties due to its effectiveness in improving expansive properties and controlling volume change. (Chen, 1988; Hausmann, 1990; Osinubi, 1995). Lime has been used to increase strength and decrease plasticity index and swell and shrinkage strain potential of expansive soils and fine-grained cohesive soils. (Hausmann, 1990; Osinubi, 1995).

The strength gain arises chiefly from chemical reactions between the lime, clay-grade minerals and amorphous constituent in the soil. When these are absent or present in small amounts use has been made of lime together with a pozzolan. A pozzolan is defined as “a siliceous or alumino-silliceous material that in itself possess little or no cementitious value but that in finely divided form and in the presence of moisture will chemically react with alkali and alkaline earth hydroxide at ordinary temperatures to form or assist in forming compounds possessing cementitious properties” (ASTM, 1980). Pozzolanic materials such as certain forms of volcanic ash and diatomaceous earth, occur naturally while calcine clays and shale, calcine bauxite waste and pulverized furnace fuel ash also known as fly ash are artificial pozzolanas. Fly ash has been extensively employed as a pozzolan in lime stabilization of soils. Also, Nicholson *et al*. (1994) reported that lime-fly ash admixture has shown tremendous potential as an economic method to update the geotechnical properties of tropical Hawaiian soil. Ashes from agricultuaral waste such as rice husk ash (RHA) and sugarcane bagasse ash (SBA) have been shown to posses pozolanic properties and have been used as admixtures in lime and cement stabilization (Osinubi and Stephen, 2005; Osinubi and Alhaji, 2005).



Mohammedbhai and Baguant (1985) reported that bagasse ash contains a large amount of silica and other relevant oxides which enhance good pozzolanic activity such as aluminum and iron oxide. There has been an extensive study in recent time focusing on the use of bagasse ash as stabilizer/admixture in soil stabilization (Osinubi and Stephen, 2005; 2006a,b: Osinubi and Alhaji, 2005; Osinubi and Eberemu, 2006; Osinubi et al., 2007a,b,c; 2008a,b). The ash has also been used as admixture along with lime and cement in stabilizing black cotton soil (Osinubi et al., 2008a,b).

It was reported that kaolin required an addition of 4-6% of lime for maximum strength development and the strength gain commenced immediately upon addition of lime. On the other hand, montmorillonite and illite minerals required lime in excess of 4-6% before there was gain in strength, (Eades and Grim, 1962).

The effect of delay between mixing and compaction (elapse time) on final strength properties of soil-lime mix was investigated by Mitchell and Hooper (1961); Osinubi, (1998a;1999b) as well as Osinubi and Katte, (1997). A decrease in compaction and strength properties of the lime treated soil was reported especially at higher lime content. Osula (1996) reported that modification of soils continued with time both for lime and cement modified laterite studied. Mitchell and Hooper (1961) reported that soil-lime samples compacted within 1 hour after mixing had higher strength than those compacted after 24 hours. Osinubi and Nwaiwu (2006) reported a decrease in maximum dry density and CBR when compaction was delayed after mixing.



The aim of this study is evaluate the effect of elapse time between mixing and compaction on moisture-density, strength and durability of lime stabilized expansive black cotton soil treated with bagasse ash. The soil was stabilized with 4 % lime and treated with 0, 2, 4, 6, and 8 % bagasse ash.

## 2.0 MATERIALS AND METHODS

### 2.1 Material

***Soil:*** The black cotton used in this study was obtained from Deba in Gombe State in the North Eastern part of Nigeria. The soil was collected by method of disturbed sampling. The top soil was removed to a depth of about 0.5 m and the soil samples were taken below 0.5 m, sealed in plastic bags and put in sacks. This was done to avoid loss of moisture during transportation. The soil was transported to the laboratory, air dried and pulverized to obtain particles passing through British Standard No. 4 sieve, (4.75 mm aperture). The lime used was a hydrated lime obtained from National Research Institute for Chemical and Leather Technology (NARICT), Zaria. While the bagasse ash used was obtained from local sugar manufacturing mills in Anchau, Kaduna State. The ash was passed through British Standard No. 200 sieve (75 µm aperture) to obtain the fraction passing sieve No. 200 which was sealed in plastic bags and used for the tests.

## 2.2 Methods

Laboratory tests were conducted to determine the index properties of the black cotton soil in accordance with BS 1377 (1990). Tests involving moisture – density relationship and unconfined compressive strength and durability were carried out using air dried soil samples passed through sieve with 4.76 mm aperture. The British Standard light (BSL), compactive effort was used to prepare specimens in accordance with BS 1377 (1990) and BS 1924 (1990). The black cotton soil was mixed with 4 % lime to form black cotton soil – lime mixture. The mixture was in turn treated with bagasse ash in stepped increment of 0 % up to 8 % by weight of the soil to obtain different samples of black cotton soil – lime - bagasse ash mixtures**.**

### *2.2.1 Moisture-Density test*

The moisture-density relationship of the soil and the soil-lime-bagasse ash mixture was determined by compaction test in accordance with BS 1377 (1990) Part 4: 3.3 and BS 1924 (1990) using the British Standard light (standard Proctor) compactive effort. The soil-lime-bagasse ash mixture were mixed thoroughly with associate amount of water and left for elapse time of 0, 1, 2, and 3 hours before compaction. A minimum of five determinations was conducted within which the optimum moisture content was obtained.

### *2.2.2 Unconfined compressive strength*

The unconfined compression test was carried out in accordance with BS1377: (1990) Part 7. The samples of soil and soil-lime-bagasse ash mixture were prepared by mixing the desired proportions of potable water, soil, lime and bagasse ash. The percentages of lime was 4 % and bagasse ash ranged from 0 to 8 % by weight of dry soil, respectively. The soil-lime-bagasse ash mixtures were first thoroughly mixed in a tray to obtain a uniform color. The require amount of water determined from moisture-density relationships for soil-lime-bagasse ash mixtures was added to the dry soil-lime-bagasse ash mixture and left for elapse time of 0, 1, 2, and 3 hours before compaction at the energy of standard Proctor. Specimens were cured for 7, 14 and 28 days in the case of the unconfined compression whereas the durability assessment of the soil-lime-bagasse ash and the admixture was done by the immersion in water tests for the measurement of resistance to loss in strength, RLS. The resistance to loss in strength was determined as the ratio of the UCS of specimen wax cured for 7 days, de-waxed top and bottom and then immersed in water for another 7 days to the UCS of specimen wax-cured for 14 days.



## 3.0 RESULTS AND DISCUSSION

### 3.1 Preliminary results and soil classification

The soil is predominantly fine-grained. It is greyish - black in colour with a liquid limit of 60%, plastic limit of 22% and plasticity index of 38%. From the combine results of the Atteberge limits and the sieve analysis the, soil was classified as CH or A-7-6 using the Unified Soil Classification System (USCS) and AASHTO classification, respectively. The maximum dry density and unconfined compressive strength of the natural soil are 1.47 Mg/m$^3$ and 173 kN/m$^2$ respectively.

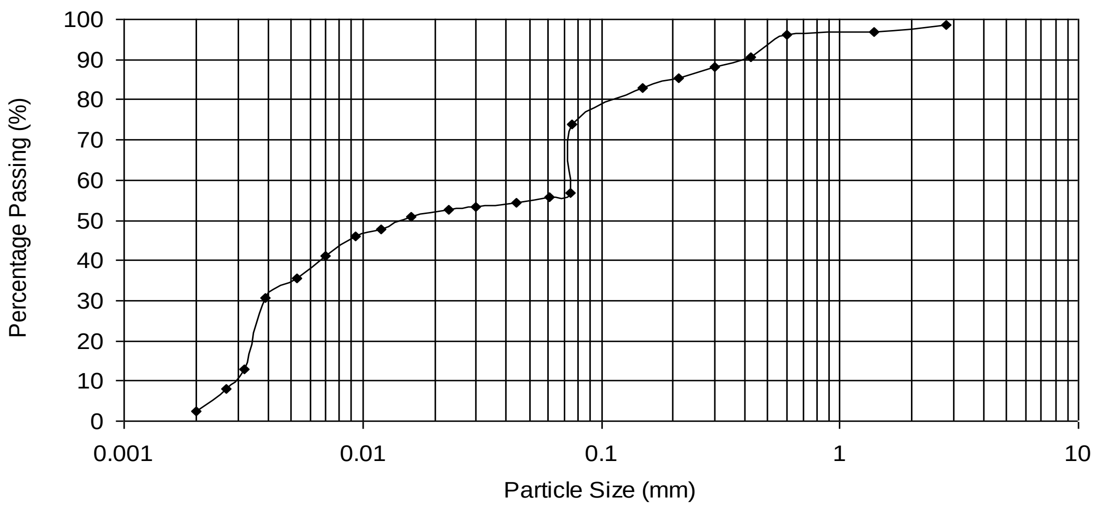


Fig.1: Paticle Size Distribution of Natural Black Cotton Soil



**TABLE 1: Index Properties of Natural Soil**

| Property | Quantity |
|---|---|
| Natural moisture content (%) | 5.1 |
| Liquid Limit, (%) | 60 |
| Plastic Limit, (%) | 22 |
| Plasticity Index, (%) | 38 |
| Linear Shrinkage, (%) | 20 |
| AASHTO classification | A-7-6 |
| USCS classification | CH |
| Specific Gravity | 2.35 |
| Maximum Dry Density (Mg/m$^3$) | 1.47 |
| Color | Grayish black |
| Dominant clay mineral | Montmorillonite |

### 3.2 Effect of elapse time on Maximum dry density and Optimum moisture content

The effect of elapse time on maximum dry density and optimum moisture content of the soil-lime mixture treated with 0, 2, 4, 6, and 8 % bagasse ash is shown in Fig 2a and b. The dry density generally decreased with increase in elapse time for all bagasse ash treatment. Similarly, the optimum moisture content decreased with increasing elapse time. This finding is consistent with the results of Osinubi and Nwaiwu (2006). They reported a decrease in maximum dry density and CBR when compaction was delayed after mixing. This may be attributed to the fact that when compaction is delayed, hydration products which bind particles in a loose state are formed. A disruption of these aggregations is required to densify the soil. Therefore, a portion of the compaction energy is used in overcoming the cementation hence the maximum dry density is reduced with increasing elapse time. The magnitude of reduction is expected to be dependent on time and the rate at which hydration products are formed. At zero elapse time, maximum dry density decreased with increasing bagasse ash content. Similar trend were reported by Hausmann, (1990) and Osinubi (1999).



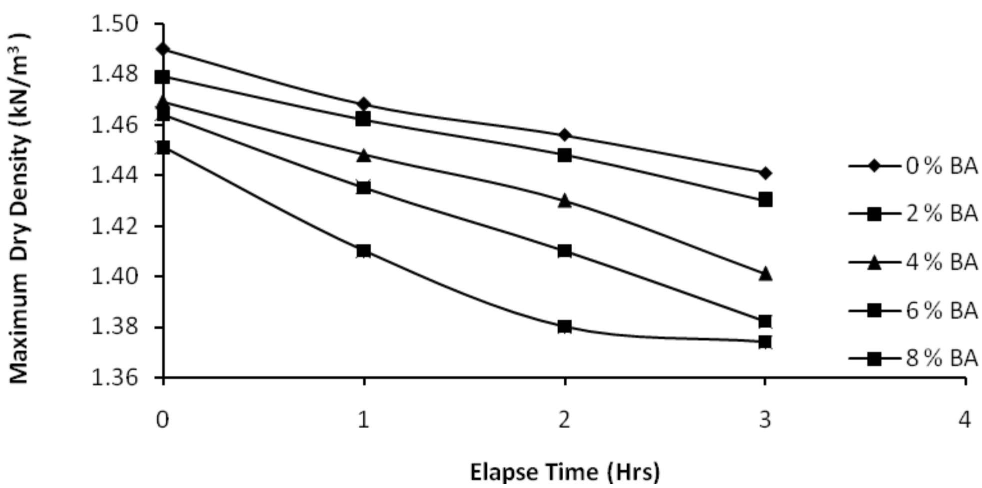


Fig 2a: Variation of maximum dry density with elapse time

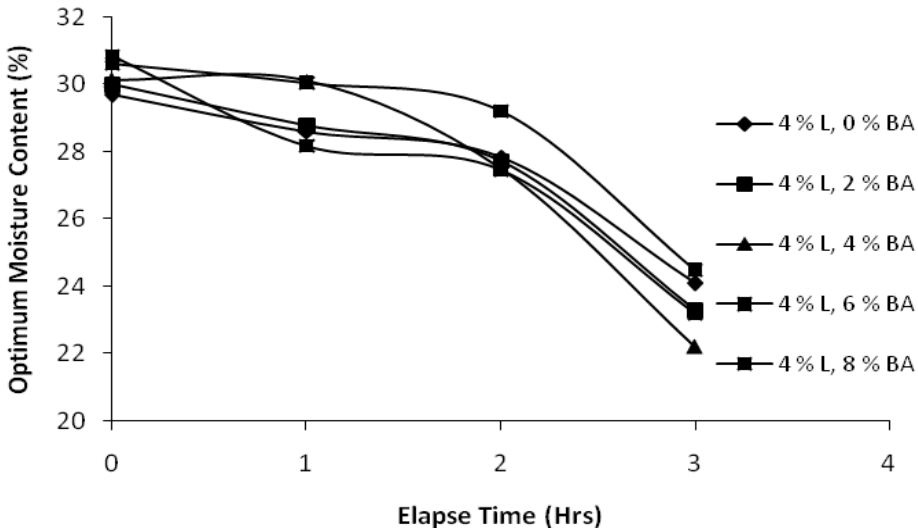


Fig 2b: Variation of optimum moisture content with elapse time



### 3.3 Effect of elapse time on UCS

The effect of elapse time on UCS at various curing age are shown in Figure 3 a, b and c respectively. Generally, the UCS decreased with increased elapse time at all bagasse ash treatment and curing age. At zero elapsed time, UCS generally increases as bagasees ash content increased. The peak value of UCS was observed at 8 % bagasse ash treatment after 28 days curing. The effect of elapse time on the resistenace to loss in strength (durability) of the specimen tested is shown in Figure 4. The resistance to loss in strength of the specimen reduced drastically with increasing elapse time for all bagasse ash treatment. On the average, the loss in strength of the specimen after immersion in water was about 70 %.

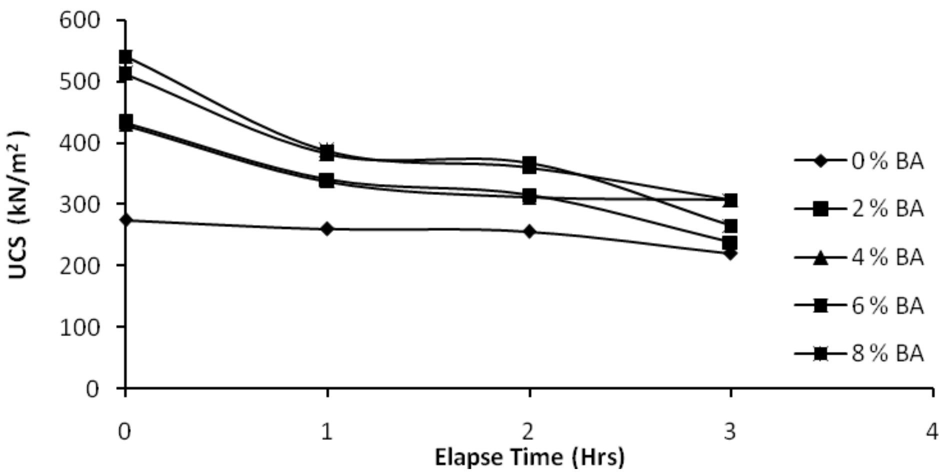


Fig 3a: Variation of unconfined compressive strength with elapse time (7 days curing)



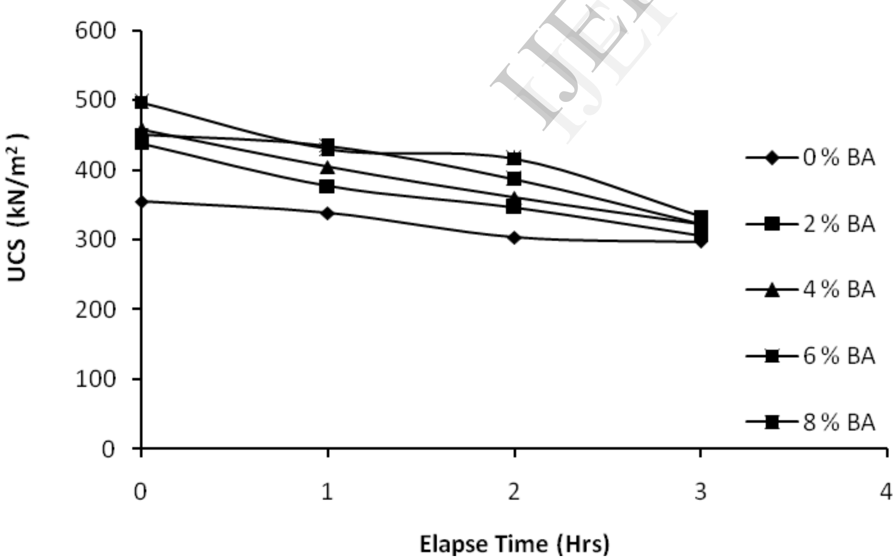


Fig 3b: Variation of unconfined compressive strength with elapse time (14 days curing)

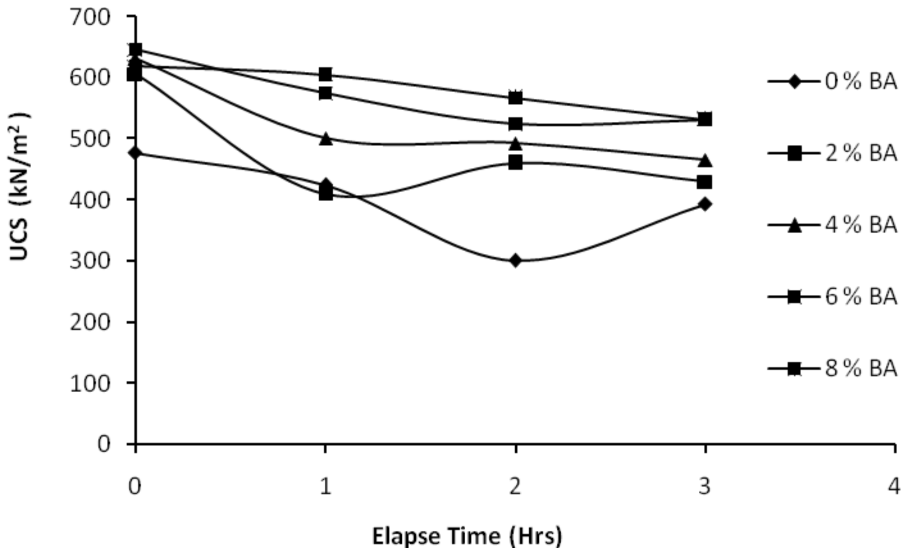


Fig 3c: Variation of unconfined compressive strength with elapse time (28 days curing)

### 3.4 Statistical analysis

A two way analysis of variance (Osinubi and Nwaiwu, 2006), was employed to check the effect of elapse time and bagasse ash content on the Compaction, UCS and RLS (durability) of the soil-lime mixture treated with bagasse ash. The relative effect of curing age and elapse time was also investigated. The calculated *F*-values shows the ratio of the between samples sum of squares to the error sum of square, which expresses the idea that the quantity estimates random error. It is considered to be the value of a random variable having the *F* distribution with k-1 and k(n-1) degrees of freedom. The letter n represents the number of observations while k is the population or sample means. The critical *F*-value is the upper limit of the *F* ratio and this can be found in statistical books. The *p*-value is the tail probability for a given distribution. The *p*-value will be less than 0.05 for (5 % level of significance) whenever the calculated *F*-value is grater than the critical F-value which is indicative of the existence of statistical significance in relation to the contribution of a given variable (Osinubi and Nwaiwu, 2006).

### *3.4.1 Statistical evaluation of elapse time on MDD and OMC of soil-lime-bagasse ash mixture*

The relative effect of elapse time and bagasse ash content on MDD and OMC are shown in Table 2 and 3 respectively. The two way analysis of variance shows that the effect of elapse time and bagasse ash content on MDD are statistically significant at 5 % level since the *p*-values are less than 0.05. The effect of elapse time on OMC is statistically significant while the effect of bagasse ash content is not, as can be seen from the *p*-value which is greater than 0.05 and the calculated *F*-value which is less than *F-critical*.

**Table 2: Two way analysis of variance for MDD with elapse time**

| Property | ***Source of Variation*** | ***Degree of freedom*** | ***F-value calculated*** | ***P-value*** | ***F critical*** |
|---|---|---|---|---|---|
| MDD | Elapse Time | 3 | 53.421 | 3.25E-07 | 3.490 |
| | Bagasse ash cont. | 4 | 32.293 | 2.45E-06 | 3.259 |



**Table 3: Two way analysis of variance for OMC with elapse time**

| **Property** | ***Source of Variation*** | ***Degree of freedom*** | ***F-value calculated*** | ***P-value*** | ***F critical*** |
|---|---|---|---|---|---|
| **OMC** | Elapse Time | 3 | 101.595 | 8.52E-09 | 3.490 |
| | Bagasse ash cont. | 4 | 2.301 | 1.18E-01 | 3.259 |

### *3.4.2 Statistical evaluation of elapse time on UCS of soil-lime-bagasse ash mixture*

The relative effects of elapse time and bagasse ash content on UCS values are shown in Table 4. The two analysis of variance shows that the effect of elapse time and bagasse ash content on UCS are statistically significant at 5 % level since the *p*-values are less than 0.05. The calculated *F*-value shows that elapse time contribute more to variation of UCS especially at 14 days curing. The contribution of elapse time is however slightly less than the effect of bagasse ash at 28 days curing as can be observed from the calculated *F*-value. From the results, both elapse time and bagasse ash content contributes significantly to variation of UCS. The calculated *F*-values were greater than the *F*-critical at all curing age.

**Table 4: Two way analysis of variance for UCS with different curing days and elapse time**

| **Property** | ***Source of Variation*** | ***Degree of freedom*** | ***F-value calculated*** | ***P-value*** | ***F critical*** |
|---|---|---|---|---|---|
| **UCS** | | | | | |
| 7 Days | Elaspe Time | 3 | 18.938 | 7.61E-05 | 3.490 |
| | Bagasse ash cont. | 4 | 9.641 | 9.96E-04 | 3.259 |
| 14 Days | Elaspe Time | 3 | 37.561 | 2.23E-06 | 3.490 |
| | Bagasse ash cont. | 4 | 14.443 | 1.54E-04 | 3.259 |
| 28 Days | Elaspe Time | 3 | 12.317 | 5.66E-04 | 3.490 |
| | Bagasse ash cont. | 4 | 15.412 | 1.13E-04 | 3.259 |



Table 5 is the results of the two way analysis of variance which shows the relative effect of curing age and elapse time on UCS values. The contribution of curing age and elapse time are all statistically significant, the *p*-values being less than 0.05 except for 0 % elapse time where the *p*-value is greater than 0.05. Judging from the calculated *F*-values, curing age has more significant effect on UCS than elapse time because the calculated *F*-value is grater than the corresponding values for elapse time. All the *F*-values calculated are greater than *F*-critical.

Similarly, the relative contribution of curing age and bagasse ash content to UCS at various elapse times are shown in Table 6. The two way analysis of variance results show that the contribution of both the curing age and bagasse ash content are statistically significant at $\alpha$ = 0.05. This is because the *p*-values are less than 0.05 and the calculated *F*-values are greater than the corresponding *F*-Critical. It can also be seen from the results that the calculate *F*-values for bagasse ash content, which indicates the relative contribution of bagasse ash decreased as the elapse time increase from a value of 13.242 at 0hr elapse time to 4.683 at 3hrs elapse time.

**Table 5: Two way analysis of variance for UCS with different Bagasse ash and elapse time**

| Property | *Source of Variation* | *Degree of freedom* | *F Calculated* | *P-value* | *F critical* |
|---|---|---|---|---|---|
| **UCS** | | | | | |
| 0 % SBA | Curing Age | 2 | 15.790 | 4.07E-03 | 5.143 |
| | Elapse Time | 3 | 3.023 | 1.15E-01 | 4.757 |
| 2 % SBA | Curing Age | 2 | 20.341 | 2.12E-03 | 5.143 |
| | Elapse Time | 3 | 13.683 | 4.31E-03 | 4.757 |
| 4 % SBA | Curing Age | 2 | 109.524 | 1.90E-05 | 5.143 |
| | Elapse Time | 3 | 37.159 | 2.86E-04 | 4.757 |
| 6 % SBA | Curing Age | 2 | 32.664 | 5.95E-04 | 5.143 |
| | Elapse Time | 3 | 10.748 | 7.93E-03 | 4.757 |
| 8 % SBA | Curing Age | 2 | 30.071 | 7.46E-04 | 5.143 |
| | Elapse Time | 3 | 10.264 | 8.89E-03 | 4.757 |



**Table 6: Two way analysis of variance for UCS with different curing days and elapse time**

| Property | *Source of Variation* | *Degree of freedom* | *F-value calculated* | *P-value* | *F critical* |
|---|---|---|---|---|---|
| **UCS** | | | | | |
| 0hr | Curing Age | 2 | 34.270 | 1.19E-04 | 4.459 |
| | Bagasse ash cont. | 4 | 13.242 | 1.33E-03 | 3.838 |
| 1hr | Curing Age | 2 | 31.356 | 1.64E-04 | 4.459 |
| | Bagasse ash cont. | 4 | 9.054 | 4.58E-03 | 3.838 |
| 2hrs | Curing Age | 2 | 21.528 | 6.03E-04 | 4.459 |
| | Bagasse ash cont. | 4 | 8.668 | 5.25E-03 | 3.838 |
| | Curing Age | 2 | 67.430 | 9.83E-06 | 4.459 |
| 3hrs | Bagasse ash cont. | 4 | 4.683 | 3.05E-02 | 3.838 |

The results of the two way Analysis of variance s carried out to evaluate the effect of elapse time and bagasse ash content on the resistance to loss in strength is shown in Table 7. From the result, the relative effect of elapse time and bagasse ash content are statistically significant α=0.05. The values of *p* being less than 0.05 and the calculated *F*-values being grater than *F*-critical. From the calculated *F*-value, the relative contribution of elapse time was more than bagasse ash content, the calculated *F*-value being about 8 times.

**Table 7: Two way analysis of variance for UCS with different curing days and elapse time**

| **Property** | ***Source of Variation*** | ***Degree of freedom*** | ***F-value calculated*** | ***P-value*** | ***F critical*** |
|---|---|---|---|---|---|
| **UCS** | Elapse Time | 3 | 75.306 | 4.72E-08 | 3.490 |
| | Bagasse ash cont. | 4 | 9.160 | 1.24E-03 | 3.259 |

## 4.0 Conclusion

A laboratory study of the effect of elapse time on compaction, UCS and durability of black cotton soil treated with 4 % lime and 0 to 8 % bagasse ash was carried out. The results obtained show a decrease in MDD, OMC, UCS and resistance to loss in strength (durability) as elapse time increased. A statistical analysis of the results carried out show shows that the effect of elapse time and bagasse ash content on MDD are statistically significant at 5 % level since the *p*-values are less than 0.05. The effect of elapse time on OMC is statistically significant while the effect of bagasse ash content is not, as was seen from the *p*-value which is greater than 0.05 and the calculated *F*-value which is less than *F-critical.* Similarly the relative contribution of bagasse ash, curing period and elapse time on USC was statistically significant at α = 0.05 with the contribution of curing age being comparably more significant. The relative effect of elapse time on resistance to loss in strength was also observed to be more significant. From the combine results of the UCS and resistance to loss in strength, it can be concluded that elapse time exceeding 1 hour could result in significant strength lost for all practical purpose.

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