EFFECT OF COMPACTION DELAY ON THE STRENGTH OF CEMENT STABILISED LATERITIC SOIL

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Abstract

Soil stabilisation is a major technique in enhancing the engineering properties of Lateritic soil. There is need to investigate the effect of scenarios when there is elapsed time between when the soil-cement is mixed and when it is spread and compacted. Therefore, this study focussed on the influence of this compaction delay on the engineering properties of cement-stabilised lateritic soil. The lateritic soil was stabilised with 1.5, 3.0, 4.5 and 6.0% cement by weight of soil. The mixture of the soil-cement was left for elapsed time of 1, 3, and 5 h. The natural, stabilised and the stabilised soils with compaction delay were subjected to Sieve analysis, LL, PL. BSL, WAS and AASHTO compaction, UCS and CBR tests. The natural soil was suitable for highway construction except for base course. The MDD of the stabilised soil decrease while the MDD, UCS and CBR increase with increase in cement content. The optimal cement content for the A-2-4(0) soil is 4.5% and the effect of the compaction delay was more prominent after 2 h elapsed time.

Keywords: Lateritic soil, Stabilisation, Highway pavement, Compaction delay, California bearing ratio, Unconfined compressive strength

1.0 Introduction

The usage of Laterite soil in Civil engineering works cannot be overemphasised, it is widely used for the construction of highway pavements, earth dams, filling in building foundations, covers and liners and so on (Osuolale *et al.* 2012; Osinubi and Nwaiwu, 2006). This extensive usage is due to its availability and abundance in the tropics. However, it has some drawbacks such as mechanical and thermal instabilities, strength reduction when in contact with water, swelling potential, volume changes and vulnerability to water, hence the need for stabilisation to enhance its properties and suitability for Civil engineering construction works (Cernica, 1995; Makusa, 2013).

Laterite soils are the product of weathering of rocks mostly due to hot and wet tropical climates and they are rich in Aluminium Oxide (Al_2O_3), Silicon oxide (SiO_2) and Iron oxide (Fe_2O_3). The iron oxide is responsible for the characteristic reddish or reddish brown colouration of lateritic soils, although they may also come in other shades of reddish colouration (Amu *et al*, 2011). Ola (1983) and lately, Adebisi *et al* (2013) reported technical classification of Laterites using the silica-sesquioxide ratio ($SiO_2/(Fe_2O_3 + Al_2O_3)$) as a standard. Laterites were soils with a ratio of less than 1.33 while those with a ratio ranging between 1.33 and 2.00 are lateritic soils, and a ratio greater than 2.00 indicates non-lateritic soil. Laterites are coarse grained with insignificant clay or fine particle contents whereas lateritic soils have more fine particles. Both soils are useful for engineering purposes (Scullion et al, 2005).

Soil stabilisation is the treatment given to natural soil to improve its engineering properties. Soil stabilisation methods can be divided into two categories, namely, mechanical and chemical. Mechanical stabilisation is the blending of different grades of soils to obtain a required grade or application of vibrating or contact pressure roller to reduce the voids in soil mass. while chemical stabilisation is the blending of the natural soil with chemical agents, such as cement, bitumen and lime (Garber and Hoel, 2014). Laterite soils are stabilised because of the problems mentioned earlier. The stabilisation is done traditionally using cement, lime, bitumen and lately industrial and agricultural waste ash such as blast furnace, bio-char, corn cob, sugarcane bagasse ash and so on.

There were scenarios where after mixing cement with soil in order to stabilise it, the grader or the compacting roller broke down or heavy rainfall or other force-majeure that impeded spreading and compacting the stabilised soil. When these occur, the hydration of the cement begins immediately it gets in contact with soil in presence of water. The delay after mixing causes hard lumps to form in the soil that hinders further effective mixing and compaction to high density. The delay leads to a decrease in density and strength of the stabilised soil (Osinubi *et al.*, 2006). West reported that 2 h delay in compaction after mixing soil with stabilising agents resulted in about 50% reduction in strength (Osinubi and Nwaiwu, 2006) . Osinubi and Nwaiwu, 2006 reported that compaction delay has significant influence on the optimum moisture content, maximum dry density, California bearing ratio and unconfined compression strength of Laterite soil stabilised with lime. Similar research by Sagar *et. al.* 2015 findings showed that increase in compaction delay caused compaction and strength characteristics to decrease despite increases in fly ash-lime content. It was also reported that Laterite soil stabilised with cement showed a decrease in strength of about 20% when compaction is delayed for 2 h.

It has been established by previous researchers that compaction delay affects engineering properties of laterite soils stabilised with both lime and cement between 1 and 2 h. Therefore, this research focused on the effect of compaction delay on the properties of Laterite soil stabilised with cement above 2 h.

2.0 Materials and Methods

2.1 Materials

Soil sample

The soil sample used in this research is Laterite from borrow pit around General Hospital, Ogbomoso, Nigeria. It was collected using disturbed sampling method. The soil was air-dry, pulverised and thoroughly mixed. The soil sample was classified using AASHTO method of soil classification.

Cement

The cement used was ordinary Portland cement (OPC) and it was purchased from a local market in Ogbomoso, Nigeria. The cement was used a stabilising agent.

Water

Potable water was used for the preparation of the soil-cement mixture at various moisture contents.

2.2 Methods

The soil-cement samples were prepared with 1.5, 3.0, 4,5 and 6.0% of cement by weight of soil, this was done in accordance with the recommendation of Nigerian General Specifications for Roads and Bridges (Nigerian, 1997). The natural soil sample and the stabilised soil were subjected to the following laboratory tests: Sieve analysis, Liquid limit (LL), Plastic limit (PL), Compaction (British Standard Light (BSL) , West Africa Standard (WAS) and AASHTO), California bearing ratio and Unconfined compressive strength tests. (BS 1377, 1990, FMWH, 1997).

For the effect of compaction delay study, the optimum moisture content from the moisture-density relationships for soil-cement mixtures was later added to the dry soil-cement mixtures and left for elapsed times of 1, 3, and 5 h before compaction at British, West African and AASHTO standard compactions (BS 1377, 1990. FMWH, 1997).

3.0 Results and Discussion

3.1 Properties of the natural soil

The laterite soil sample was classified as A-2-4(0) soil. It is therefore rated as good subgrade soil and gravelly sand in composition (Garber and Hoel, 2014). The percentage of soil passing BS No 200 sieve is 17.35%. It indicates that the soil sample contains less fine particles. The Liquid limit (LL), Plastic limit (PL) and Plastic Index (PI) are 26.0, 17.0 and 9.0% respectively. The results are within Nigerian General Specifications for Roads and Bridges (FMWH, 1997). The results of LL, PL and PI indicate that the natural soil sample contains less clay particles, which makes it less susceptible to swelling when in contact with water. The results of the Optimum moisture content (OPC), Maximum dry density (MDD), California bearing ratio (CBR) and Unconfined compressive strength (UCS) are presented in Table 1. The results indicate that the soil sample is suitable for subgrade and subbase layers construction in highway pavement in accordance with Nigerian General Specifications for Roads and Bridges (FMWH, 1997).

3.2 Properties of the soil-cement mixture

The influence of cement content on the OMC and MDD of the soil-cement mixture without compaction delays are shown in Fiqure 2 and 3 respectively. The MDD decreases with increase in cement content regardless of the compactive efforts used. The decrease in MDD was more pronounced at higher cement content of 4.5 to 6.0%. This trend is similar to the findings of Osinubi and Nwaiwu, 2006; Bello, 2011 and Okonkwo, 2009. The decrease can be attributed to difference in specific gravity of cement and laterite soil. The specific gravity of laterite is greater than that of cement, therefore, the MDD of soil-cement mixture is expected to be decreasing with increase in cement content except if there are formation of transitional compounds that had high densities.

Table 1: Properties of natural laterite soil

Properties	Quantity
Liquid limit (%)	26.0
Plastic limit (%)	17.0
Plastic index (%)	9.0
Percent passing BS No. 200 sieve (%)	17.35
Group index	0
AASHTO classification	A-2-4(0)
Maximum dry density (Mg/mm^3) at BS compaction	1.88
Maximum dry density (Mg/mm^3) at WAS compaction	1.90
Maximum dry density (Mg/mm^3) at AASHTO compaction	1.99
Optimum moisture content (%) at BS compaction	13.4
Optimum moisture content (%) at WAS compaction	12.7
Optimum moisture content (%) at AASHTO compaction	12.0
California bearing ratio (%) at BS compaction	12
California bearing ratio (%) at WAS compaction	46
California bearing ratio (%) at AASHTO compaction	64
Unconfined compressive strength (kN/mm^2)	206
Colour	Reddish- Brown

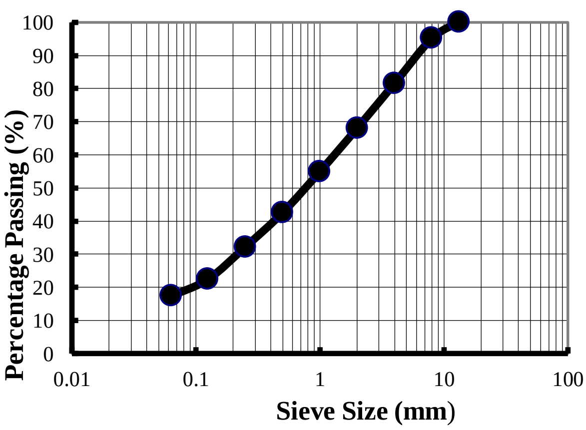

Figure 1: Particle Size Analysis

The OMC increases with increase in cement content for the BS compactive effort. This was attributed to the hydration process taking place in the soil-cement mixture. However, there was decrease in OMC as the cement content increases for WAS and AASHTO compaction energy. The decrease was more noticeable at cement content of 3 to 6%. The trend was not in consonant with the findings of earlier researchers (Osinubi and Nwaiwu, 2006 and Bello, 2011). This could be attributed to either eperimental error or other factors.

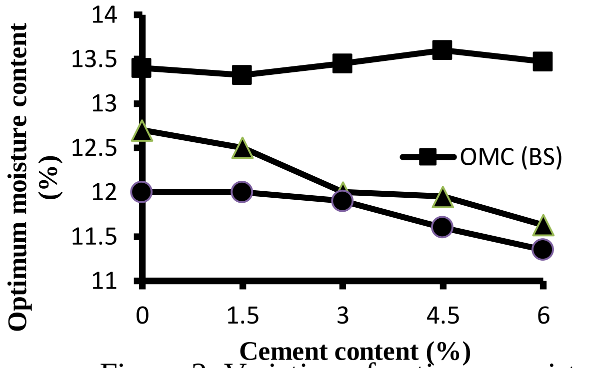

Figure 2: Variation of optimum moistu content with cement content

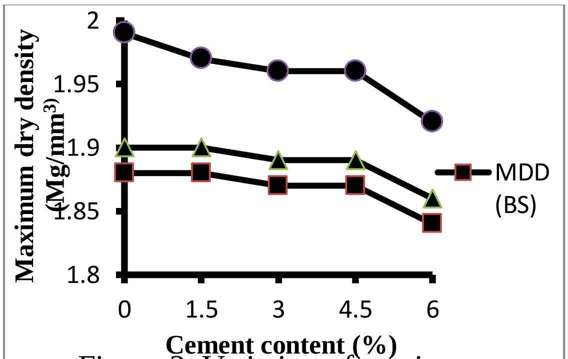

Figure 3: Variation of maximum dry density with cement content

The variations of UCS and CBR with cement content without compaction delays are shown in Figures 4 and 5 respectively. The UCS increases with increase in cement content in the soil-cement mixture. The increase is proportional to increase in cement content as shown in Figure 4. This is as a result of the binding characteristics of the cement. The CBR equally increases with increase in cement content in the soil-cement mixture regardless of the compactive efforts. This increase was attributed to the binding properties of cement. This trend is similar to the work of Osinubi et. al, 2006 and Bello et al., 2010).

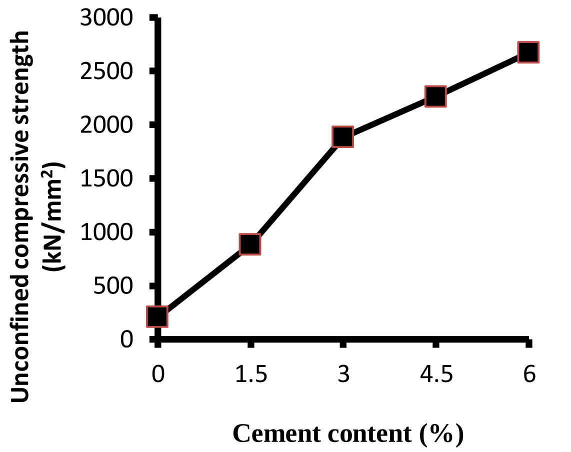

Figure 4: Variation of unconfined compressive strength with cement content

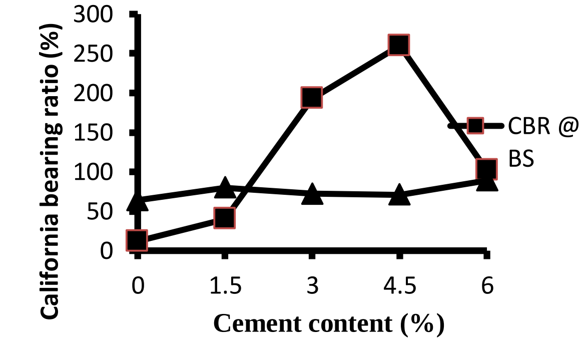

Figure 5: Variation of California bearing ratio with cement content

3.3 Properties of soil-cement mixture with compaction delay

The variations of UCS and CBR with elapsed time after mixing for BS compaction energy for UCS while the compaction energy for CBR are BS and AASHTO are as shown in Figures 6, 7 and 8. There was an observed decrease in the value of UCS regardless of the cement content. The decrease was more noticeable at elapsed time between 1 and 3 h while before 1 and 3 to 5 h were mild. The decrease in UCS was above 50% after 2 h. Similar trend was observed for the CBR at BSL and AASHTO compaction energy. The decrease in strength as a result of elapsed time after mixing was more pronounced for higher cement content. This is in agreement with the work of Okonkwo, 2009. Therefore, elapsed time after mixing before compaction of 2 h is tolerable.

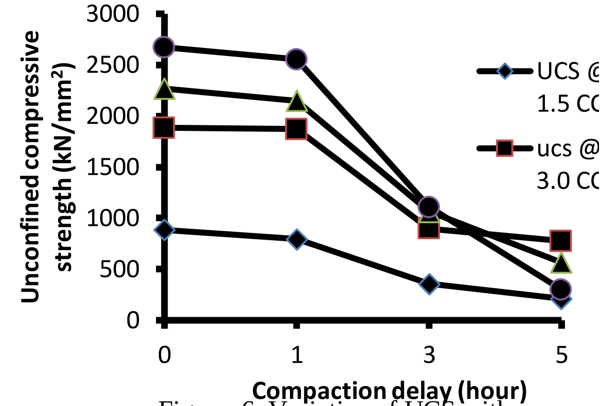

Figure 6: Variation of UCS with compac delay

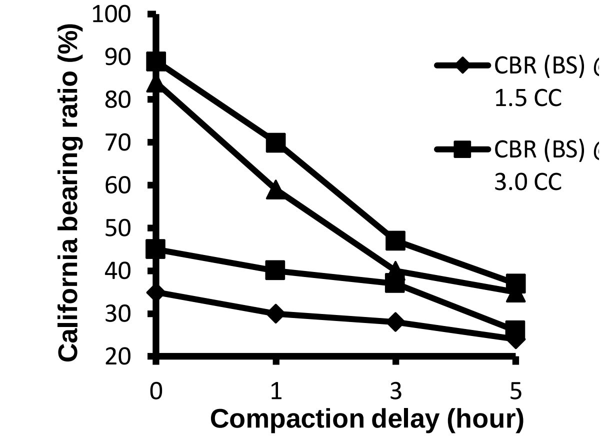

Figure 7: Variation of CBR (BS) with compaction delay

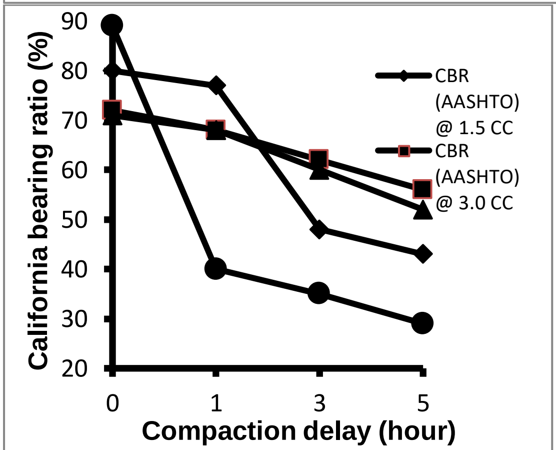

Figure 8: Variation of CBR (AASHTO) with compaction delay

4.0 Conclusion

The optimal cement content for the A-2-4(0) is 4.5% for highway pavement (Base course) construction. The compaction characteristics and strength properties of the soil-cement mixture decrease with increase in compaction delay. It is therefore recommended that not more than 2 h compaction delay should be tolerated during site construction.

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