EFFECT OF COMPACTION DELAY ON THE PROPERTIES OF CEMENT STABILIZED LATERITIC SOILS

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ABSTRACT

Two samples from common existing borrow pits were taken, classified as A-2-6 types of lateritic soils using the AASHTO soil classification method, having group index(GI) of zero (0) which were described as good granular soils, suitable for sub base and sub grade materials. The effect of compaction delay between period zero to three hours in an interval of 30 minutes, for the two samples with addition of cement 1, 2, 3, 4, 5 and 6% for both samples "A" and "B" have been established. For both samples, the Maximum Dry Density is at Optimum (1.956Mg/m^3 at 1.5 hour delay for sample A and 1.840 Mg/m^3 at 0.5 hour delay for sample B) with 1% Cement content and the more the compaction delay, the lower the maximum dry density (MDD) values obtained. The California bearing ratio (CBR) is at optimum (46% at 1.5 hour delay for sample A and 63% at 2.0 hour delay for sample B) with 6% cement content for both samples. CBR values for sample "A" continues to increase with time delay up to 1.5 hours, while CBR values for sample "B" continues to increase with time delay up to 2.0 hours. For fine materials, higher fine (300µm) material with lower cement content (1 and 2%) produced optimum CBR values (30% at 0.0 hour delay for sample A and 32% at 0.0 hour delay for sample B). 6% cement content is recommended for both samples for Optimum values of CBR and UCS, while 1% cement content is recommended for MDD for both samples.

SIGNIFICANCE: Stakeholders in construction industries and government can be sensitized by the findings of the study on the time limit a stabilized soil can still be useful after stabilization before compaction.
KEYWORDS: Lateritic soil, Portland cement, compaction delay. Stabilization, maximum dry density (MDD), soaked CBR.

1.0 INTRODUCTION

Laterite was defined by Smith (1978) as a residual soil formed from limestone after the leaching out of soil rock material by rainwater to leave behind the insoluble hydroxides of iron and aluminium. Similarly, Alexander and Cady (1962) defined laterite as a highly weathered material, rich in secondary oxides of iron, and aluminium or both. It is nearly void of bases and primary silicates but it may contain large amount of quartz and kaolinite. It is either hard or capable of hardening on exposure to wetting and drying. Ola (1978) defined laterite using local terminology as all products of tropical weathering with red, reddish brown or dark brown colour, with or without nodules or concretion and generally (but not exclusively) found below hardened ferruginous crusts or hard pan. Osula (1985) modified the definition of laterite as a highly weathered tropical soil, rich in secondary oxides of any or combination of iron, aluminium of any or a combination of iron, aluminum and manganese.

Laterite soils are the most common reddish tropically pedogenic surface deposit occurring in Australia, Africa and South America. Yet while that differences of opinion exist in regard to their identification and classification than for any other soil type. The existing chemical, geologic-pedological including an understanding of the soil properties such as those of cohesion, resistance to stress, moisture relationships; susceptibility to volume change and reaction to various kinds of additives incorporated for the purpose of moisture or strength stabilization and geotechnical information concerning laterite soils indicate that the terminology used to describe them is not standardized and consequently, numerous in consistencies have developed in the identification, classification and nomenclature of laterite soil. Lateritization or the processes involved in the formation of larerites and lateritic soils include weathering, leaching and hardening. The degree of leaching which involves the residual enrichment of the aluminosilicates and the removal of the lighter particles mainly alkalis is responsible for the wide varieties of lateritic soils and their geotechnical behaviour in the tropical areas of the world (Gidigasu, 1975).

Stabilization is the process of blending and mixing soil and a material to improve the soil's strength and durability. The process may include blending soils to achieve a desired gradation or mixing commercially available additives that may alter the gradation, change the strength and durability, or act as a binder to cement the soil. Soil stabilization is a process of improving the structural quality and workability of soils used for base courses, sub-base courses, select materials and sub-grades for pavements.

Additive refers to a manufactured commercial product that when added to a soil in the proper quantities, will improve the quality of the soil layer. Chemical stabilization is achieved by the addition of proper percentages of Portland cement, lime, lime – cement – fly ash (LCF), or combinations of these materials to the soil. Selection and determining the percentage of additives depends on the soil classification and the degree of improvement in the soil, and quality desired. Smaller amounts of additives are usually required to alter soil properties (such as gradation, workability, and plasticity) than to improve the strength and durability sufficiently to permit a thickness – reduction design. After the additive has been mixed with the soil, spreading and compacting are achieved by conventional means. The addition of the adequate percentage of Portland cement to a soil can modify drastically the properties of the mixture produced independent of the soil used. The importance of cement stabilization of laterite soils has been emphasised by Osinubi (1998).

Although there are some lateritic soils which do not require treatment to give them adequate load bearing capacity, most lateritic soils require some sort of stabilization. The addition of the adequate percentage of Portland cement to a soil can modify drastically the properties of the mixture produced independent of the soil used. However, construction specifications commonly require that compaction and final shaping should be carried out as soon as possible after mixing is completed, but this is not the case. More often there is delay between mixing and compaction of which most of the times are due to equipment failure, and the mixing and construction procedures also relatively difficult hence causing delay between mixing and compaction of the stabilized soils. The aim of this study was to determine the adequate time that can be used to mix and compact a stabilized lateritic soil with cement without loosing the stabilized properties.

2.0 MATERIALS AND METHODS

2.1 Materials

The soil samples used were obtained from two different existing borrow pits outside Katsina metropolis. Sample 'A' was collected at a village called Kabukawa, km 4 along Katsina-Dutsinma road, (Longitude 7° 53' 07" E and Latitude 12° 32' 74" N) and sample B at a village called Barawa, KM12 along Katsina – Batsari road (Longitude 7° 52' 05" E and Latitude 12° 33' 75" N). A study of geological map of Nigeria 1994 shows that the samples taken belong to the group of Cretaceous (Gundumi formation), and soil type is clay plus grits with pebbles beds. Both samples were collected by method of representative or disturbed sampling at a depth of 2.0m and 2.5m respectively. The samples were about 16km apart. The cement used in stabilizing the lateritic soils was Portland cement (Dangote Obajana).

2.2 Methodology

The following tests were conducted immediately the samples were brought to the laboratory some in sacks and others in small polythene bags. This is in order to evaluate the natural engineering properties of the lateritic soil samples as well as the treated samples. The three major materials used for this research work are Dangote Cement, Light brown laterite (sample A) and Gray material (sample B). For cement test (BS 4550) Part 3 – 1978 were critically adhered to for the following tests on Dangote cement: (i) Standard consistency of cement; (ii) Setting time, initial and final setting time of cement; (iii) Soundness test of cements; and (iv) specific gravity test. For laterite material test BS 1377: parts 4 of 1990 were adequately employed for the following test on sample (A) and sample (B) respectively: (i) Moisture content test; (ii) Consistency limits; (iii) Sieve analysis; (iv) Compaction and

CBR test; (v) Unconfined compressive strength test (UCS).

For the improved sample (A) and sample (B), specified percentage of cement were selected due to the Natural classification for sample (A) and (B) respectively for improvement. Sample (A) was improved starting with 1, 2, 3, 4, 5 and 6% of cement with a specific delay starting from 0 min, 30 min, with 30 minutes constant space delay up to 3 hours on each percentage cement improvement to lateritic material after mixing before compaction.

2.3 Fine materials

In sample (A) the Retain in sieve 150 um and the passing through sieve No. 200 was treated in accordance with above specified percentages respectively to determine required properties on delay before compaction to ascertain the reaction of cement during the delay.

Sample (B) was improved with 1, 2, 3, 4, 5 and 6% with a specific delay starting from 0 min to 30 min, with 30 min constant space delay up to 3 hours on each percentage cement improvement to the laterite material after mixing, before compaction to determine the efficiency of the cement due to delay before compaction.

In sample (B), the Retain in sieve 150 μm and the passing through sieve No. 200 was treated in accordance with the specified percent as in sample (B) to determine the required properties on delay after mixing before compaction in relationship with the clay content. The compaction process were based on fill compaction, with 2.5 kg Rammer of 300 mm dropping distance, in three layer of 63 blows each on 152 mm diameter by 127 mm depth C.B.R California Bearing Ratio mould as required for fill material in BS 1377: 1990 (Part 4).

The summary of the natural properties of the soils are shown in Table 1.

Table 1: Summary of the Natural Properties of the Soils

Soil Property	Sample A	Sample B
Colour	Light brown	Grey Ash
Liquid Limit (%)	32	37
Plastic Limit (%)	18	26
Plasticity Index	14	11
Natural Moisture content (%)	3	8
(%) Passing BS No.200	36.70	30.52
AASHTO Classification	A-2-6	A-2-6
Major Clay Mineral	illite	illite
Maximum dry density (Mg/m^3)	1.975	1.863
Optimum moisture content (%)	10%	12.20%
California Bearing Ratio (CBR soaked)	11%	13%
Linear shrinkage	7	5
Unconfined Compressive Strength (UCS) (KN/m^2)	51.09	48.28
Group Index	0	0

3.0 RESULTS AND DISCUSSION

The data generated during the course of the study is presented graphically (Figures 1-10).

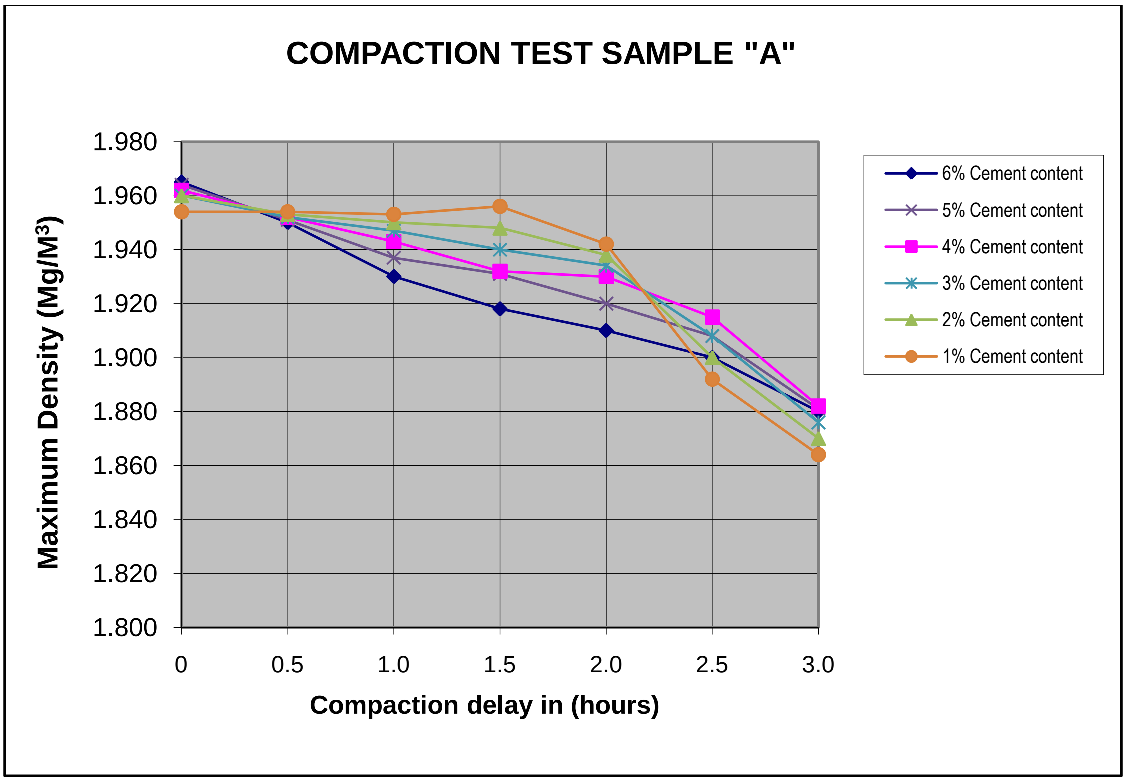

Figure 1: Variation of maximum Dry Density (MDD) with compaction delay on stabilized laterite

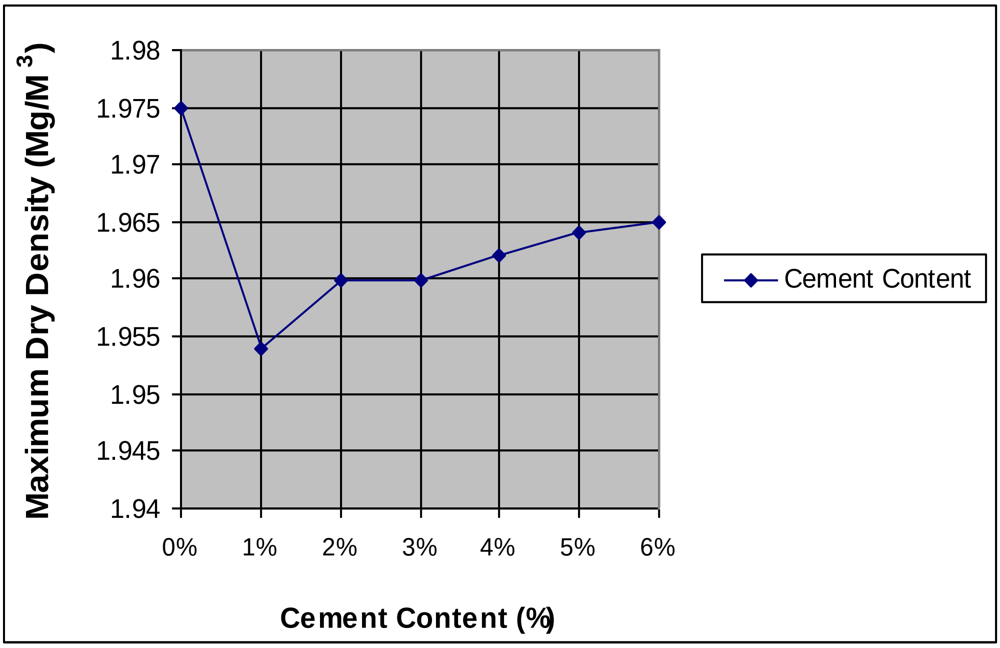

Figure 2: Variation of maximum dry density (MDD) with cement content of stabilized laterite sample 'A' with no compaction delay.

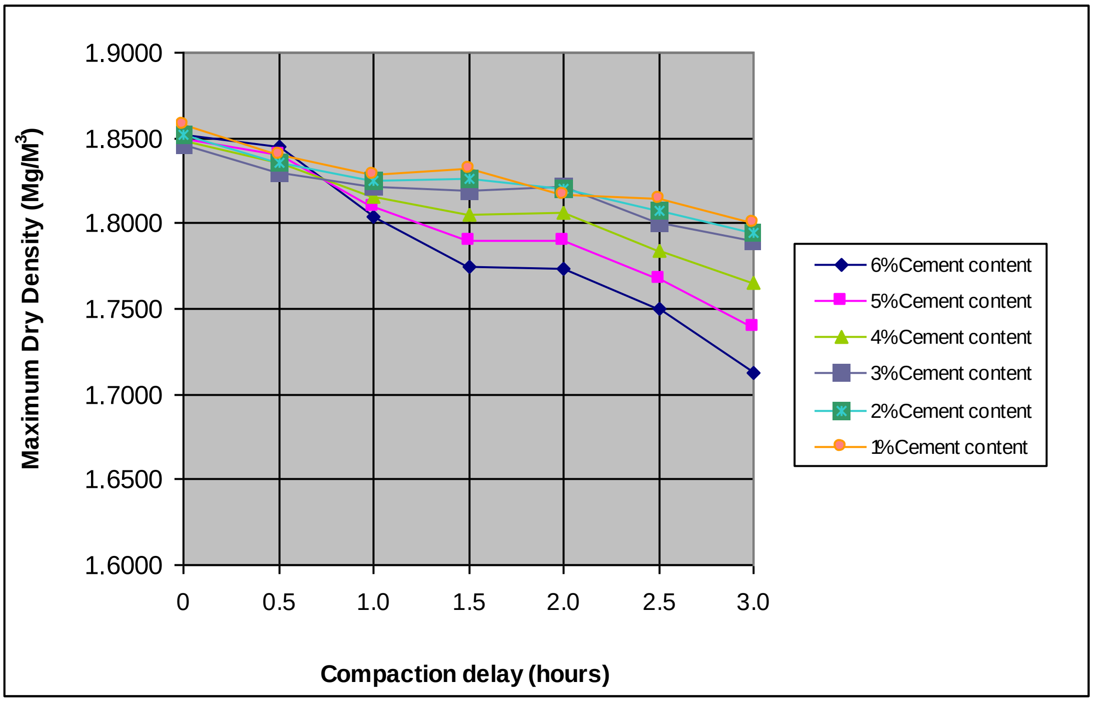

Figure 3: Variation of maximum Dry Density (MDD) with compaction delay on stabilized laterite sample 'B'.

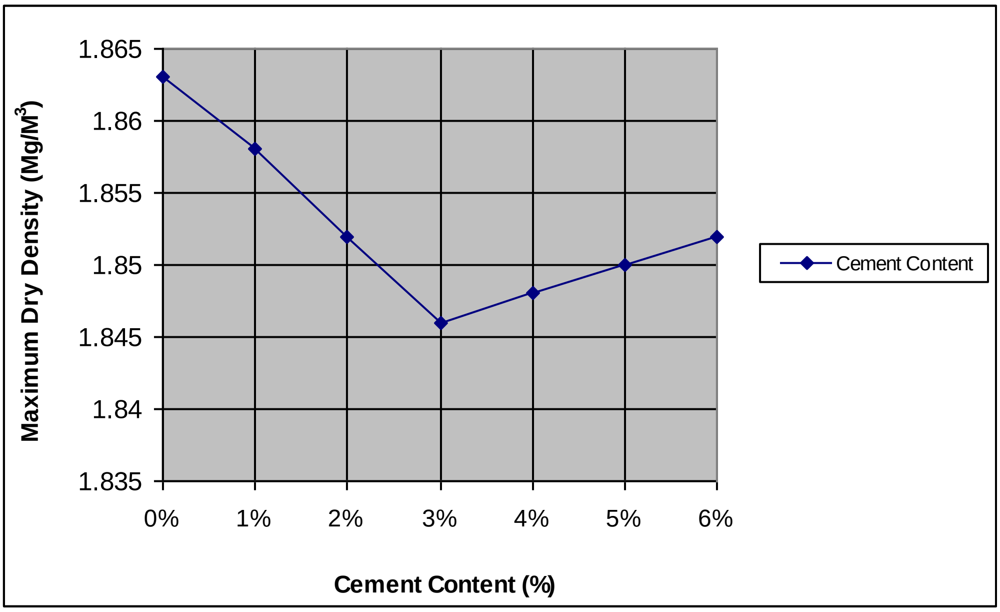

Figure 4: Variation of maximum dry density (MDD) with cement content of stabilized laterite sample 'B' with no compaction delay

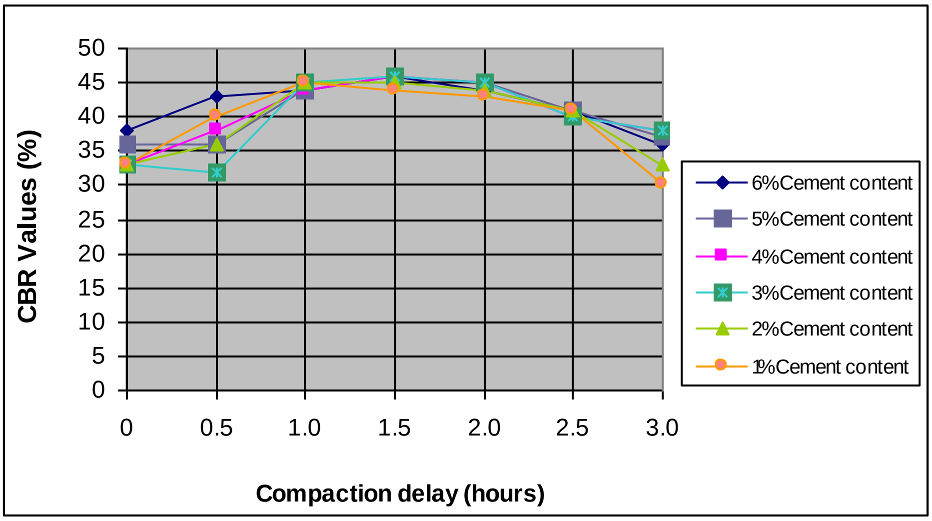

Figure 5: Variation of CBR values with compaction delay on the stabilized laterite sample 'A'.

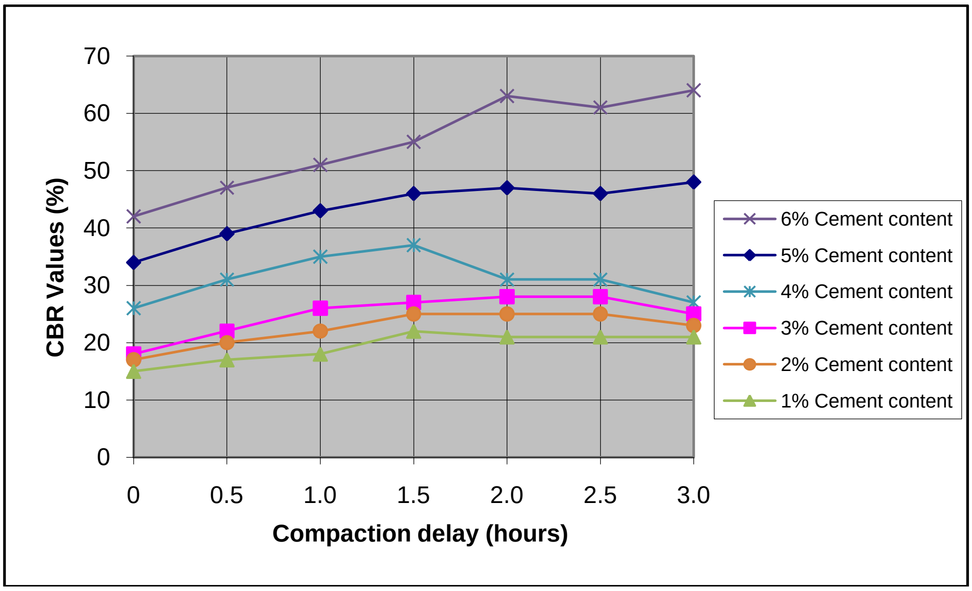

Figure 6: Variation of CBR values with compaction delay on the stabilized laterite sample 'B'.

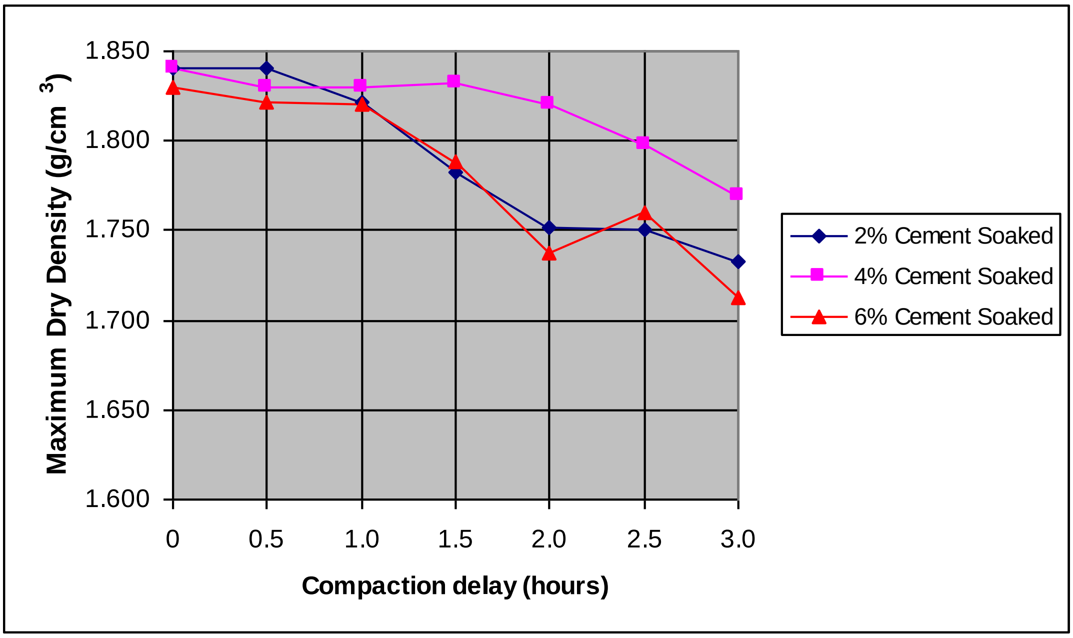

Figure 7: Variation of maximum dry density (MDD) with compaction delay on fine materials retained on 150µm sieve, retained on 75µm sieve and passing sieve 75µm sample 'A'.

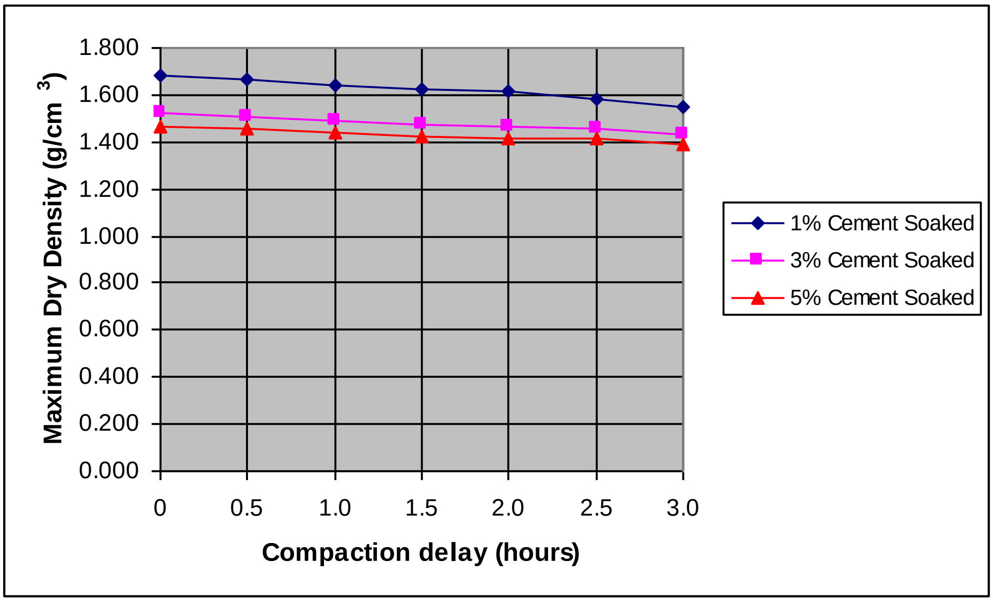

Figure 8: Variation of maximum dry density (MDD) with compaction delay on fine materials retained on 150µm sieve, retained on 75µm sieve and passing sieve 75µm sample 'B'.

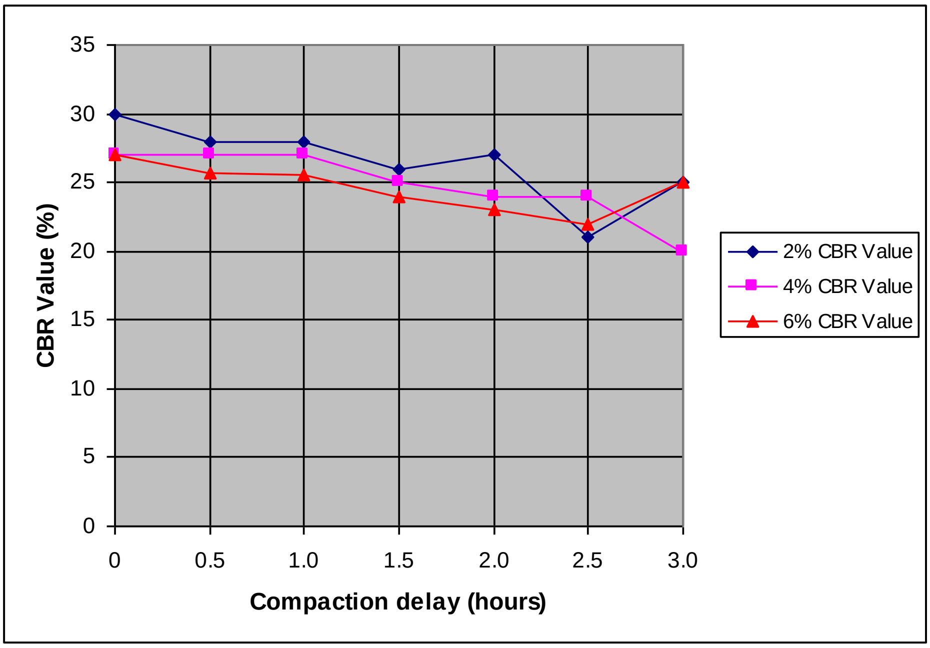

Figure 9: Variation of CBR values with compaction delay on the stabilized laterite on fine materials retained on 150µm sieve, retained on 75µm sieve and passing sieve 75µm sample 'A'.

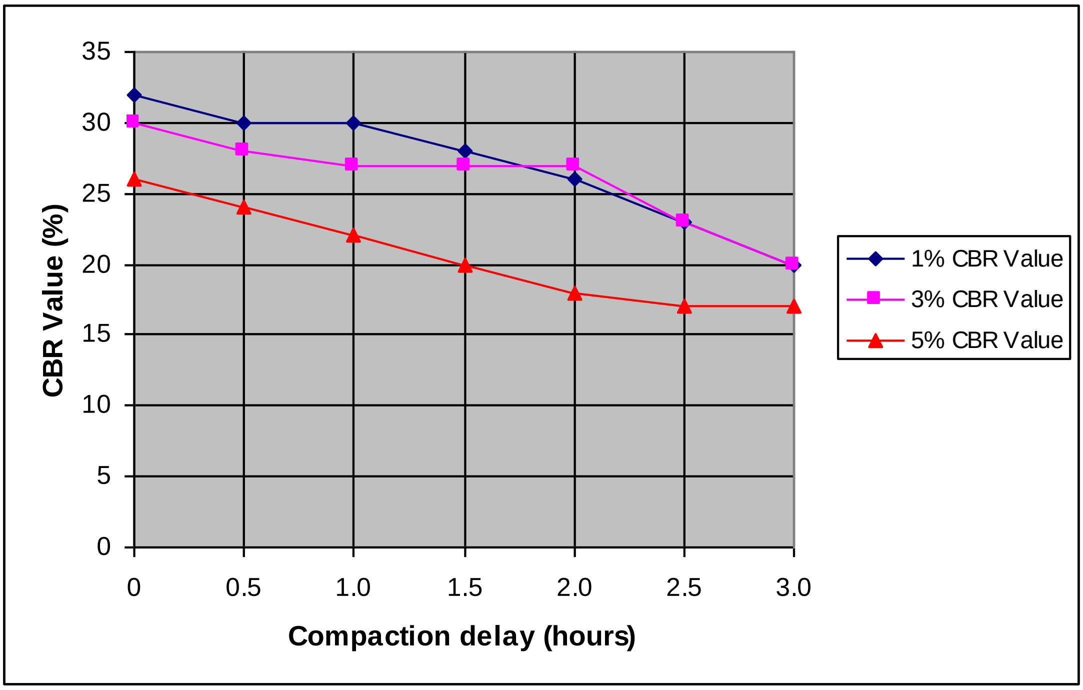

Figure 10: Variation of CBR values with compaction delay on the stabilized laterite on fine materials retained on 150µm sieve, retained on 75µm sieve and passing sieve 75µm sample 'B'.

3.1 Discussion

Figures 1 and 3 show that the maximum dry density for both samples (A and B) reduced as the cement content and time delay increases. The decrease in maximum Dry Density (MDD) up to certain percentage of cement was due to the reaction between cement and the fine fraction during which coarse aggregations were formed. The aggregates occupied larger spaces thus increasing their volume and consequently decreasing the dry density. The Figures indicate that, the two samples attained optimum MDD with addition of 1% cement content.

Figure 2, shows that, maximum dry density reduced from 0% (1.975Mg/m^3) cement content to 1% (1.954 Mg/m^3) cement content and continue to rose again with increase in cement content without delay for sample “A”. While Figure 4 indicated that the maximum dry density for sample “B” begin to decline from 0% (1863 kg/m^3) to 3% (1846 kg/m^3) cement content without delay, then rose from 3 to 6% (1852 kg/m^3) cement content with no delay. The cause of rise of MDD (Sample B) from 3% to 6% cement content could be due to oxide composition that affects reactivity with additives. Materials compacted immediately after mixing. The change in compaction characteristics is primarily due to alteration of the soils gradation, while compaction delays results in the formation of hydration products between particles in the loose state. Consequently, disruption of these aggregations is required to densify the soil-cement which may not regain full strength.

Figure 5 shows that the CBR for sample ”A” with 1, 2, 4, 5 and 6% cement content increases positively, reaches its peak at 1.5 hours delay and then declines. While same sample with 3% cement content decreases from 0 hour (CBR = 33%) to 0.5 hour (CBR = 32%), then continues to increase and also reaches its peak at 1.5 hours (CBR = 46%) delay. The declination of the CBR for this Sample after 1.5 hour delay is either due to reaction of hydrated lime with tricalcium aluminate and water to form tetracalcium aluminate hydrate which formed a protective coating on the surface of the unhydrate grains of tricalcim aluminate or due to hydrated lime decreased the concentration of aluminate ions, thus slowing down the rate of hydration of tricalcium aluminate to form the strength producing compound of tetracalcium aluminate hydrate. The Figure indicates that the CBR has a general positive relationship with time delay and percentage cement content, with the higher points of between 45 to 46% CBR value at 1.5 hours delay. Furthermore, the CBR for all percentage cement content have no much variation between 1.0 and 2.5 hours delay. Optimum CBR (36 - 46%) is attained with 6% cement content in sample (A)

Figure 6 shows that, the CBR for sample ”B” have a positive relationship with both delay and percentage cement content. It can further be observed that 6% cement content in sample “B” produce optimum CBR values (42% - 64%) from 0 to 3 hours delay, then followed by 5% cement content, which started rising from 34% CBR value at 0 hour delay to 48% CBR value at 3 hours delay. The least CBR is observed from 1% cement content, which starts rising from 0 hours (CBR = 15%) delay, reaches peak at 1.5 hour (CBR = 22%) delay, drop at 2 hours (CBR = 21%) delay then stabilized up to 3 hours delay. The increase and decrease in CBR values is due to the fact that soils stabilized with cement harden quite rapidly due to initial hydration of cement more particularly at high ambient temperatures which are common in tropical regions. With addition of higher values of cement content, the CBR values increased.

Figure 9 shows the CBR for sample “A” with compaction delay on fine materials retained (150 and 75µm). It shows that, CBR has a negative relationship with compaction delay at all cement contents (2, 4, and 6%) – the higher the time delay the lower the CBR. Figure 10 shows same situation from sample “B” with regard to the applied cement contents (1, 3, and 5%). Furthermore, Figures 9 and 10 indicates that better CBR is attained with higher fine materials at low (2 and 1%) cement content and at no delay.

Reference to the chemistry of cement, the decrease in MDD with respect to compaction delay was due to calcium silicate hydrate and hydrated lime from tricalcium and dicalcium silicate compounds of the cement begin to bond particles in a loose state and disruption of these aggregates is required to densify the soil. Therefore, a portion of the compactive energy is utilized in overcoming the cementation and maximum densities are reduced with increased compaction delay.

Secondly, the initial drop in MDD is as the result of flocculation and agglomeration of clay particles caused by the cation exchange reaction in agreement with Ola (1997).

From Figure 5 of Sample (A) and Figure 6 of Sample (B) the trend in CBR values increases with delay in time up to 1.5 hours (1:30 mints) after which the value begins to decline, this is attributed to the fact that up 1.5 hrs there is evaporation of water and hydration taking place which increases the strength of the soil by dryness and consequently increasing resistance to penetration in to the soil. So beyond 1.5 hrs owing to the fact that the soil is rich in the swelling type of clay mineral (illite), there is a possibility of high shrinkage which will live voids that consequently reduces the strength.

From Figure 7 of Sample (A) and Figure 8 of Sample (B) for finer materials (size 300µm) particle size, it can be seen that the trend of the values of MDD obtained shows a decrease with delay in compaction; which is attributed to the fact that with time there will be loss in water which will make the soil becomes stiff and brittle and hence difficult to be compacted efficiently.

Principally, the cement contained within the mixture hardens by hydration (only a small quantity of water is required to hydrate cement). Additional water within the mixture evaporates leaving voids, which reduce the density, strength and durability of the product.

From Figure 9 of Sample (A) and Figure 10 of Sample (B) finer particles (75µm) have high degree of reactivity than coarse size materials because of high specific surface area and high consumption.

Fine soil particles have higher chemical reactivity because of greater specific surface area. Hence there will be higher reaction with cement in fine particles than in coarse grained particles having smaller specific surface area. (Specific surface area is the area available for chemical reaction). Hence low cement but higher CBR value for materials retained on 150µm i.e. 300µm particle size while high cement but low CBR value for materials passing sieve 75µm.

4.0 CONCLUSION

Based on results and discussions from the study the following conclusions were drawn:

1. The California bearing ratio (CBR) for sample "A" continues to increase with delay from 0.5 to 1.5 hours. It is at optimum with 6% cement content. For sample "B", the CBR continues to increase with delay from 0 to 3 hours. It is at optimum with 6% cement content.
2. For both samples, the more the compaction delay, the lower the maximum dry density values obtained.
3. In the case of the fine particles, the more the compaction delay, the lower the MDD values obtained for both samples, which is the same with CBR for both samples. However, higher fine (300µm) materials with lower cement content (2% and 1%) produced optimum CBR values. In other words, coarse materials at no delay produce better California bearing ratio (CBR).
4. In general, the determination of compaction and strength characteristics at no compaction delay (at 0 delay) defines optimum properties of the cement – stabilized material, while compaction and strength characteristics determined following the compaction delays, define the minimum that can be achieved in the field for the specified elapsed time between mixing and compaction.
5. The optimum period that the stabilized lateritic soil at Kabukawa existing borrow pit sample (A) can be delayed after stabilization is between 0 to 1.5 hours, while for Barawa borrow pit the period is between 0 to 3 hours.
6. For the fine materials, the study shows that higher fine materials require less cement to give better CBR values, while finer materials require more cement to obtain better CBR values. Thus, it is uneconomical to stabilize a soil with high percentage of fine particles.

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