EFFECTS OF COMPACTION DELAY ON THE PROPERTIES OF CEMENT-BOUND LATERITIC SOILS

By

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ABSTRACT

This study is an investigation into the effect of 0 to 3 hours compaction delay with half an hour intervals on soil-cement mixes 3,5,8; and 1, 3, 5 percent cement contents by weight of dry soils, for yellow and red lateritic soils respectively. The tests carried out on the cement stabilized soils were the Compaction test (Standard Proctor), the Unconfined Compressive Strength (UCS), the California Bearing Ratio (CBR) test and Durability test. The results obtained indicated that compaction and strength characteristics decreased with increase in compaction delay for both lateritic soils. For yellow and red lateritic soils 5% and 3% cement content respectively were sufficient and compaction delay must not be more than 2 hours. They are good in stabilized form for sub-base and base of light trafficked ro ads with red lateritic soil more economical.

KEYWORDS: Lateritic soils, Stabilization, Compaction delay, California Bearing Ratio, Unconfined Compressive Strength, Maximum Dry Density, and Optimum Moisture Content.

1.1 INTRODUCTION

Soil stabilization techniques for road construction are used in most parts of the world although the circumstances and reasons for resorting to stabilization vary considerably. In industrialized, densely populated countries, the demand for aggregates has come into sharp conflict between agricultural and environmental interests. In the less developed countries and in remote areas the availability of good aggregates of consistent quality at economic prices may be limited. In either case these factors produce an escalation in aggregate costs with maintenance costs. The upgrading by stabilization of materials therefore emerges as an attractive proposition. Kogbe (1975) stated that in pre-cambian times, Nigeria consisted of uplifted continental landmass made up of basement sediments. This resulted in the formation of lateritic soils which are of relatively good quality for road construction works.

The addition of adequate percentage of Portland cement to a soil can significantly modify the properties of the mixture produced, independent of the soil used. However, excessive addition of cement becomes uneconomical. The importance of cement stabilization of lateritic soils has been emphasized in the past (Bulman, 1972; Ola, 1974; and Portland Cement Association, 1959). It is important to note that it is difficult to estimate precisely the adequate amount of cement required in soil-cement mix. However, the Nigerian General Specifications (1997) established the usual range of cement requirements for various

AASHTO group classifications of soils in Nigeria. Hence, possible trial cement content adopted for the red and yellow lateritic soils were 1%, 3%, 5%; and 3%, 5%, 8% respectively by weight of the dry soil.

Construction specification commonly requires that compaction and final shaping should be carried out as soon as possible after mixing/placing is completed, but usually this not the case. Sometimes, there is a delay between mixing/placing and compaction because of some unforeseen circumstances like machine breakdown, injury to workers in the field, among others. Some researchers (Osinubi, 1998; Obeahon, 1992; Osinubi and Katte, 1991) have worked on elapsed time after mixing with lateritic soils. In most cases, the works were focused on modified lateritic soils. Besides, soils have peculiarities of structures and variations in behavior at mixing operation. This may be the case even when they have similar plasticity index but may depend on the size and strength of their aggregates (Osinubi, 1998). Thus, the objective of this work is to investigate the effect of 0-3 hours delay in compaction with half an hour intervals on the properties of soil-cement mixtures of two lateritic soils with emphasis on their strength and compaction characteristics.

1.2 MATERIALS AND METHODS

The materials used were ordinary Portland cement which was the stabilizer for the two lateritic soil samples. The soil samples were collected by the method of disturbed sampling from two spots of deposits in Rigyar Zaki, Ungogo local government area, Kano state of Nigeria. The BS 1377; 1990 was used for the preliminary tests. The Standard Proctor was used for the compaction test and the clay mineral identification was done using the plasticity chart developed by Casagrande , data in Mitchell (1976). The results were summarized in table 1.

The test specimens were prepared by first thoroughly mixing dry predetermined quantities of pulverized soil and Portland cement in a mixing tray to obtain a uniform colour. The amount of water required was determined from moisture-density relationships for soil-cement mixtures. The tests were also carried out as specified by BS 1924: 1990 for Unconfined Compressive Strength, California Bearing Ratio and Durability tests. Specimens for unconfined compressive strength were wax cured as specified by Nigerian general specifications (1997). The California Bearing Ratio was modified so as to conform to Nigerian general specification (1997), which stipulates that specimens should be wax cured for six days un-soaked and immersed in water for 24 hours before testing. The resistance of loss in strength [durability] was determined as a ratio of the Unconfined Compressive Strength [UCS] of specimen wax-cured for 7 days, de-waxed top and bottom, and later immersed in water for another 7 days to the unconfined compressive strength of specimen wax-cured for 14 days as specified by BS 1924: part 2: 1990.

TABLE 1: SUMMARY OF THE PROPERTIES OF LATERITIC SOILS

Soil Property	Red Lateritic Soil	Yellow Lateritic Soil
Liquid limit (%)	30.3	31.0
Plastic limit (%)	20.0	19.2
% passing BS No. 200 sieve	35	39
AASHTO classification	A-2-4(0)	A-6(1)
Major clay mineral	Illite	illite
Maximum Dry Density (Mg/m^3)	1.88	1.92
Optimum Moisture Content (%)	11.8	12.0
Unconfined Compressive Strength (KN/m^2)	169	196
California Bearing Ratio (un-soaked %)	7	8
Drying Shrinkage (%)	3.08	3.43
Resistance to water erosion (mm)	42.33	21.44
Moisture Absorption (%)	23.25	22.62

1.3 RESULTS AND DISCUSSION

Compaction Characteristics

Figure 1 shows the relationship between the Maximum Dry Density [MDD] of the cement-bound lateritic soils and compaction delay after mixing. It was glaring that the MDD decreased with increase in elapsed time after mixing. As soon as the water was added to the soil-cement mix, hydration reaction kicks off. This resulted in the bonding of the particles in the loose state and disruption of particles was required to increase the density of the soil. Consequently, some of the hardening effect of the cement will be lost and in addition, part of the compactive effort was directed in overcoming the cementation. Thus, the MDD decreased with increase in compaction delay and it is dependent on the rate of hydration of the cement. According to Shetty (2005), the rate of hydration is very rapid at the initial stage but reduces with time.

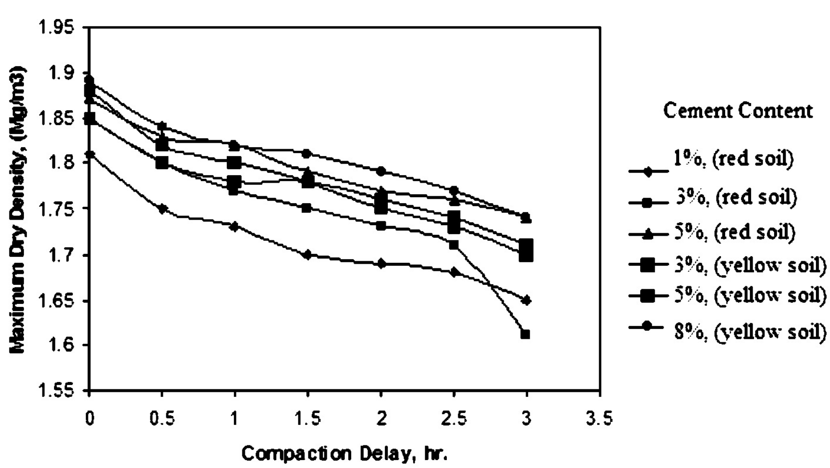

Figure1: Variation of Maximum Dry Density with Compaction Delay

It can also be deduced that MDD reduced from $1.92Mg/m^3$ and $1.88Mg/m^3$ to

1.85Mg/m^3 and 1.81Mg/m^3 at no cement content to 3% and 1% cement content respectively for yellow and red lateritic soils, these indicate that for a given level of compaction, a stabilized soil has a lower MDD than that of the unstabilized soil [Sherwood, 1993]. The reduction in the MDD can be attributed to the reaction between cement and the fine fraction as pozzolanic components in which they form clusters like coarse aggregates. These clusters occupied larger spaces thus increasing their volume and in consequent decreasing the MDD.

In further addition of the stabilizing agent [cement] at 8% and 5% for yellow and red lateritic soils respectively, the MDD increased because the clusters formed were strongly bonded and behaved more as coarse particles and it was as a result of excess cement. These disagree with the normal trend of continuous reduction of MDD with progressive addition of stabilizing agent as stated by Sherwood [1993].

Figure 2 represents the relationship between Optimum Moisture Content [OMC] of the cement-bound lateritic soils and compaction delay after mixing. It was discovered that the OMC of the lateritic soils decreased steadily with increase in compaction delay. This was because the hydration reaction kicks off rapidly at the addition of water and continues to decrease with time, thus the demand for water in the system also reduced continuously.

In the corollary of the decrease in MDD at the introduction of stabilizing agent ought to be an increase in the OMC [Sherwood, 1993]. However, these were upsets from the trend. The decrease in OMC at no stabilizing agent to that of 3% and 1% cement content of the yellow and red lateritic soils respectively was probably due to lack of water in the system which caused a self-desiccation condition and as a result lowered hydration. If there is no free flow of water within the soil-cement mix, the hydration reaction uses up the water until too little will be left to lubricate the soil particles and relative humidity decrease within the mix [Osinubi, 1998].

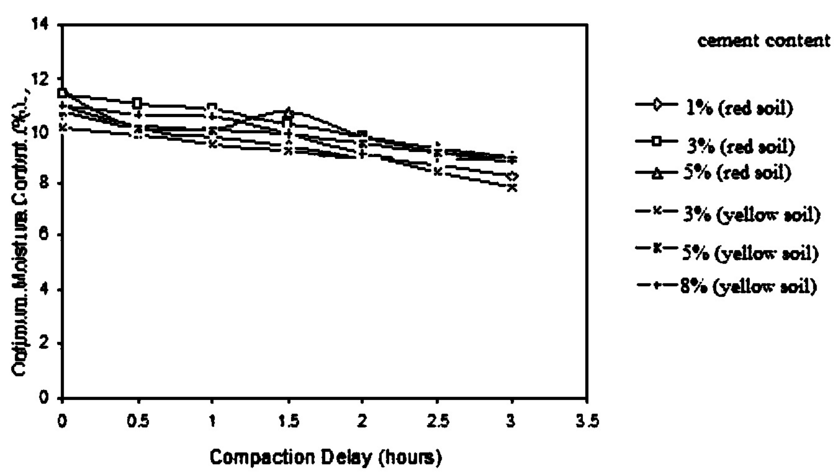

Figure 2: variation of Optimum Moisture Content with Compaction Delay

Strength Characteristics

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Unconfined Compressive Strength [UCS], California Bearing Ratio [CBR] and Durability are measures of strength properties of the cement-stabilized lateritic soils. The UCS and CBR of yellow lateritic soil rose from 196KN/m^2 and 8% at no cement content to 1410KN/m^2 [7 days] and 140% respectively at 3% cement content and also that of the red lateritic soil rose from 169kN/m^2 and 7% at no cement content to 1215kN/m^2 [7 days] and 129% respectively at 1% cement content. It is obvious that there was an appreciable improvement in strength properties of both lateritic soils at a little addition of cement but the red lateritic soil gave a more positive response to the addition of cement. This was as a result of the higher percentage of fine fractions in the yellow lateritic soil because gravel and sand are almost inert in the hydration reaction from which strength develops. Therefore, they have little or no contribution to the determination of the quantity of stabilizer required. In other words, soils with higher percentage of fine fractions will likely require higher stabilizer content.

In figures 3, 4 and 5 showed that strength properties decreased with increase in compaction delay for both lateritic soils. This was because, as soon as water was added to the soil-cement mix, the cement began to hydrate and it was therefore desirable to compact as soon as mixing was completed. When this was not done, not only that some of the hardening effects of the cement would be lost but in addition extra compactive effort will be required to break down the cemented bonds that have been formed. Both of these effects together will lead to serious loss in strength.

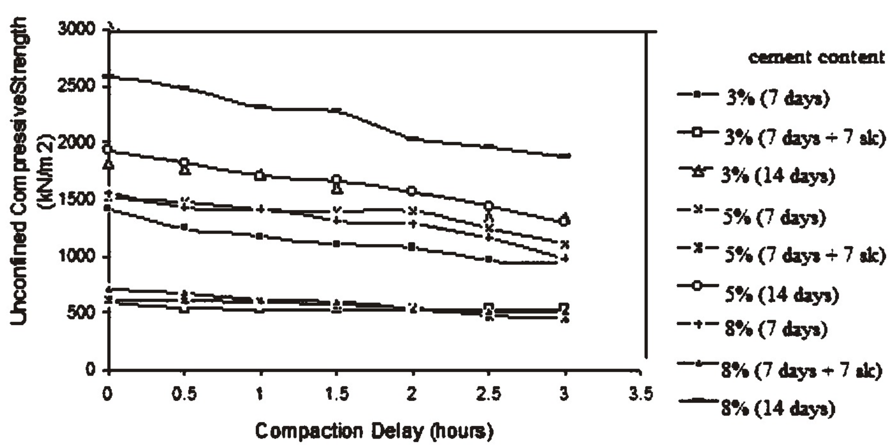

Figure3: Variation of Unconfined Compressive Strength with Compaction Delay for Yellow lateritic soil

Considering the minimum conventional values of UCS at 7 days for cement stabilized soils which are 750-1500, 1500-3000, 3000-6000 kN/m^2 for sub-base, base [lightly trafficked roads], base [heavily trafficked roads] respectively in evaluating the strength of the soil specimens. The 7 days UCS values for both yellow and red lateritic soils at no compaction delay with cement content of 5% and 3% were 1520kN/m^2 and 2210kN/m^2 respectively, showed that only the sub-base and base requirements for light trafficked roads were met. Judging by the 180% value of CBR of mix in place condition as recommended by the Nigerian General Specification [1997], the 5% and 3% cement content for yellow and red lateritic soils recorded CBR values of 208% and 192% respectively at no compaction delay which indicated that both lateritic soils met the requirement for the mixes. The durability requirement for soil-cement mixes was not satisfied for both lateritic soils. This was because the resistance to loss in strength which were determined by comparing 14 days old cured specimen with 7 days curing and 7 days soaking in water were more than 20% allowable loss in strength. The high loss in strength may be because of high water absorption of the clay mineral

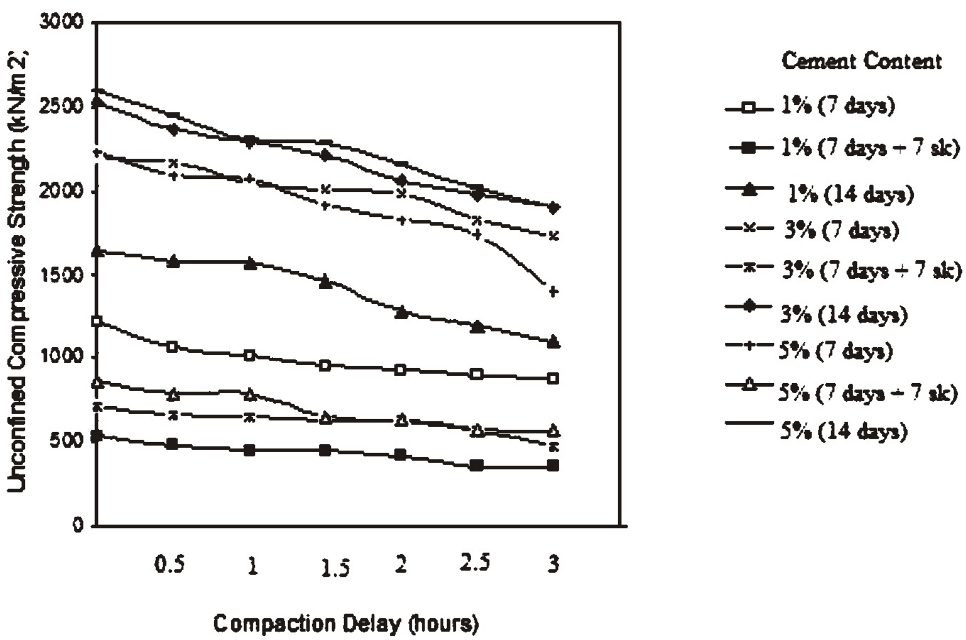

Figure 4: variation of Unconfined Compressive Strength with Compaction Delay for Red lateritic soil

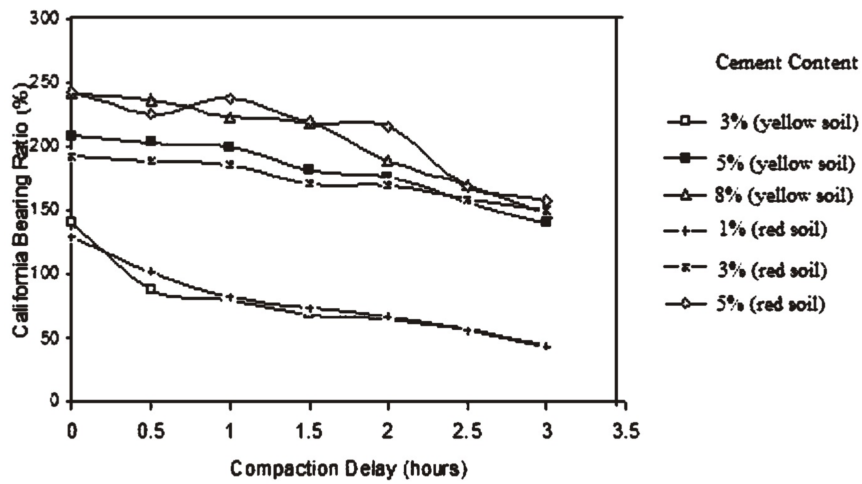

Figure 5: Variation of California Bearing Ratio with Compaction Delay for stabilized lateritic soils

1.4 CONCLUSIONS

The following conclusions were drawn after this work has been carried out:

1. Addition of 3% and 1% cement content for the yellow and red lateritic soils respectively, appreciably improved their strength properties.
2. Though the durability requirement was not satisfied for both lateritic soils, they can still be adopted for sub-base and base of light trafficked roads because Kano experiences less rainfall, so alternate cycles of wetting and drying will be reduced.
3. 5% and 3% cement content will be adequate for yellow and red lateritic soils respectively.
4. The red lateritic soil will be more economical to be adopted as a material for stabilization because of less cement content requirement.
5. The compaction and strength characteristics decreased with increase in compaction delay.
6. At 5% and 3% cement content for yellow and red lateritic soils respectively, not more than 2 hours compaction delay should be allowed because in most values of strength at 2 hours time elapsed between mixing and compaction not more than 20% losses were experienced in their strength properties.

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