IMPACT: International Journal of Research in Applied,
Natural and Social Sciences (IMPACT: IJRANSS)
ISSN(E): 2321-8851; ISSN(P): 2347-4580
Vol. 2, Issue 6, Jun 2014, 189-200

EFFECT OF CURING TIME ON UNCONFINED COMPRESSIVE STRENGTH OF LATERITIC SOIL STABILIZED WITH TYRE ASH

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ABSTRACT

This study was to assess the effect of tyre ash on the geotechnical characteristics of compacted lateritic soils derived from migmatite gneiss in order to discover a conventional and cheaper stabilizer for pavement construction. Method employed included field sampling operation during which lateritic soil samples labeled A, B and C were collected. The basic index and engineering properties of soil were determined following the procedures stipulated by British Standard 1337 of 1992. The samples were compacted at modified American Association of State Highway and Transportation Official (AASTHO) level. The soil samples were subsequently stabilized with 2%, 4%, 6%, and 8% tyre ash in order to determine the influence of the stabilizer on the engineering properties of the soils.

Samples were cured for 7, 14 and 28 days in case of unconfined compression test. Samples for the determination of unsoaked CBR were cured for six days while samples for soaked CBR were also cured for thesame number of days and soaked in water for 24 hours before tests were conducted. Specific gravity (2.74-2.78) revealed the soils were inorganic lateritic soil while the grain size analysis indicated that the percentages passing No. 200 BS sieve were 74.4%, 74.61% and 77.78% for samples A, B and C respectively. The soils were well graded and belong to group A-7-6 of the AASTHO classification system. The lateritic soils were of high plasticity and compressibility.

Stabilization of the lateritic soil derived from migmatite gneiss with tyre ash was quite effective. Significant increase in the values of Optimum Moisture Content, Unconfined Compressive Strength and California Bearing Ratio were obtained upon stabilization with 2-8% of the stabilizer. However there was reduction in the Maximum Dry Density of all the soil samples. Increasing the curing time decreased the UCS of the stabilized lateritic soils. Although the geotechnical properties of the stabilized lateritic soils were significantly improved, none of them met the requirements for road construction.

KEYWORDS: Curing Time, Tyre Ash, Engineering Properties, Lateritic Soils, Stabilization

INTRODUCTION

The materials used in the construction of a highway are of intense interest to the highway engineers, in contrast to many other branches of civil engineering where the engineer may not be deeply concerned with the properties of the materials being used (O'Flaherty, 1974). Construction materials selected for use in the construction of flexible pavements must be evaluated to provide information for adequate and economical design. Osunubi and Katte (1997) have described lateritic soils as the most common pavement material in the tropics and subtropics.

The proper understanding of the engineering characteristics of these lateritic soils has been shown to be paramount in their evaluation for certain utilities. This has made geotechnical engineers and engineering geologists aware of their wide range of properties even within a small area (Ogunsanwo, 1985). There are occurrences where a laterite may contain significant amount of clay minerals such that its strength and durability cannot be guaranteed under load, especially in the presence of moisture. In such cases sourcing for an alternative soil may prove economically unwise. When the soils at a site are poor or when they have an undesirable property making them unsuitable for use in a geotechnical projects, they may have to be stabilized (Bowles, 1996). Soil stabilization is a technique introduced many years ago with the main purpose to render the soils capable of meeting the requirements of the specific engineering projects (Kolias et. al; 2005). Stabilized soil is, in general, a composite material that results from combination and optimization of properties in individual constituent materials (Basha et. al; 2005)

Extensive studies have been carried out on the stabilization of soils using additives such as lime and cement as well as the combination of compaction method and cement stabilization (e.g. Bell, 1996; Adeyemi, 2003, Al Rawas and Goosen, 2006; Kenai et. al., 2006). In recent years, industrial byproducts or agricultural wastes have been added and mixed with different types of soils to improve their engineering properties. Some of these industrial byproducts or agricultural wastes include forage ash, rice-husk ash, fly ash, bagasse, sugarcane straw etc.

The enhanced engineering properties of various soils, resulting from the utilization of industrial byproducts or agricultural wastes, bring about environmental and economic benefits (Walid, and Harichane, 2010). Addition of such additives reduced the plasticity index, increased optimum moisture content, decreased maximum dry density and improved both the compressive strength and California Bearing Ratio of soils (Rahman, 1986; Ferguson, 1993; Zia and Fox, 2000; Parsons and Kneebone, 2005; Koliaset al., 2005; Basha et al., 2003; Senol et al., 2006; Amu et. al,2011;).

Limited researches have been conducted to investigate the suitability of using the ash generated from used vehicle tyres in soil stabilization. Tyre is one of the components of a vehicle and the disposal of used tyres has been a concern. One of the common ways of disposing such material is by burning them. This paper presents the results of the effect of curing time on unconfined compressive strength of lateritic soils derived from migmatite gniess, stabilized with tyre ash.

STUDY AREA

The study area, Iworoko- Ekiti, is in Ekiti State, southwestern Nigeria. The area lies within latitudes 7^0 40^1 – 7^0 45^1 and longitude 5^0 15^1 – 5^0 18^1. The climate is of the West African monsoonal type, characterized by distinct wet and dry seasons typical of West African region. This type of climate is considered the most important primary factors of laterization.

The area under investigation lies within the Precambrian Basement Complex of Nigeria. Previous workers (Adekoya et. al., 2003) have variedlydeciphered the Basement Complex into four lithological units, viz, migmatite gneiss quartzite complex, older granites, schist belts and minor intrusive. The study area is underlain by migmatite gneiss quartzite complex (Adekoya et. al., 2003). The rock type, within the migmatite gneiss quartzite complex, encountered in the study area is the migmatite gneiss representing the oldest lithologic units of the Basement complex Figure 1.

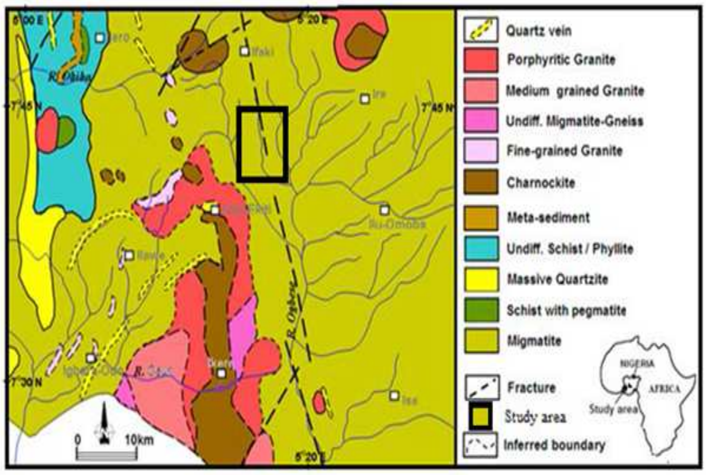

Figure 1: Geological Map of the Study Area

MATERIALS AND METHODS

The methodological approach includes sampling of soil obtained from a road-cut along Iworoko-Ifaki road, in Ekiti State, southwestern, Nigeria where residual soil developed over migmatite-gneiss. Selective sampling was carried out by collecting soil from laterite horizon being the preferred soil as sub-base and sub grade materials. Six bulk soil samples were collected and air-dried for two week to take advantage of the aggregating potentials of lateritic soils upon exposure (Omotosho and Akinmusuru 1992). Subsequently, the tyre ash used for this study was obtained from the burning of used and discarded tyres sourced from Ado-Ekiti. It was burnt under normal atmospheric temperature and pressure (open burning) to obtain the ash. After carefully removing the metal from the ash, the tyre ash was sieved through BS sieve No. 200. The sieved ash was immediately kept in air tight containers to prevent pre-hydration during storage or when left in open air. The oxide composition of the ash was determined at the Central Research Laboratory, Federal University of Technology Akure, Nigeria using Energy Dispersive X-Ray Fluorescence.

The tyre ash treatments considered were 0%, 2%, 4%, 6% and 8% by dry weight of soil samples used. The specific gravity of the tyre ash is 1.33. Laboratory analysis involving the basic index and geotechnical properties of soil were determined following the procedures stipulated by British Standard 1337 of 1992 (Part II)and Federal Ministry of Works and Housing specifications (1997). These tests include grain size distribution, Atterberg limits, specific gravity, compaction parameters, unconfined compression test as well as unsoaked and soaked California Bearing Ratio (CBR). For effective segregation of grains of the soils for sieve size analysis, each soil sample was soaked in weak calgon solution for 24 hours, during which it was regularly agitated before wet sieving. The soil samples were compacted at modified American Association of State Highway and Transportation Official (AASTHO) compactive effort.

The compaction test involved the application of dynamic load on soil samples divided into five layers. The five layers of soil in a mould of volume 0.002124m^3 was subjected to 55 blows of a 44.5N rammer falling through a height of 0.46m. The soil samples were subsequently stabilized with 2%, 4%, 6%, and 8% tyre ash in order to determine the influence of the stabilizer on the engineering properties of the soils. The compaction test was done repeatedly for the unstabilized soil and those stabilized with 2%, 4%, 6%, and 8% tyre ash. Two sets of CBR (unsoaked and soaked) tests were conducted on each soil sample, one at the Optimum Moisture content compacted to the Maximum Dry Density and the other test on a similarly compacted under soaked conditions usually 24 hours of soaking in water, in accordance with

FMWH specifications (1997). Similarly, the OMC and MDD determined from each compacted sample were also used to compact specimens for unconfined compression tests. Samples were cured for 7, 14 and 28 days in case of unconfined compression tests.

RESULTS AND DISCUSSIONS

Major Oxide Composition of the Tyre Ash

The result presented in Table 1 shows that tyre ash contains some of the elements (oxides) found in pozzolana. However, the total percentage of iron oxide, silicon oxide and aluminum oxide is less than the minimum of 70% specified by pozzolanas (ASTM 618, 2005). ASTM C 618 (2005) defined pozzolana as siliceous or siliceous and aluminous materials which in themselves have little or no cementitious properties but in finely divided form and in the presence of moisture, they react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

Table 1: Chemical Composition of the Tyre Ash

Oxide	Composition (%)
SiO_2	33.8
Al_2O_3	7.8
Fe_2O_3	11.4
CaO	13.3
MgO	6.4
SO_3	1.6
Na_2O	1.4
K_2O	1.1
TiO_2	1.0
LOI	12.5

Index Properties

The result of the preliminary tests on the soil samples are presented in Table 2. The average natural moisture content of the soil samples was found to be 4.33%. The specific gravity of the soil samples (A, B and C) were 2.77, 2.74 and 2.78 respectively. These values are indicative of a high degree of laterization. On the basis of the specific gravity values the soils are classified as inorganic lateritic soils (Ramamurthy and Sitharam, 2005). The particle size distribution curve of the lateritic soils is shown in Figure 2. The grain size analysis indicated that more than 35% of the three samples pass through the 200µm sieve. This showed that the soil samples all belong to the silt-clay materials of the AASTHO classification system. The samples fall within group A-7-6 group. Hence, all the samples can be deduced as not suitable for sub-grade and base materials as the percentage by weight finer than No.200 BS test sieve is more than 35% (FMWH, 1997). The liquid limits (LL), plastic limits (PL) and the plasticity indices (PI) for sample A, B and C are (58.4%, 21.2%, 37.2%), (60.4%, 23.2%, 37.2%) and (54.2%, 22.2%, 32.0%) respectively. The plasticity index and liquid limit of the soil samples show that the soils are not suitable as base/sub-base materials in road construction because they are above the maximum 12% and 30% values respectively recommended for sub-base/base soils by Federal Ministry of Works and Housing (FMWH) specification (1997). The linear shrinkage (samples B and C) were higher than the maximum 8% recommended by Madedor (1983) for highway sub-grade soils. Casagrande chart classification Figure 3 shows that the soils are of high plasticity and hence compressibility.

Table 2: Index Properties of Soil Samples

Index Properties	A	B	C
Specific Gravity	2.77	2.74	2.78
% Passing BS No. 200 sieve	74.4	74.61	77.78
Gravel (%)	1.9	0.5	0.0
Sand (%)	23.8	24.9	22.2
Silt (%)	13.4	14.6	16.5
Clay (%)	61.0	60.0	61.3
Liquid limit, LL (%)	58.4	60.4	54.2
Plastic limit, PL (%)	21.2	23.2	22.2
Plasticity index, PI (%)	37.2	37.2	32.0
Shrinkage Limit (%)	7.7	8.2	8.2
AASHTO Classification	A-7-6	A-7-6	A-7-6

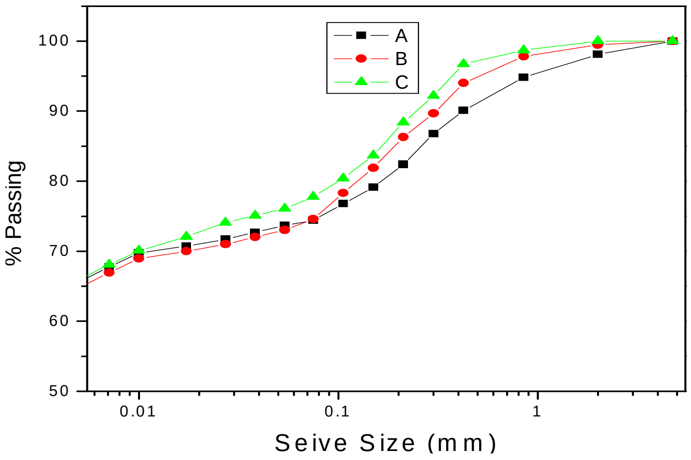

Figure 2: Particle Size Distribution of the Lateritic Soil

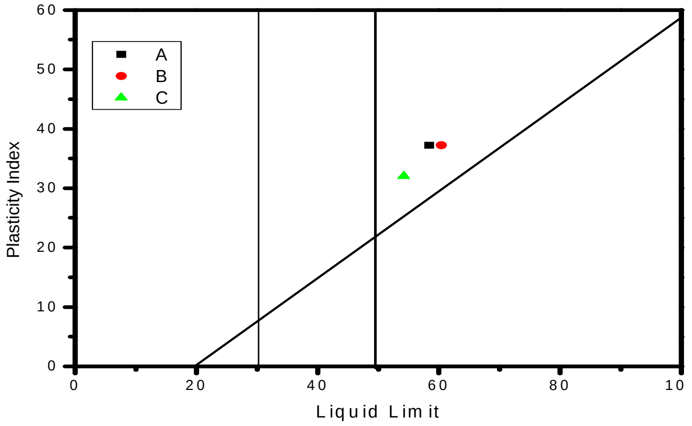

Figure 3: Casagrande Classification Chart of the Soil Samples

Compaction Characteristics

The compaction test was used to determine the influence of stabilizers on maximum dry density (MDD) and optimum moisture content (OMC). The results of the MDD and OMC of soil samples mixed with tyre ash are reported in Table 3 and further illustrated in figures 4 and 5. The results show that adding tyre ash increased the OMC and reduced the amount of MDD progressively with the increase of tyre ash addition. Similar behavior was observed by other researcher for lime, volcanic ash, rice husk ash, sugarcane straw ash, lime-natural pozzolana mixture and stabilized soils

(Bell, 1996; Hossain *et. al*, 2007; Eberemu, 2011; Amu *et. al*, 2011 and Harichane *et. al;*2011). The increase in OMC was due to the additional water required for wetting the large surface area of the fine tyre ash particles. The increase in OMC is also probably due to the additional water held within the flocculent soil structure due to excess water absorbed as a result of the porous property of tyre ash. The decrease in MDD of all treated lateritic soil was due to the partial replacement of relatively heavy soils with light weight tyre ash (specific gravity 1.89). This decrease in density could also be influenced by increase in porosity of all compacted soil samples due to addition of tyre ash. In addition, the decrease can also resulted from the flocculation and agglomeration of clay particles, caused by the cation exchange reaction, leading to corresponding increase in volume and decrease in dry density as advanced by Lees *et al.,* (1982). The increase in dry density is an indicator of improvement of soil properties; however the addition of tyre ash reduced the MDDs. Several researchers [Basha et. al, 2005 and Ola 1977] found that the change in dry density occurs because of both the particles size and specific gravity of the soil and stabilizer.

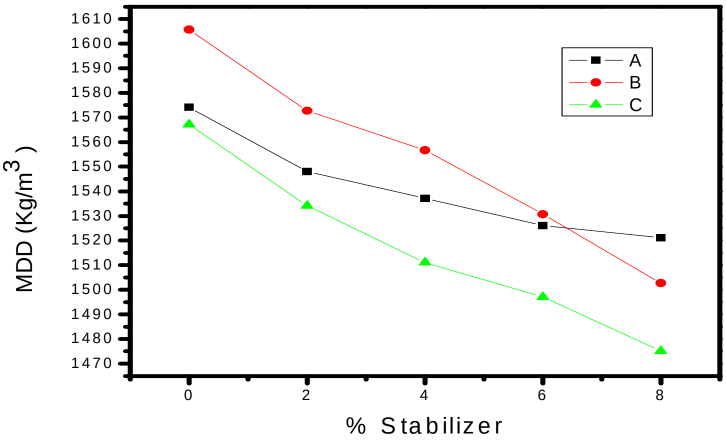

Figure 4: Variation of Maximum Dry Density with Tyre Ash Content

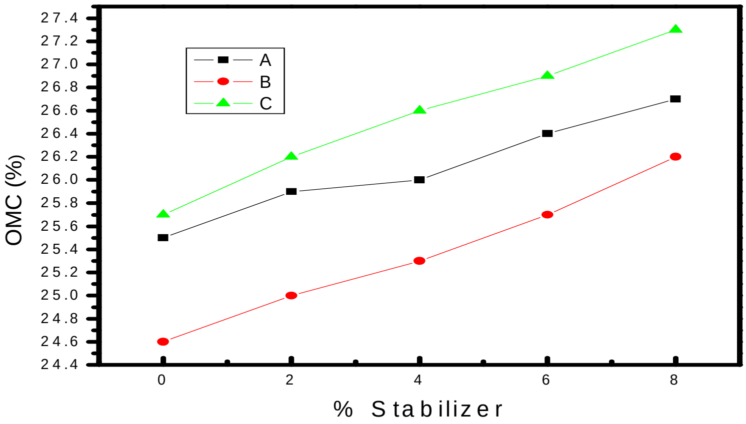

Figure 5: Variation of Optimum Moisture Content with Tyre Ash Content

Table 3: Summary of Compaction Test Results

Sample	% Stabilizer	MDD(Kg/m^3)	OMC (%)
A	0	1574.1	25.5
	2	1548.1	25.9
	4	1537.1	26.0
	6	1526.1	26.4
	8	1521.1	26.7

Table 3: Contd.,

B	0	1605.7	24.6
	2	1572.7	25.0
	4	1556.7	25.3
	6	1530.7	25.7
	8	1502.7	26.2
C	0	1567.1	25.7
	2	1534.1	26.2
	4	1511.1	26.6
	6	1497.1	26.9
	8	1475.1	27.3

California Bearing Ratio

The California Bearing Ratio (CBR) test is a relatively simple test that is commonly used to obtain an indication of strength of a subgrade soil, sub-base and the base course materials for use in road and airfield pavement design (Liu and Evett, 2003). The results of the California Bearing Ratio test are shown in Table 4. Expectedly the influence of soaking is evident in the results obtained as the CBR values for the 24 hours soaked samples were much lower compared to the unsoaked samples. The unsoaked and soaked CBR values of all the soil samples increased considerably on stabilization with tyre ash Figures 6 and 7.

This shows that the load bearing capacity of the soil increased with the stabilization mix. The increase in both the soaked and unsoaked CBR may be due to the availability of calcium from the ash for the cementations reaction with the silica and iron oxide from the lateritic soil. Despite the increase in soaked CBR with stabilization, the soaked CBR values of the soils indicate that none can be used for sub-base and base course of roads because the values fall below the 30% and 80% respectively stipulated by FMWH (1997).

The soaked CBR values make the stabilized materials suitable for use as subgrade in road pavement because the value falls within the range (5–11%) specified by FMWH (1997) for sub grade soils. According to Simon *et. al.*, (1973), a high reduction in CBR values after soaking indicates that the soil is very sensitive to changes in the moisture content. Hence, adequate drainage facilities are to be provided if these soils are to be used for any construction purpose to prevent loss of strength.

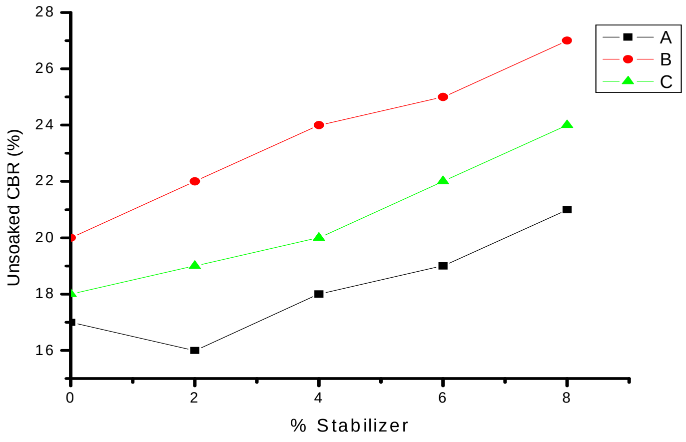

Figure 6: Influence of Amount of Stabilizer on California Bearing Ratio (Unsoaked)

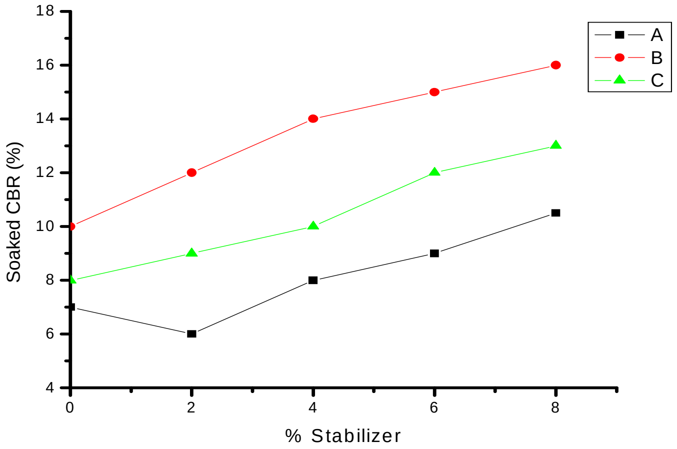

Figure 7: Influence of Amount of Stabilizer on California Bearing Ratio (Soaked)

Table 4: Variation of California Bearing Ratio with the Amount Stabilizer

Sample	Percent Stabilizer	Unsoaked CBR	Soaked CBR
A	0	17	7
	2	16	6
	4	18	8
	6	19	9
	8	21	10.5
B	0	20	10
	2	22	12
	4	24	14
	6	25	15
	8	27	16
C	0	18	8
	2	19	9
	4	20	10
	6	22	12
	8	24	13

Unconfined Compressive Strength

The results of the unconfined compressive strength (UCS) of the stabilized soils are presented in table 5. The trends of changes in UCS with various percentages of stabilizers for the lateritic soil are presented in figures 8, 9 and 10 for 7, 14 and 28 days curing respectively. It is pertinent to note that curing was not necessary for soil samples without tyre ash additive. It can be seen from figures 8-10 that the addition of tyre ash increased the UCS of the stabilized lateritic soil samples for the various curing periods. This could probably be as a result of the increased pozzolanic reaction with increased tyre ash treatment which results in the formation of calcium silicate hydrates and micro fabric changes which is responsible for increased strengthKedzi (1979).

Similar behaviors were also observed by other researcher for lime, volcanic ash, rice husk ash, sugarcane straw ash, lime-natural pozzolana mixture and Lime- rice husk mixture stabilized soils (Bell, 1996; Hossain*et. al;* 2007; Eberemu, 2011; Amu *et. al;* 2011 and Harichane *et al;* 2011). However at 2% tyre ash, the UCS of the stabilized lateritic soil (sample A and B) is lower than the UCS of the unstabilized soil during 14 and 28 days curing. This trend is also noted at 4% tyre ash during 14 days curing in sample A.

Increasing the curing time decreased the UCS of the stabilized lateritic soils. The UCS achieved after 14 and 28 days of curing were considerably lower than those realized for soil mixtures at 7 days. However, it is interesting to note that a significant percentage of this decrease was recorded in the first 14 days of curing. Similar behavior was observed by Zia and Fox (2000). They reported that the majority of strength development occurs within 7 days of compaction for Indiana loess-fly ash mixtures, and that between 14 and 28 days the strength of stabilized loess decreases when compared to the strength of the loess alone and attributed the strength loss to shrinkage cracks that developed in the stabilized samples, which they observed to be more prominent at higher ash contents. Shrinkage cracks were also noticed in the stabilized samples during the laboratory test and are detrimental to strength development. Although the cured UCS of the stabilized samples increased with percentage stabilizer, they are lower than 1034 KN/m^2 recommended by the Central Road Research Institute of India reported by (De Graft et. al; 1969)

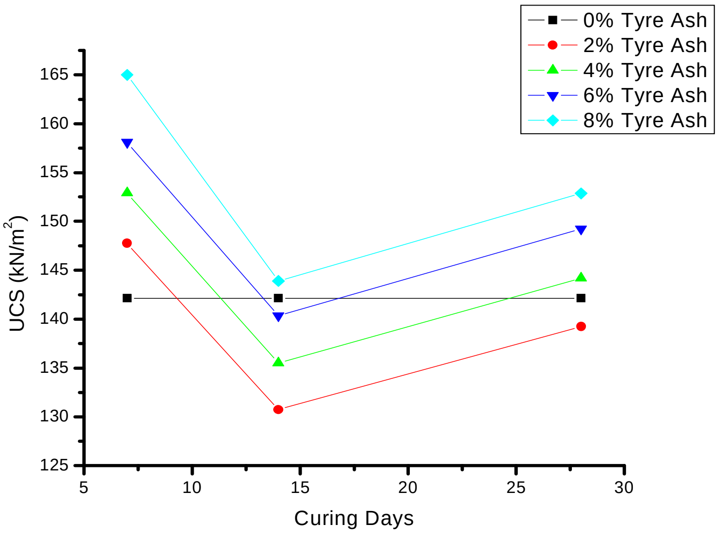

Figure 8: Variation of 7-Day Unconfined Compressive Strength with Tyre Ash Content

Table 5: Variation of Unconfined Compressive Strength with Amount of Stabilizer

Curing Days	% Stabilizer	Unconfined Compressive Strength(kN/m^3)		
		A	B	C
7	0	142.14	142.14	170.35
	2	147.78	145.71	179.32
	4	152.89	150.78	188.65
	6	158.10	158.96	198.35
	8	165.00	167.48	206.45
14	0	142.14	142.14	170.35
	2	130.72	143.45	175.91
	4	135.49	146.43	185.10
	6	140.35	154.44	189.11
	8	143.91	159.68	193.16
28	0	142.14	142.14	170.35
	2	139.25	145.71	179.32
	4	144.19	150.78	188.65
	6	149.23	158.96	192.69
	8	152.87	164.30	196.77

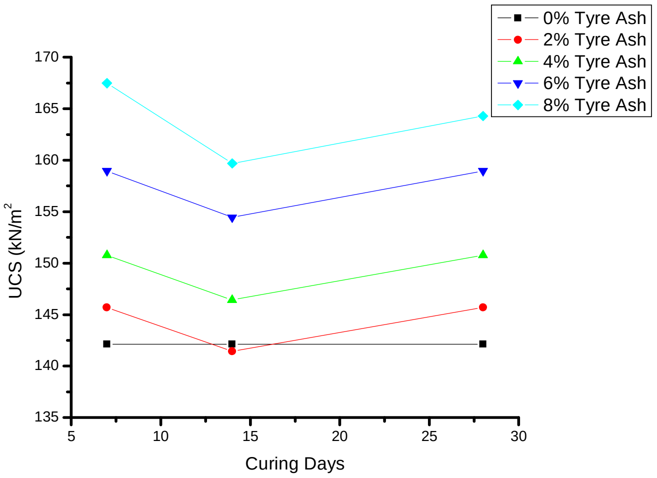

Figure 9: Variation of 14-Day Unconfined Compressive Strength with Tyre Ash Content

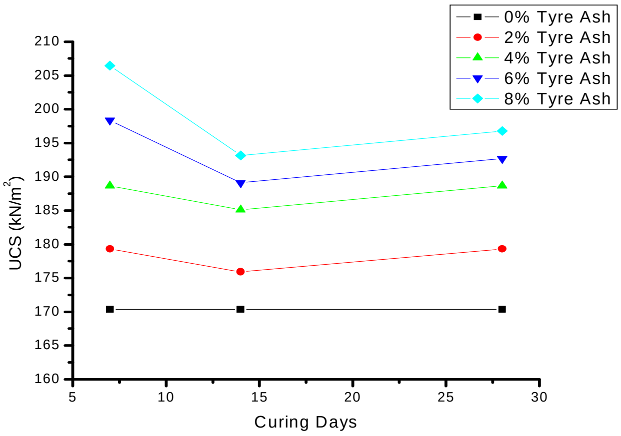

Figure 10: Variation of 21-Day Unconfined Compressive Strength with Tyre Ash Content

CONCLUSIONS

This paper presented the effect of tyre ash on the geotechnical characteristics of compacted lateritic soils derived from migmatite gneiss. On the basis of the tests results the following conclusions can be drawn. Specific gravity revealed that the soils are inorganic lateritic soil. Grain size analysis indecated that the percentages passing No. 200 BS sieve are 35% for all the samples. The soils are well graded and belong to group A-7-6 of the AASTHO classification system. The plasticity index and liquid limit of the soil samples show that the soils are not suitable as base/sub-base materials in road construction because they are above the maximum 12% and 30% values respectively recommended for sub-base/base soils. Casagrande chart classification indicated that the soils are of high plasticity and hence compressibility. The compaction results revealed that addition of tyre ash increased the OMC and reduced the amount of MDD with the increase of tyre ash addition. The unsoaked and soaked CBR values of all the soil samples increased considerably on stabilization with tyre ash. Furthermore, the addition of tyre ash increased the UCS of the stabilized lateritic soil samples for the various curing periods. However, increasing the curing time decreased the UCS of the stabilized lateritic soils. The results of the findings show that the geotechnical properties of the stabilized lateritic soils were significantly improved but still unsuitable for base/sub-base materials in road construction.

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