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Cement Stabilization of Laterite and Chikoko Soils Using Waste Rubber Fibre

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Abstracts

This paper presents a study of cement stabilization of laterite and Chikoko soils using waste shredded rubber tyre chips as the reinforcement material at 5%, 10% and 15% fibre content by weight of soil. Tests conducted include index, physical and engineering properties of the soils, particularly the California Bearing Ratio (CBR) and the unconfined compression tests (UCS). In comparison with the unreinforced samples, the results obtained show considerable improvement in the shear strength and bearing capacity parameters of the soils. It is therefore concluded that waste shredded rubber fibre is a good earth reinforcement material; and which reinforcement can be substituted for deep or raft foundation to save cost.

Keywords: Waste rubber fibre, Laterite, Chikoko, UCS, CBR, Shear strength

Introduction

In Port Harcourt, Nigeria, scrap tyres are generated daily in large volumes, particularly at Anozie street, mile 2 – Diobu, Port Harcourt which are threat to the environment. Management of such solid waste is one of the world's major environmental concerns. Therefore, there is serious need to recycle these non –hazardous solid wastes. One way, is by using it for soil stabilization.

Figure 1: Map of the Niger Delta, Nigeria, showing the location of Port Harcourt City, Nigeria

Soil stabilization is changing the chemical properties of soft soils by adding something to it, to increase the strength and stiffness of the original weak soils (Yilmez and Degirmenci 2009; Lee and Lee 2002).

Most of the Niger Delta area of Nigeria, which is undergoing rapid industrialization; consists of extremely soft marine clay (locally known as Chikoko) and consists of weak laterite in some places, all of which require expansive deep foundations. Deltaic marine clays (Chikoko clay) is a highly fibrous organic soil consisting mainly of vegetative matter in various states of decomposition (Wong et al 2006; 2008). They present as dark grey, dark brown to black material (Adesunloye 1987), and as peat having high compressibility, medium to low permeability, low strength and volume instability (Wong et al 2008, Deboucha and Alawi 2007; Hashim and Islam 2008; Huat 2007; Kalantari and Huat 2008a, 2008b, 2009).

Clayey laterites on the other hand, may swell when in contact with water and crack when dry, which may decrease the mechanical properties of the soil (Selah 1995). One of the solutions to the problem is stabilization (Tabatabaee 1985); Hudyma and Burcin 2006, El Ravi and Al – Samadi 1995; Peethamparan et al 2009).

Soil stabilization with fibres have been reported by Puppala and Musenda 2000; Loher et al 2000; Bann et al 2009; Sivakumar et al 2008; Marandi et al 2008, Zare 2006 and Otoko et al 2014).

Cement stabilization reduces the atterberg limits and volume change of soils (Bell 1988), but increases the shrinkage limit and strength of the soil – cement matrix (Chen and Wong 2006); as a result of the major hydration products formed; which are hydrated calcium aluminates, hydrated calcium silicates and hydrated lime (Croft 1967; Al – Rawas et al 2002; Peech 1965).

This paper therefore presents an in investigation into the stabilization of Chikoko soil and laterite soil with randomly distributed 5%, 10% and 15% shredded rubber tyre chips and 2%, 4% cement content. For all mix proportions, the unconfined compressive strength (UCS) and the California Bearing Ratio (CBR) were determined. Results obtained shows a lot of strength improvement provident for 6% rubber content.

Materials used for the study

Chikoko Soil

Chikoko soil is abundant in the Niger delta swamp location, typical sample was collected from 1m below ground level at eagle island, port Harcourt. The atterberg limits, the physical and engineering properties of the Chikoko soil is shown in table 1.

Laterite Soil:

Laterites are abundant in Port Harcourt within the dry flat country. The laterite used for the study was collected from 1m below ground level, at the premises of the Rivers State University of Science and Technology. The atterberg limits, the physical and engineering properties of the laterite soil is shown in table 1.

Table 1: Atterberg, Physical and Engineering properties of the soils.

S/No	Properties	Laterites	Chikoko
1	Colour	Reddish brown	Dark grey
2	Specific gravity	2.65	2.40
	Atterberg limits		
3	Liquid limit (%)	39.8	67.5
4	Plastic limit (%)	22.3	29.7
5	Plasticity index (%)	17.5	37.8
6	Unconfined soil classification	CI	CH
	Compaction characteristics		
7	Maximum dry unit weight (kN/m^3)	22.1	14.5
8	Optimum moisture content (%)	16.4	20.9
	Grain size distribution		
9	Gravel (%)	5	0
10	Sand (%)	20	10
11	Silt (%)	38	43
12	Clay (%)	37	47
13	Unconfined compressive strength UCS (kPa)	55.9	15
	California Bearing Ratio (CBR)		
14	Unsoaked (%)	16.32	5.20
15	Soaked (%)	2.45	3.18

Cement

Ordinary Portland Cement (OPC) of 53 grades was used in the cement stabilization. The physical requirements of the OPC 53 grade cement are as follows

Table 2: Physical requirements of the OPC 53 grade cement

S/No	Physical Properties	Range
1	Fineness (m^2/kg)	330
2	Standard consistency (%)	30.5
3	Initial setting time (min)	150
4	Find setting time (min)	225

Rubber fibre

Rubber fibre was obtained from waste tyre collected from Anozie in mile 2, Diobu, Port Harcourt. The tyre was then shredded into size 10mm to 20mm in length and thickness ranging from 1.5 to 2.5mm. Care was taken to ensure that the shreds did not contain any steel wire or nylon fibres. Measured specific gravity was in the order of 1.0.

Experimental methods

Unconfined Compressive strength (UCS)

Two sets of cement content were used (2% and 4%) to mix air dried soil passing sieve 425µ. The soil cement was then cured for 4, 7 and 14 days. Each set has 0%, 5%, 10% and 15% shredded rubber content, mixed at optimum moisture content. Maximum dry unit weight and optimum moisture content were determined from standard Proctor Compaction Tests. Thereafter, the unconfined compressive strength tests were carried out on the samples in accordance with BS 1377 (1990).

California Bearing Ratio (CBR)

Two sets of cement were used (2% and 4%) to mix air dried soil passing sieve 425µ. The soil cement was then cured for 4, 7 and 14 days. Each set has 0%, 5%, 10% and 15% shredded rubber content. Maximum dry unit weight and optimum moisture content were determined from standard proctor compaction tests. CBR tests were conducted in soaked and unsoaked conditions in accordance with BS 1377 (1990).

Results and discussions

All tests including CBR and UCS tests were conducted for laterite and Chikoko soils with 2% and 4% cement content and 0%, 5%, 10% and 15% rubber content. The results of the UCS and CBR (unsoaked) test are shown in tables 3 and 4 respectively; while the result of CBR (soaked) is shown in table 5; all for curing periods of 4, 7 and 14 days. Fig. 4, 5 and 6 show the graphical plots of the UCS, CBR (unsoaked) and CBR (soaked) respectively.

Table 3: Unconfined compressive strength test results for Chikoko and laterite soils

Rubber Content (%)	**Unconfined compressive strength, UCS (kPa)**											
	Chikoko soil						**Laterite soil**					
	2% cement			**4% cement**			**2% cement**			**4% cement**		
	Curing periods in days			**Curing periods in days**			**Curing periods in days**			**Curing periods in days**		
	4 days	**7 days**	**14 days**	**4 days**	**7 days**	**14 days**	**4 days**	**7 days**	**14 days**	**4 days**	**7 days**	**14 days**
0	25	46	68	103	140	200	132	150	174	216	247	265
5	37	49	75	125	180	245	159	172	200	231	279	327
10	21	36	62	107	125	170	115	131	168	182	208	210
15	13	17	43	74	100	118	87	103	147	155	166	175

Table 4: California Bearing Ratio test (unsoaked) results for Chikoko and laterite soils

Rubber Content (%)	**California Bearing Ratio (%)**											
	Chikoko soil						**Laterite soil**					
	2% cement			**4% cement**			**2% cement**			**4% cement**		
	Curing periods in days			**Curing periods in days**			**Curing periods in days**			**Curing periods in days**		
	4 days	**7 days**	**14 days**	**4 days**	**7 days**	**14 days**	**4 days**	**7 days**	**14 days**	**4 days**	**7 days**	**14 days**
0	2.08	2.27	3.99	5.70	8.62	10.98	5.80	12.06	14.44	7.10	16.28	19.10
5	3.16	3.29	4.35	6.25	9.75	12.82	6.51	14.35	16.68	8.35	18.05	21.05
10	2.15	2.66	3.20	5.44	8.48	10.50	4.54	10.17	12.76	6.44	14.96	18.75
15	1.23	1.55	1.87	2.73	4.51	6.15	3.65	8.19	10.15	4.11	10.87	14.04

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Table 5: California Bearing Ratio test(soaked) results for Chikoko and laterite soils

Rubber Content (%)	**California Bearing Ratio (%)**											
	Chikoko soil						**Laterite soil**					
	2% cement			**4% cement**			**2% cement**			**4% cement**		
	Curing periods in days			**Curing periods in days**			**Curing periods in days**			**Curing periods in days**		
	4 days	**7 days**	**14 days**	**4 days**	**7 days**	**14 days**	**4 days**	**7 days**	**14 days**	**4 days**	**7 days**	**14 days**
0	1.56	1.95	2.34	4.34	7.76	9.27	4.25	8.13	10.98	5.04	9.84	11.11
5	2.25	2.34	2.95	5.56	8.71	11.15	5.43	10.96	12.53	6.36	12.05	13.78
10	1.47	1.66	1.86	3.73	7.37	9.04	3.56	7.37	8.46	4.23	8.22	9.95
15	1.10	1.25	1.38	1.50	3.80	5.92	2.44	5.5	7.21	3.70	6.40	7.74

Table 3; fig. 1 and 2 clearly shows peak values of unconfined compressive strength for 2% cement content and 5% rubber content of Chikoko and laterite in the order of 75kPa and 200kPa respectively, whereas, for 4% cement content and the same rubber content and curing period, it is in the order of 245kPa and 327kPa for Chikoko and laterite respectively. This shows that the unconfined compressive strength is directly proportional to the curing period at an optimum shredded rubber of 5%; which also indicates that the achieved stiffness of the stabilized soil

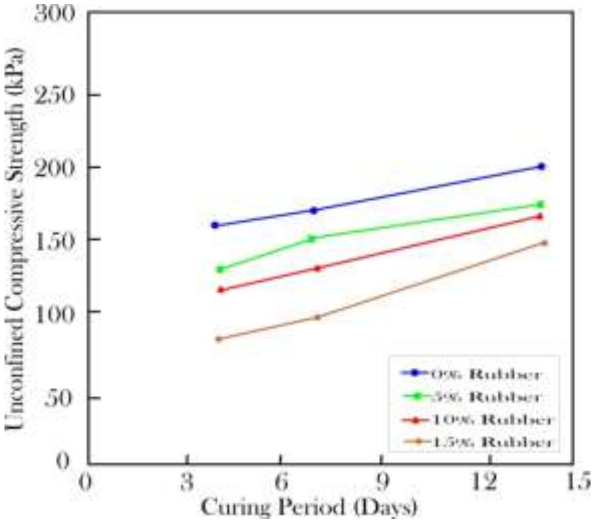

Figure 2: Variation of UCS with curing period for laterite with 2% cement

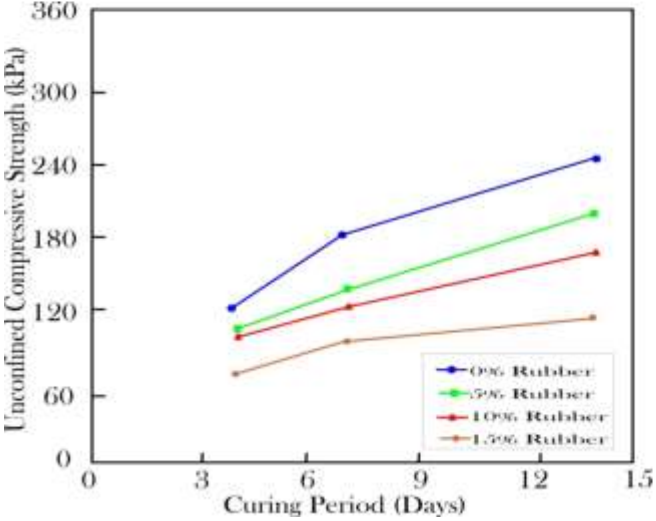

Figure 3: Variation of UCS with curing period for Chikoko with 4% cement

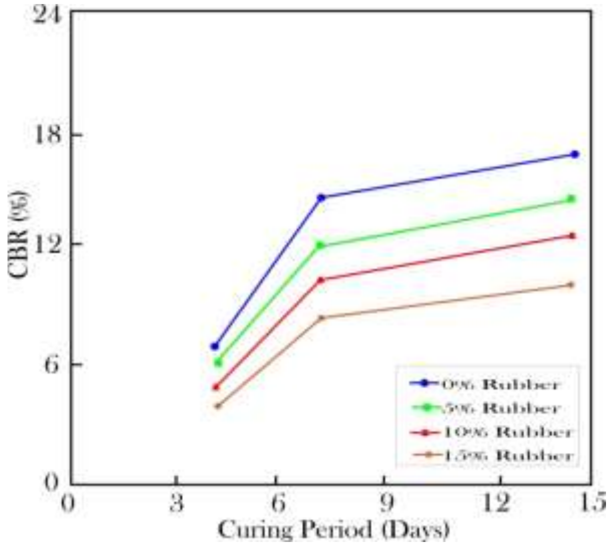

Figure 4: Variation of CBR (unsoaked) with curing period for laterite with 2% cement

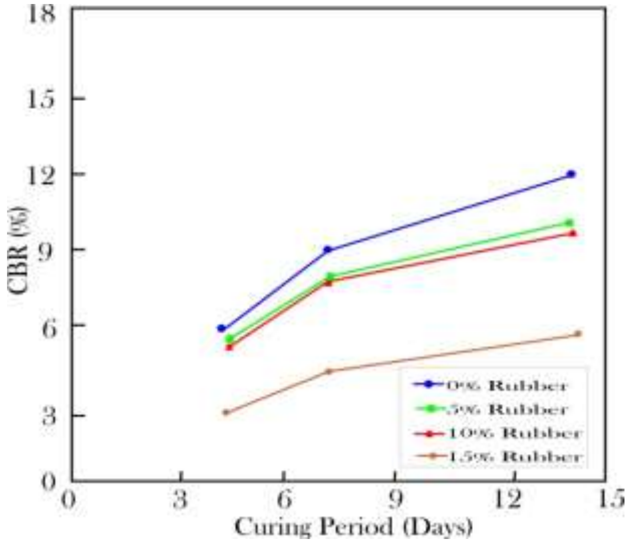

Figure 5: Variation of CBR (unsoaked) with curing period for Chikoko with 4% cement

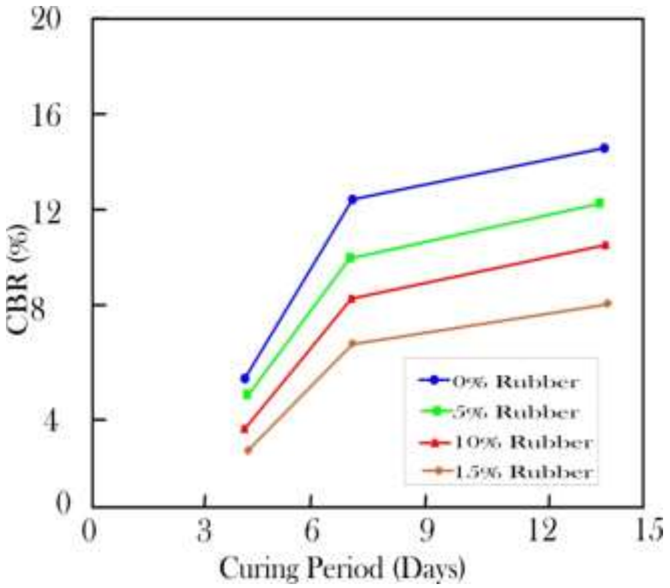

Figure 6: Variation of CBR (soaked) with curing period for laterite with 2% cement

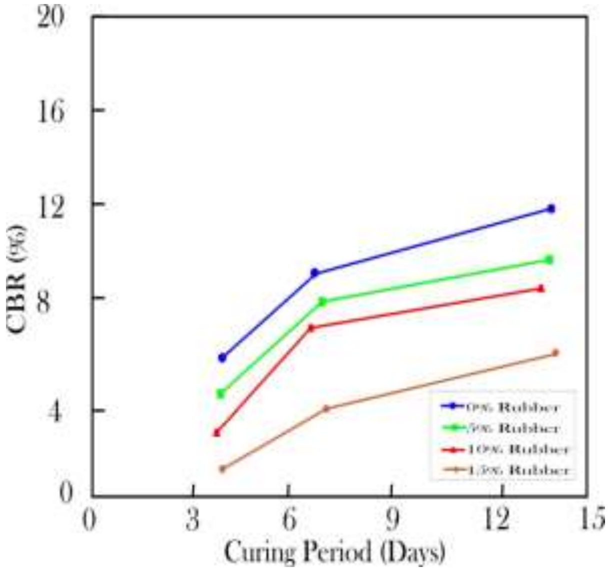

Figure 7: Variation of CBR (soaked) with curing period for Chikoko with 4% cement.

is not only due to the hydration of cement with time, but also due to optimum rubber content; which agrees with the results of Meei – Hoan Ho and Chee – Ming Chan (2010).

For same 2% cement content at 5% rubber content and curing period of 14days the unsoaked CBR are in the order of 4.35% and 16.68% for Chikoko and laterite respectively; whereas for 4% cement and same 5% rubber content and 14days curing period, the unsoaked CBR are in the other of 12.82% and 21.05% for Chikoko and laterite respectively (table 4; fig. 3 and 4). This shows that the unsoaked CBR is directly proportional to the curing period at an optimum shredded rubber of 5%; which also indicates that the achieved bearing capacity of the stabilized soil is not only due to the hydration of cement with time, but also due to optimum rubber content, which agrees with the results of KoterwaraRoa et al (2012).

Similarly table 5; fig. 5 and 6, show peak values for 2% cement content at 5% rubber content and 14days curing period of the soaked CBR in the order of 2.95% and 12.53% for Chikoko and laterite respectively and for 4% peak values of 11.15% and 13.78% for Chikoko and laterite respectively. This shows that the soaked CBR is directly proportional to the curing period at an optimum shredded rubber of 5%; which also indicates that the achieved increase in CBR, which can considerably reduce the pavement thickness, is not only due to the hydration of cement with time, but also due to optimum rubber content, which agrees also with the results of KoterwaraRao et al (2012).

Conclusion

A study of cement stabilization of laterite and Chikoko soils is presented. From the study, it is observed that:

i) The UCS and CBR are directly proportional to the cement content at an optimum fibre content of 5%

ii) The UCS for Chikoko increased from 15kPa to 75kPa for 2% cement and to 245kPa for 4% cement respectively; whereas for laterite, it increased from 55.9kPa to 200kPa for 2% cement and to 327kPa.

iii) Soaked CBR for Chikoko increased from 2.18% to 11.15% for 4% cement; whereas soaked CBR for laterite increased from 5.45% to 13.78% for 4% cement.

It is therefore concluded that most of the Niger Delta area, Nigeria, which is undergoing rapid industrialization consisting of extremely soft marine clay (locally known as Chikoko) and soft laterite, calling for expensive deep and raft foundations, can be comfortably replaced by shallow foundation with soil stabilized by waste shredded rubber tyre chips.

In case of roads, the increase in CBR value will considerably reduce the total thickness of the pavement and hence the total cost of the project. Waste shredded rubber tyre chips is therefore a good soil reinforcement material.

Priorities for further research include study of other stabilization agents and shredded rubber tyre.

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