ADMIXTURE OF PERIWINKLE (*Littorina littorea*) SHELL ASH AND CEMENT FOR STABILIZATION OF SOME LATERITIC SOILS FROM WESTERN NIGER DELTA, NIGERIA

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Abstract

The frequent failure of road pavement is the major problem in the Niger Delta, and this may be due to the soils having poor engineering strength. This failure can be minimized by stabilization of the soils. Conventional soil-improving additive cement is the most widely used in stabilization. However, due to the ever-rising cost of cement, alternative materials that are less costly and available locally have been considered to argument or reduce the cement percentage for the stabilization of the lateritic soil. Preliminary tests and engineering properties were carried out on six and four respectively on natural lateritic soil samples. Soil-cement stabilization was taken at 0, 5, 7, and 9%. Periwinkle Shell Ash (PSA) at various percentage proportions of 0, 2, 4, 6, 8 and 10% was thoroughly mixed with 5 and 7% soil-cement. The result of the classification tests shows that the soils are A-2-6 and A-7-6 which are the dominant lateritic soil types in Western Niger Delta and are poor for road construction. The unconfined compressive Strength (UCS) test results revealed that its values increase as the additive content of PSA increases for all the samples. However, the PSA used as a stabilizer has helped to reduce the quantity of cement in modifying the soil from 7 to 5 % in the stabilization of some of the soils of the Western Niger Delta when PSA is incorporated alongside with the cement to obtain the recommended standard of 1500 KPa for use as road construction materials.

Keywords: Lateritic Soil, Geotechnical Properties, Periwinkle Shell Ash, Road construction, Stabilization

Introduction

In civil engineering works, wherever there is a deficiency in the properties of soil, it is usually accompanied by problems such as cracking, heaving and break up of pavements, building foundations etc. As a result of these problems associated with poor soils, various methods (such as stabilization) are employed globally to modify these soils (Amu *et al*., 2019). (Amu and Salami, 2010) defined soil stabilization as improving some soil properties to make it more useful for a specific purpose. The main reason for soil stabilization is to enhance the mechanical and performance properties of the soil, e.g., Strength, stability, water resistance etc. Soil stabilization can be done by mechanical means of mixing various materials. Soil stabilization is very important, because most lateritic soils in their natural state commonly have low bearing capacity and low strength, due to the high clay content. A-2-6 and A-7-6 soils are the dominant soils types in Western Niger Delta and according to Ugbe, (2011) have been noted to be unsuitable for road construction in their natural state. So, there is a need for stabilization of the soil for better performance as a pavement material. There is also the need to reduce construction costs by searching for a waste material that can be blended with cement in other to reduce the quantity of cement that may be needed for stabilization. However, the use of waste materials, an innovation in research, is continually advancing, particularly concerning the feasibility and performance of the beneficial reuse of industrial and agro-industrial waste products (Nnochiri *et al*., 2017). In some studies, recycled materials such as egg shell powder (Maduabuchi and Obikara, 2018), groundnut shell ash (Amend *et al*., 2021), snail shell ash (Amu *et al*., 2019), cow bone ash (Adanikin *et al*., 2021), saw dust ash (Nnochiri *et al*., 2017), periwinkle shell ash (Nnochiri *et al*., 2016), cassava peel ash (Bello *et al*., 2015), bamboo leaf ash (Amu *et al*., 2011), rice husk ash (Oyetola *et al*., 2006), sugar cane straw ash (Ogunribido *et al*., 2011) have been used, and their influence in the improvement of engineering properties of lateritic soil was considerably eminent at an extent where at a particular concentration they were able to perform as good as some other renowned stabilizer agent such as cement and lime (Oluwatuyi *et al*., 2018). The advantage of using Periwinkle Shell Ash (PSA) is to solve the environmental problem of clearing the waste and also the advantage of adding periwinkle ash to cement to reduce the cement content that may be needed thereby saving huge cost associated cement stabilization approach. However, considering the cost of cement and geo-environmental implication of this organic waste material, periwinkle, this study tends to investigate the use of periwinkle shell ash (PSA), a calcium-rich material, as a stabilizer when mixed with different proportions of cement for effective construction material

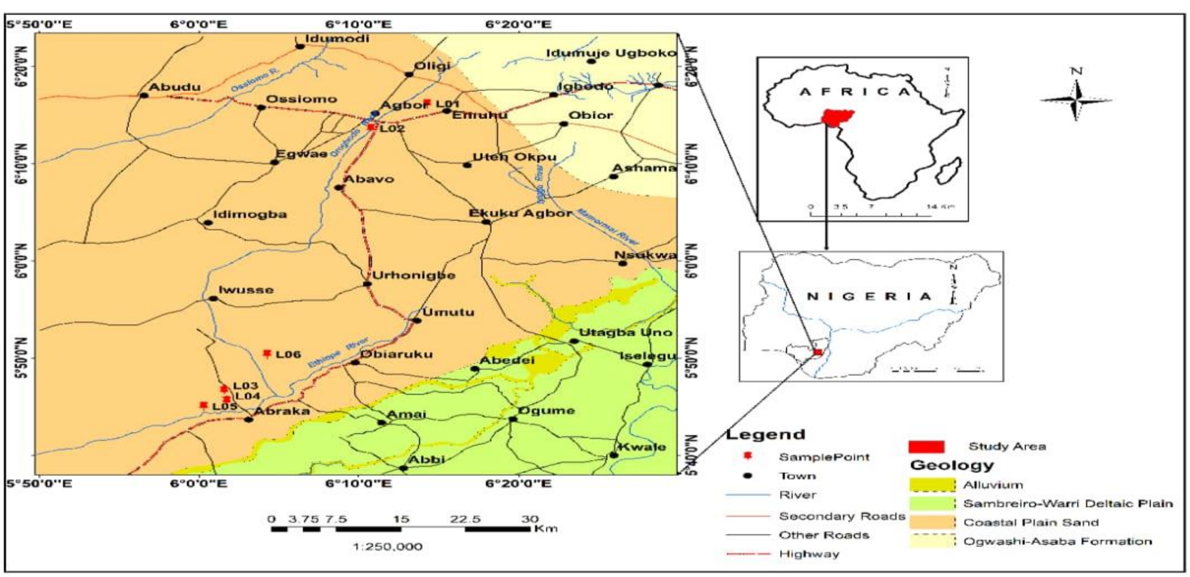

Figure 1. Geological Map of the Study Area Showing Sampling Locations

Materials and Methods

The materials used in this research work were lateritic soil, Portland cement and Periwinkle Shell Ash (PSA) and water.

Lateritic Soil: A total number of six lateritic soil samples were collected from different borrow pits in the study area as shown in Figure 1. For easy identification of the soil samples, labels were placed on them to describe their dates of excavation, depth of excavation from the source and locations, before taken to the laboratory for analysis.

Periwinkle Shell Ash: The periwinkle shell ash was obtained from periwinkle shells collected from dumping sites in Abraka and the environs. The fleshy parts were already removed from the shell before collection.

Ordinary Portland Cement (OPC): The required quantity of Ordinary Portland Cement used for the research work was obtained locally from Cement Depot and kept in a safe platform to prevent any contact with moisture and any other external material that may affect its property.

Water: Potable water was obtained from treated available water in the laboratory.

Categorizing the soil

At the laboratory, the natural soil samples were aired dried for about two weeks in other to allow for partial elimination of natural water which may affect the analysis, then sieved with sieve number 200 (75mm opening) to obtain the final soil samples for the required tests. The natural lateritic soil samples were divided into three categories. The first category was the untreated natural lateritic soil. Classification test like natural moisture content, particle size analysis and Atterberg's limit test were performed on the untreated natural lateritic soils.

Cement Stabilization

The second category was treated with cement in proportions of 0, 5, 7 and 9 % dry weight of the lateritic soil. The unconfined compressive strength (UCS) was determined for the lateritic soil samples. This was done by measuring about 2000 g of soil sample into a pan, and mixing with 5, 7 and 9 % of cement using a hand trowel then a calculated volume of water was then added to the mixture and mixed thoroughly. Moisture content was taken note of. The prepared soil was divided into 3 parts, and one-third of the mold was filled with the prepared soil. That layer was then compacted evenly by 27 blows using a rammer. The blows were uniformly sdistributed over the surface of each layer. The top surface of the first layer was scratched with a spatula before placing the second layer. Likewise, the same compaction process was repeated for the second and third layers respectively. The amount of the soil used was sufficient just to fill the mold and about 5mm was left above the top of the mold which was later struck off when the collar was removed. The excess soil projecting from the tip of the mould was trimmed off. Then the base plate was cleaned inside-out. The sample was ejected and weighed and left for 7 days undisturbed before it was crushed to get the strength.

The mixture of PSA + Cement and Soil

The third category of the natural soil was treated with cement concentration and periwinkle shell ash. The shells were thoroughly washed air dried for about one week and calcined in electric muffle finance at temperatures between 800 ^{0}C and 1000 ^{0}C. Then the shells were ground into powder particle form with the aid of a grinding machine. The ash obtained was later sieved through B.S sieve No.200 (75um) to obtain fine ash and kept in a sack bag to prevent it from moisture and other external influence that can affect its property to meet the requirement (BS 1924). The natural soil was treated with 5, 7 % cement concentration and the periwinkle shell ash by proportions of 2, 4, 6, 8 and 10 % by dry weight of the lateritic soil, in other to determine the unconfined compressive strength. Each compaction and stabilization is done in pairs whereby a pair is to represent the dry season while the other is to represent the wet season. The stabilized compacted samples are then wrapped with a firm transparent film and left undisturbed for 7 days whereby one pair is soaked for 24 hours before its 7 days crush while the other is unsoaked at the 7^{th} day, both pairs were crushed and their compressive strengths determined.

Results and Discussions

Geotechnical properties and the type of soil

The results from the preliminary tests, such as natural moisture content, grain size analysis, and Atterberg tests are shown in Table 1. The natural moisture content ranges from 6.6 % to 14.3 %, the result shows that sample A has the highest natural moisture content and sample F the lowest. Lambe *et al*., 1979 stated that the moisture content of soil depends mainly on the void ratio; thus, the result could be attributed to the void. However, the natural moisture content for all the locations is within the range of 5% to 15% specified by FMWH (2010) for engineering construction. This indicates that all the samples have low natural moisture contents, which implies that the natural soils have low water absorption capability.

The particle size analysis of the lateritic soil samples consists of gravel ranging from 0.30 to 2.90 %, sand 56.60 to 79.20 %, silt 3.90 to 8.20 % and clay 12.00 to 35.60 % with sand content more dominant (Table 2). FMWH specification requirement, for a soil sample to be used for road construction, the percentage by weight passing No. 200 sieve shall be less than but not greater than 35 %.

Identifying and classifying lateritic soil. Atterberg limits have proved to be valuable tools. The liquid and plastic limits values ranged from 26 % to 47 % and 3 % to 17 % respectively, with corresponding plasticity index ranging from 13 % to 46 % of the natural soil. The natural lateritic soil, according to Casagrande's plasticity chart, can be classified as CS (Clayey Sand), while according to the American Association of State Highway and Transportation Officials (AASHTO) soil classification guide; the soil can be classified as A-2-6 and A-7-6. Gidigasu, (1972) stated that a liquid limit of less than 35 % indicates low plasticity, between 35% and 50% indicates medium or intermediate plasticity, between 50 % and 70 % high plasticity, and between 70 % and 90 % very high plasticity. Based on this, sample B has low plasticity while samples A, C, D, E and F have medium or intermediate plasticity (Table 1). Jegede, (2000) recommended a plasticity index not higher than 12 % for base material while the FMWH recommended not greater than 20 % plasticity index for soil used as sub-grade material, 16 % maximum for Sub-base and 13 % maximum for a base course (FMWH, 1997). Considering the lateritic soils, only sample B fall within the range considered suitable for the base course, while samples A, C, D, E and F, their foundational qualities of natural soils, do not meet the requirement for a base and sub-base material for road construction, hence would require stabilization. The chemical composition of ordinary portland cement and periwinkle shell ash are presented in Table 3

Table 1: Summary of the preliminary test results for natural soil

Sample	Location	Natural Moisture Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)	AASHTO Classification	Soil Types
A	Emuhu	14.3	47	17	30	A-7-6	Clayey Sand
B	Owa-Ofie	10.4	26	13	13	A-2-6	Clayey Sand
C	Sanubi	13.1	37	14	23	A-6	Clayey Sand
D	Sanubi	11.6	49	3	46	A-7-6	Clayey Sand
E	Eku	13.5	41	9	32	A-7-6	Clayey Sand
F	Urhuoka	6.6	38	9	29	A-2-6	Clayey Sand

Table 2: Summary of results for particle size distribution

Samples	Coordinates	Soil Type	% Gravel (75mm-2mm)	% Sand (2mm-0.075mm)	% silt (0.075mm-0.002mm)	% clay <0.002mm
A (LO1)	6^0 13 6 N $6^0$14 17 E	A-7-6	2.90	57.80	8.00	31.30
B (LO2)	6^0 13 35 N 6^0 10 48 E	A-2-6	8.10	74.50	5.40	12.00
C (LO3)	5^0 45 34 N 6^0 01 42 E	A-6	0.00	59.90	6.60	33.50
D (LO4)	5^0 45 35 N 6^0 01 45 E	A-7-6	0.40	60.10	4.80	34.70
E (LO5)	5^0 45 00 N 6^0 00 18 E	A-7-6	0.10	56.60	8.20	35.10
F (LO6)	5^0 50 00 N 6^0 06 11 E	A-2-6	0.30	79.20	3.90	16.60

Table 3: Chemical composition of ordinary portland cement/PSA

Element Oxides	Weight (%) Cement	Weight (%) PSA
Chloride (Cl)	0.08	1.88
Silicon Dioxide (SiO_2)	19.25	40.88
Aluminium Oxide (Al_2O_3)	8.40	8.89
Ferric Oxide (Fe_2O_3)	0.42	1.55
Calcium Oxide (CaO)	66.15	45.15
Magnesium Oxide (MgO)	3.30	1.04
Sulphur Trioxide (SO_3)	2.20	0.10
Phosphorus Oxide (P_2O_5)	-	0.05
Titanium Oxide (TiO)	-	0.08
Sodium Oxide (NaO)	-	0.03
Potassium Oxide	-	0.03
Loss on Ignition (L. O. I)	2.50	6.30
Insoluble Residue (I. R)	1.42	28.0

Effect of cement stabilization on the lateritic soils from the study area

The most popular and flexible method of evaluating the strength of stabilized soil is the unconfined compressive strength. It is also the test to determine the required amount of addition to stabilizing soil (Singh and Singh, 1991). Federal Ministry of Works and Housing recommended 1500 KPa as a standard for use as road construction materials. Looking at samples B and F (A-2-6 soils), table 4 it takes 7 % cement content to stabilize the soils without any additive to obtain 1511 and 1501 KPa (soaked) respectively although marginal and is greater than the recommended standard of 1500 KPa. Also, in samples B and F, it takes 9 % cement content to stabilize the soil to obtain 1732 KPa. Again, in sample E (A7-6 soil), 7 % of cement content was used without any additive to obtain 1732 KPa, meaning that more cement content was used to stabilize A-2-6 soil compared to A-7-6 soil.

However, A-2-6 soil is better than A-7-6 soil (AASTHO Classification Chart); hence A-7-6 soil needs more cement content in stabilization, but the reverse is the case. This could result from the high percentage of fine particles (silt and clay), 39.5 and 43.3 % for samples D and E respectively Table 2. Fine particles significantly affect the mechanical properties of cement- treated sand, even at negligent proportions (Moon *et al,* 2019). Consoli *et al,* (2009) explored the effect of fine particles in cemented sand and reported that the presence of fine particles increases the materials' tensile strength and stiffness. This could be attributed to the fine particles acting as a filler material, facilitating more contact points among the particles. Again table 4, from the results and analysis, it could be established that some of the lateritic soils from the Western Niger Delta can be stabilized with 7 – 9 % cement content without any additives. Akpkodje, (1986) recommended using 3-5 % by weight of cement which corresponds to 5-7 % by volume of cement to stabilize some lateritic soil of the Eastern Niger Delta for road construction materials. However, this has not significantly improved the lateritic soil of the Western Niger Delta (Ugbe *et al*, 2021). Also, some of the soils of the Eastern Niger Delta (A-1 soil) are better and stronger than the soils (A-2 and A-7) of the Western Niger Delta (Casagrande Classification Chart), hence more cement content is needed to stabilize this soil, this is because soil stabilization using 3-5 % by weight of cement were only estimated value recommended for use only on A-1 soil (Little and Nair, 2009). Figure 2 and 3 shows the variation of UCS values with cement percentage unsoaked after 7 days and soaked for 24 hours respectively. A critical evaluation of the influence of soaking in water for not less than twenty – four hours reveals a percentage reduction in UCS (Table 4) with values ranging from 31.9 – 80.0 % using 0, 5, 7 and 9 % cement content. Adeyemi, (2013) confirmed that even when lateritic soil absorbs a low amount of water on soaking, it may suffer a great loss in strength in terms of UCS.

Table 4: Summary of Unconfined Compressive Strength test on cement stabilized soils

Location	Soil Type	Cement Content (%)	UCS. Unsoaked 7days (KPa)	UCS. Soaked 24hrs (KPa)	Percentage Reduction (%)
B Owa-Ofie	A-2-6	0	120	0	
		5	1677	577	65.6
		7	2218	1511	31.9
		9	3150	1732	45.0
D Sanubi	A-7-6	0	80	0	
		5	1155	577	50.0
		7	1732	808	53.3
		9	2079	1155	44.4
E		0	120	0	
		5	2887	577	80.0

Eku	**A-7-6**	**7**	**3464**	**1732**	**50.0**
		9	**4042**	**2079**	**48.6**
F Urhuoka	**A-2-6**	**0**	**120**	**0**	
		5	**1732**	**577**	**66.7**
		7	**2309**	**1501**	**35.0**
		9	**4042**	**1732**	**57.1**

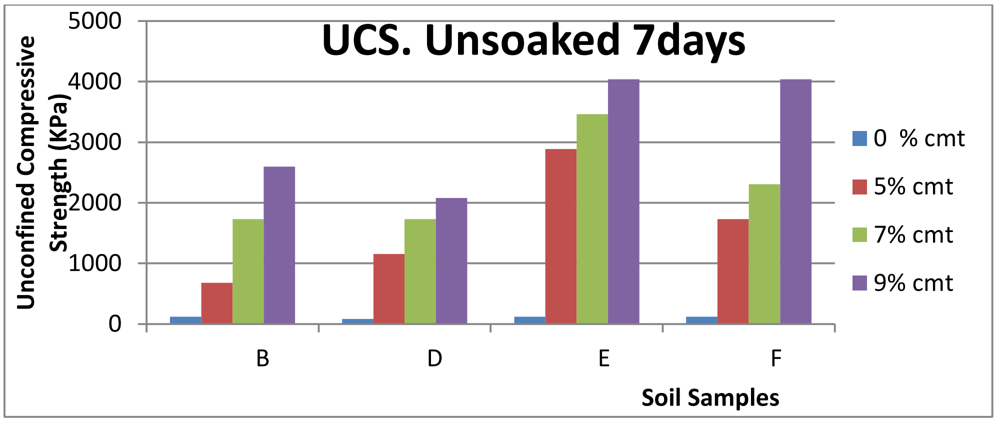

Figure 2. Variation of UCS with cement % Unsoaked after 7 days

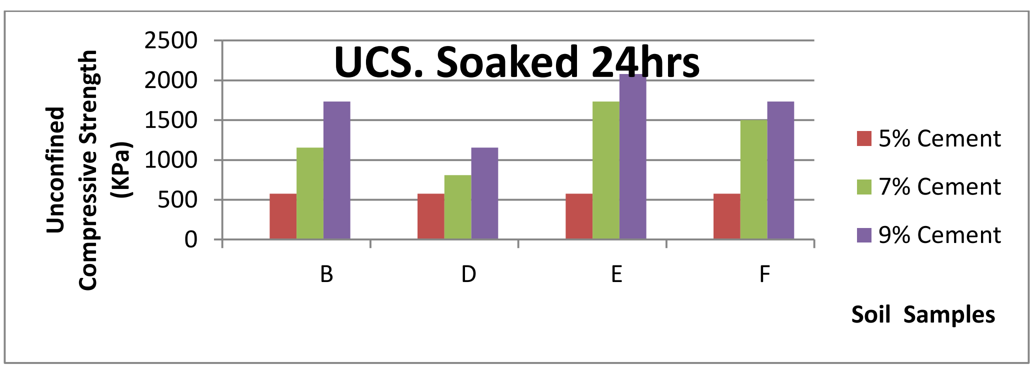

Figure 3. Variation of UCS with cement % Soaked after 24 hours

Effect of Cement/PSA on Unconfined Compressive Strength

The effect of Cement/PSA on unconfined compressive strength (UCS) soaked, with percentage dosage of cement and periwinkle shell ash for 7 days unsoaked and 24 hours soaked, respectively, as presented in Table 5, Figure 4 and 5. There was a general increase in UCS with the increase in Cement/PSA admixture. However, the increase in the sample could be due to the self-cementitious behaviour of the soil due to water as well as the stabilizer that influences the hydration reaction mechanism

(Etim *et al*, 2021). This is in agreement with previous studies by Onyelowe *et al* (2013), Abu-Farsakh *et al* (2015) and Idris *et al*, (2019). The unconfined compressive strength standard is 1500 KPa as per specification for the construction of roads and bridges (FMWH, 1997). Due to the flooding season in the Niger Delta region of Nigeria, resulting in water table elevation, the soaked sample was used for judgment.

From the results of the soil-cement stabilization, it could be established that it takes 9 % of cement content to stabilize the soil without any additives to obtain the values of UCS above the recommended standard with a drastic percentage reduction ranging from 44.4 – 57.1 %. Looking a sample B(A-2-6 soil), at 5 % cement content + 6 % PSA the value of UCS obtain is 1443 KPa with a 21.9 % reduction in UCS but does not meet the standard even though lower percentage reduction. Again, at 5 % cement content + 8 % PSA the value (1617 KPa) of UCS obtained meets the standard with a 22.2 % reduction in UCS. Considering sample F (A-2-6 soil), at 6 and 8 % PSA the values of UCS are 1617 and 1848 KPa with 36.3 and 33.3 % reduction in UCS respectively. Looking at sample D, at 5 % stabilized soil-cement + 6 % PSA the value of UCS is 1640 KPa with a 27.5 % reduction in UCS, while at 8 % PSA the value of UCS is 1732 KPa with a 28.2 % reduction in UCS. Again, sample E (A-7-6 soil), at 5 % stabilized soil-cement, with the addition of 6 and 8 % PSA, the values of UCS obtain are 1848 and 2079 PKa with 46.7 and 43.7 % reduction in UCS respectively. Comparing samples B and F although the same soil type (A-2-6) the values of UCS and percentage reduction in UCS differ, this could be as a result of different soil properties in the soil composition. This is also applicable to samples D and E.

However, in terms of percentage reduction in UCS, for all the samples, as the percentage of PSA increases the corresponding values of UCS also increase with the percentage reduction in UCS decreases gradually. A similar finding was also reported by Rafalko *et al*, (2007), in their study on the rapid chemical stabilization of soft clay soils. From the analysis above at 9 % cement content only we were able to obtain values of UCS above recommended standard with a high percentage reduction in UCS, but using 5 % cement content with the addition of 6 and 8 % PSA the values of UCS increases to recommended standard with minimum percentage reduction in UCS. It implies that the PSA affect the soil thereby increasing the strength at a minimum percentage reduction. That is to say, there could be properties in the composition of the PSA that is not present in the composition of ordinary cement that is responsible for the increase in strength and percentage reduction in UCS. Preferably, the soil-stabilized sample that meets the recommended standard upon the addition of PSA with a minimum percentage reduction in UCS could be recommended as used for construction material.

From the results and analysis comparing 5 % stabilized soil-cement + PSA and 9 % cement content without the admixture of PSA what we could not achieve using 9 % cement content, but were able to achieve with 5 % cement content with the addition of PSA which are waste constituting an environmental hazard. As a result, a 4 % quantity of cement would be saved if we considered the 5 % stabilized soil-cement with the addition of PSA instead of 9 % stabilized soil-cement without any additive of PSA, this is consistent with Ogirigbo *et al*, (2020). Still, with 5 % cement content, it will be less cost-effective considering the high cost of cement compared to PSA which are waste, abandoned and cheap when constructing considerably long kilometer road

Table 5: Comparison between A-2-6 and A-2-7 soils Stabilization

Sample	At 9 % Cement Soaked (KPa)	% Reduction	At 5 % Cement + 6 % PSA		% Reduction	At 5 % Cement + 8 % PSA		% Reduction
			Unsoaked (KPa)	Soaked (KPa)		Unsoaked (KPa)	Soaked (KPa)	
B	**1732**	**45.0**	**1848**	**1443**	**21.9**	**2079**	**1617**	**22.2**
F	**1732**	**57.1**	**2540**	**1617**	**36.3**	**2771**	**1848**	**33.3**
D	**1155**	**44.4**	**2263**	**1640**	**27.5**	**2413**	**1732**	**28.2**
E	**2079**	**48.6**	**3464**	**1848**	**46.7**	**3695**	**2079**	**43.7**

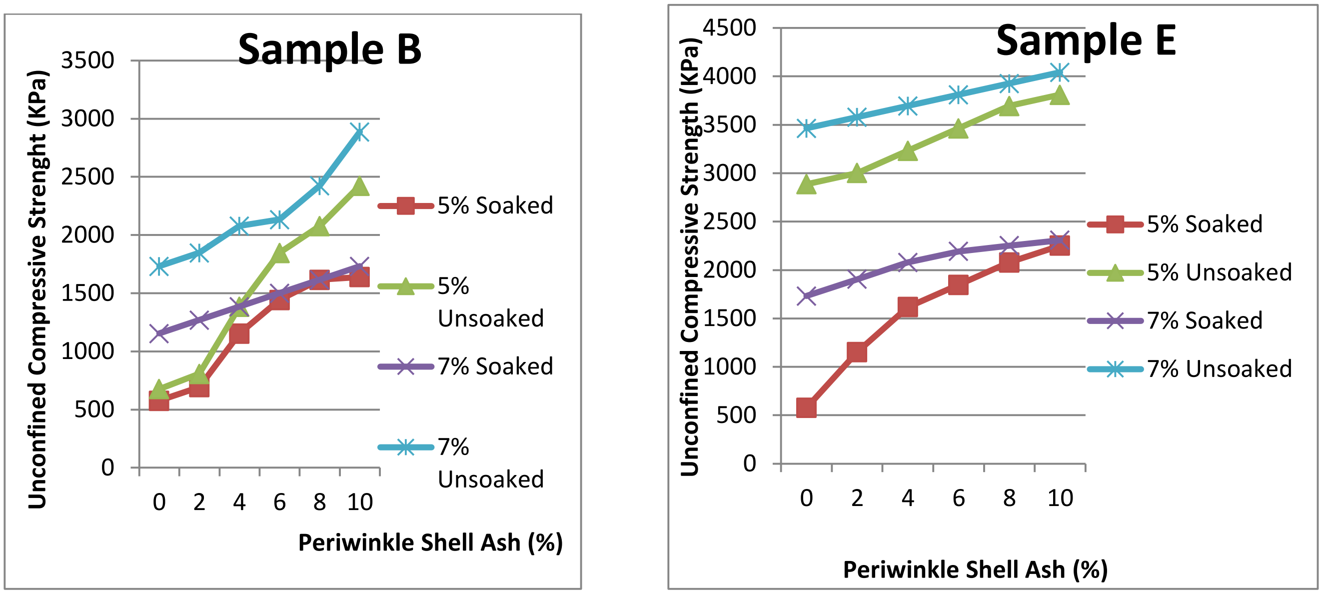

Figure 4.Variation of UCS with an increased percentage of Cement/PSA for sample B and E

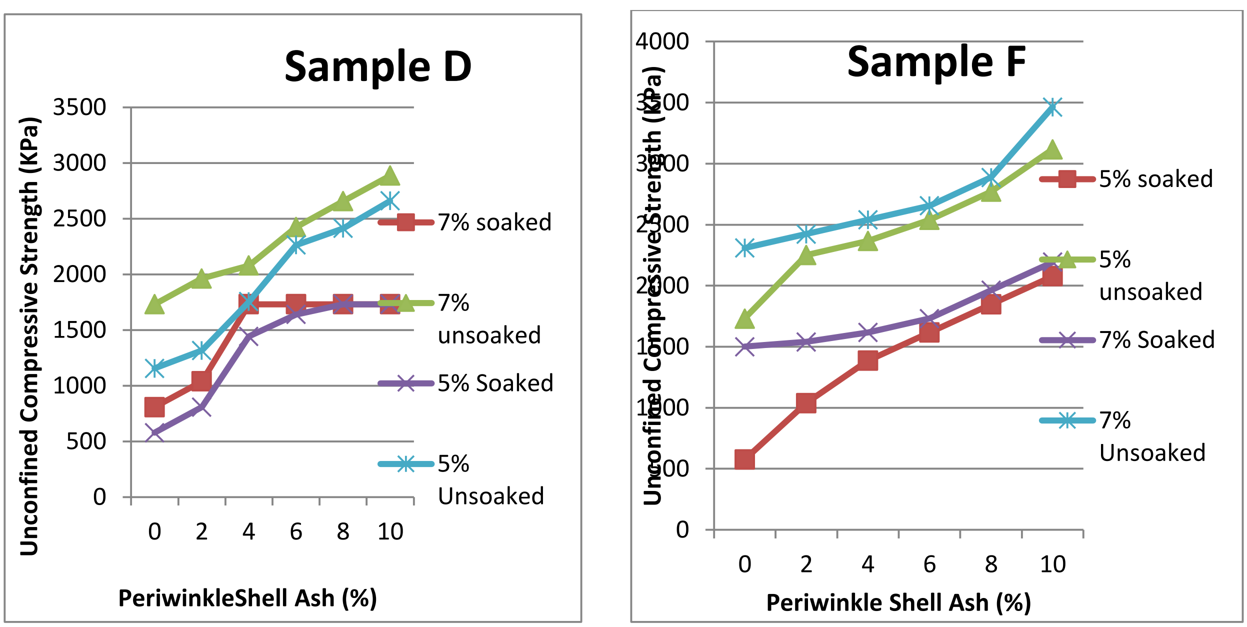

Figure 5. Variation of UCS with an increased percentage of cement and PSA for sample D and

Conclusion

The lateritic soils from the study area, according to the AASHTO classification system, belong to A-7-6 and A-2-6 groups and Clayey Sand (CS) using the USCS classification system. From the results obtained from cement-soil stabilization, it was seen that the method involving the use of cement and PSA improved the strength of the lateritic soil. Also, the Western Niger Delta soil could be stabilized using 5 to 9% cement. The effect of cement and PSA on UCS characteristics showed that the UCS increased as the additives increased. According to the recommended standard of 1500 KPa for road construction, the investigated soil samples meet the standard when stabilized with periwinkle shell ash. Again, it was observed that the quantity of cement required to obtain a UCS value of 1732 KPa was significantly reduced when PSA was added alongside the cement. This approach will result in cement savings and, more importantly, the use of waste materials. In a nutshell, the research work has confirmed that the combining effect of cement and PSA admixtures could be a helpful soil stabilizer in the construction of roads.

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