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The Impact of Pulverized Cow Bone on the Atterberg Limits of Lateritic Soil from Uwheru Town, Delta State, Nigeria

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Abstract

This study investigated the effect of pulverized cow bone (PCB) on the Atterberg limits of lateritic soil samples in Southern Nigeria. The liquid limit (LL), plastic limit (PL), and plasticity index (PI) of natural soil and soil mixed with different proportions of PCB were determined in the laboratory. The results showed that the liquid limit of the soil decreased with increasing PCB content, while the plastic limit increased, except for the sample mixed with 6% PCB, which had a lower plastic limit than the sample mixed with 4% PCB. The plasticity index of the soil also reduced with increasing PCB content. All the soil samples, both natural and stabilized, met the recommended maximum liquid limit for sub-base and base materials. The findings suggest that the addition of PCB may improve the soil's shear strength and reduce its susceptibility to plastic deformation. These results can be useful in the design and construction of roads and other civil engineering structures using lateritic soils in Southern Nigeria.

1.0. Introduction

Soil stabilization is a crucial factor in the construction industry, as it enhances the strength and durability of soil. Various techniques have been developed to stabilize soil, including the use of additives such as cement, lime, and fly ash. However, these materials can be expensive and can have adverse environmental impacts. The use of waste materials as soil additives has gained significant attention in recent years due to their low cost and environmentally friendly nature. One of the commonly used stabilizers is cow bone, which is a by-product of the meat industry. Cow bone is a cheap and easily available material that can be used as an alternative to expensive soil stabilizers. This study aims to investigate the effect of pulverized cow bone on the Atterberg limits of soil.

The Atterberg limits are a basic measure of the critical water content of soil. They correspond to the water content values at which the soil changes its behavior from plastic to semisolid and from semisolid to solid [1]. These limits are essential in soil mechanics as they define the soil's ability to support loads and undergo deformations under different environmental conditions. Therefore, changes in the Atterberg limits due to the addition of cow bone could have significant implications for the stability of soils.

Pulverized cow bone (PCB) is a waste product generated from the meat processing industry and is an abundant and inexpensive material. Previous research has indicated that the addition of PCB to soil can improve its strength and stability [2, 3]. For example, Gupta et al. in [4] investigated the use of cow bone powder as a stabilizer for soil and found that it significantly improved the soil's compressive strength. Similarly, Ali et al. in [5] reported that the addition of cow bone to soil

improved its stiffness and reduced its deformation. However, there is a need for more research on the effect of cow bone on the Atterberg limits of soil, especially the lateritic soil.
The Atterberg limits, including the liquid limit (LL) and plastic limit (PL), are important indicators of soil behavior, and they play a significant role in soil stabilization. Therefore, this study aims at investigating the potential of using PCB as an additive to enhance the Atterberg limits of soil. The findings of this study can be useful for soil stabilization in construction projects, especially in areas where traditional additives are not readily available or are too expensive. The result from the study could also provide valuable insight into the use of PCB as a soil stabilizer and its potential impact on soil stability.

2. Material and Methods

2.1 Materials

2.1.1 Lateritic soil

The lateritic soil samples were collected from Uwheru Town in the Delta Central Region of Delta State, Nigeria. The pits were excavated using diggers and shovels, and the soil samples were collected in polyethylene bags to prevent the exchange of moisture between samples. The samples were labelled according to their depths and location and left to air dry to eliminate existing moisture in the soil.

Figure 1. Sample of air-dried lateritic soil

2.1.2 Pulverized cow bone

The cow bones used in the study were obtained from an abattoir located on Eburu Street, off Eboh Road, Okumagba layout, Warri, Delta State. The bones were sun-dried for several months to remove excess fats and oils, allowing them to be ground into a powder. The pulverized cow bone was then stored in an air-tight container to prevent moisture from being added to it before testing. The sample of pulverized cow bone used in the study is shown in Figure 2.

Figure 2. Pulverized cow bone

2.2 Methods

The samples were air-dried and then pulverized to pass through a 2 mm sieve. Each soil sample was subdivided into 5 parts, with each part receiving a single dose of 0, 2, 4, 6, and 8% of PCB by weight. The soil sample's moisture content and maximum dry density were determined. The laboratory tests in Table 1 were performed on both the raw soil samples and their pulverized cow bone stabilized counterparts, excluding the preliminary grain size analysis test:

Table 1. Summary of test on soil sample and percentage stabilizer ratio

S/N	PCB Content (%)	Test performed	Lateritic soil Designation (S: CBA)
1	0	Liquid Limit	100:0
2	2	Liquid Limit	98:2
3	4	Liquid Limit	96:4
4	6	Liquid Limit	94:6
5	8	Liquid Limit	92:8
6	0	Plastic Limit	100:0
7	2	Plastic Limit	98:2
8	4	Plastic Limit	96:4
9	6	Plastic Limit	94:6
10	8	Plastic Limit	92:8

2.2.1 Atterberg limits test

The Atterberg limits of the soil were determined in accordance with ASTM D4318–10 - Standard Test Method for Liquid Limit (LL), Plastic Limit (PL), and Plasticity Index (PI) of Soils, to determine the plastic and liquid limits of the fine-grained soil. The test was conducted as prescribed in ASTM D4318. The Plastic Limit (PL) is the moisture content, expressed as a percentage, at which a soil can no longer be molded into 3.2 mm (1/8 in.) diameter threads without crumbling. The liquid limit (LL), on the other hand, is the moisture content that characterizes the point at which a soil changes from a plastic to a viscous fluid state. The shrinkage limit is the moisture content that characterizes the point at which the soil volume will no longer decrease if the moisture content is reduced. The Plasticity index (PI) is a measure of the plasticity of a soil. It is the range of water contents at which the soil exhibits plastic properties. Soil descriptions based on PI include: Non-

plastic (PI=0), slightly plastic (PI <17), medium plastic (7 – 17), and highly plastic (> 17). Soils with a high PI are generally clay, those with a lower PI are often silt, while those with a PI of zero (non-plastic) typically have little to no silt/clay. Various soil engineering properties have been correlated with the liquid and plastic limits, and these Atterberg limits are also used to classify a fine-grained soil according to the Unified Soil Classification System or AASHTO system.
Cow bone was sourced from a nearby abattoir and pulverized to a size of less than 0.5 mm. The pulverized cow bone was then added to the soil samples at different weight percentages (0%, 2%, 4%, 6%, and 8%). The soil samples were remolded and compacted using the Proctor compaction method. The Atterberg limits of the soil samples were then determined again after the addition of cow bone.

3. Results and Discussion

The British standard was used to determine the Atterberg limits and classification for the laterite samples used in this research. According to BS 1377: Part 2: 1990: 4.3 classifications, using the plasticity chart classification, the results obtained from the Atterberg Limits Test (Table 2 – 6) revealed that the Liquid Limit (LL) of the laterite decreased from 32.5 to 29.6% upon addition of 0 to 8% PCB while the Plastic Limit increased from 23.2% to a maximum value of 25.1% upon addition of 0 to 2% PCB and decreased from 25.1 to 23.3% upon addition of 4 to 8% PCB. The plasticity index (PI) reduced from 9.3 to 6.3% upon addition of 0 to 8% PCB. These results agree with the findings of Adanikin et al. in [6] and Adeboje et al. in [7].

Table 2. Atterberg limit test readings for the Lateritic soil with 0% PCB

Natural lateritic soil									
Liquid limit (LL)					**Plastic limit (PL)**				
Trial No:	1	2	3	4	**Trial No:**	1	2	3	4
Container No:	101	116	114	112	**Container No:**	111	226	264	
W_O	20.18	24.28	20.42	21.37	**W_O**	26.10	21.86	32.91	
W_1	39.69	38.92	40.10	40.03	**W_1**	33.83	28.27	39.18	
W_2	35.08	35.38	35.20	35.17	**W_2**	32.33	27.08	38.02	
W_W	4.61	3.54	4.90	4.86	**W_W**	1.50	1.19	1.16	
W_S	14.90	11.10	14.80	13.80	**W_S**	6.23	5.22	5.11	
W_C	30.94	31.89	33.10	35.22	**W_C**	24.10	22.8	22.7	
No. of blows	19	23	26	31	**Nb**				
LL = 32.5					**PL** = 23.2				
Plasticity Index (PI) = LL – PL = 9.3									

Table 3. Atterberg limit test readings for the lateritic soil with 2% PCB

Natural lateritic soil + 2% PCB									
Liquid limit (LL)					**Plastic limit (PL)**				
Trial No:	1	2	3	4	**Trial No:**	1	2	3	4
Container No:	102	115	100	113	**Container No:**	98	222	260	
W_O	21.41	20.37	20.82	21.93	**W_O**	20.16	25.21	27.01	
W_1	39.07	40.67	37.35	43.22	**W_1**	26.89	31.17	34.39	
W_2	35.12	35.96	33.34	37.91	**W_2**	25.58	29.93	32.92	
W_W	3.95	4.71	4.01	5.31	**W_W**	1.31	1.24	1.47	
W_S	13.71	15.59	10.52	15.98	**W_S**	5.42	4.72	5.91	
W_C	28.81	30.21	32.03	33.24	**W_C**	24.17	26.27	24.87	
No. of blows	17	21	24	29	**Nb**				
LL = 31.8					**PL** =25.1				
Plasticity Index (PI) = LL – PL = 6.7									

Table 4. Atterberg limit test readings for the lateritic soil with 4% PCB

Natural lateritic soil + 4% PCB									
Liquid limit (LL)					**Plastic limit (PL)**				
Trial No:	1	2	3	4	**Trial No:**	1	2	3	4
Container No:	200	201	206	203	**Container No:**	57	85	88	
W_O	20.12	23.31	21.67	21.09	**W_O**	21.43	21.32	20.05	
W_1	36.06	38.16	36.10	36.04	**W_1**	28.83	26.99	27.43	
W_2	32.28	34.75	32.71	32.45	**W_2**	27.45	25.82	25.96	
W_W	3.78	3.41	3.39	3.59	**W_W**	1.38	1.16	1.47	
W_S	12.16	11.44	11.04	11.36	**W_S**	6.02	4.51	5.91	
W_C	31.09	29.81	30.71	31.6	**W_C**	22.92	25.72	24.87	
No. of blows	18	22	27	30	**Nb**				
LL = 31.0					**PL** = 24.5				
Plasticity Index (PI) = LL – PL = 6.5									

Table 5. Atterberg limit test readings for the lateritic soil with 6% PCB

Natural lateritic soil + 6% PCB									
Liquid limit (LL)					**Plastic limit (PL)**				
Trial No:	1	2	3	4	**Trial No:**	1	2	3	4
Container No:	52	55	57	61	**Container No:**	38	47	43	
W_O	22.21	21.64	21.17	21.55	**W_O**	20.01	20.82	21.04	
W_1	43.16	42.34	41.84	42.91	**W_1**	26.24	27.02	27.70	

W_2	38.30	37.56	37.03	37.67	**W_2**	25.05	25.80	26.44	
W_W	4.86	4.78	4.81	4.91	**W_W**	1.19	1.22	1.26	
W_S	16.09	15.92	15.86	16.12	**W_S**	5.04	4.98	5.40	
W_C	30.21	30.03	30.33	30.45	**W_C**	23.61	24.5	23.33	
No. of blows	17	20	23	27	**Nb**				
LL = 30.4					**PL** = 23.8				
Plasticity Index (PI) = LL – PL = 6.6									

Table 6. Atterberg limit test readings for the lateritic soil with 8% PCB

Natural lateritic oil + 8% PCB									
Liquid limit (LL)					**Plastic limit (PL)**				
Trial No:	1	2	3	4	**Trial No:**	1	2	3	4
Container No:	341	290	326	331	**Container No:**	332	339	323	
W_O	26.31	20.66	22.61	22.19	**W_O**	20.99	21.04	21.19	
W_1	47.10	41.62	43.39	43.06	**W_1**	28.12	28.13	28.28	
W_2	42.37	36.80	38.63	38.27	**W_2**	26.79	26.77	26.94	
W_W	4.73	4.82	4.76	4.79	**W_W**	1.33	1.36	1.34	
W_S	16.06	16.14	16.02	16.08	**W_S**	5.80	5.73	5.75	
W_C	29.45	29.86	29.71	29.78	**W_C**	22.93	23.73	23.3	
No. of blows	19	23	29	32	**Nb**				
LL = 29.6					**PL** = 23.3				
Plasticity Index (PI) = LL – PL = 6.3									

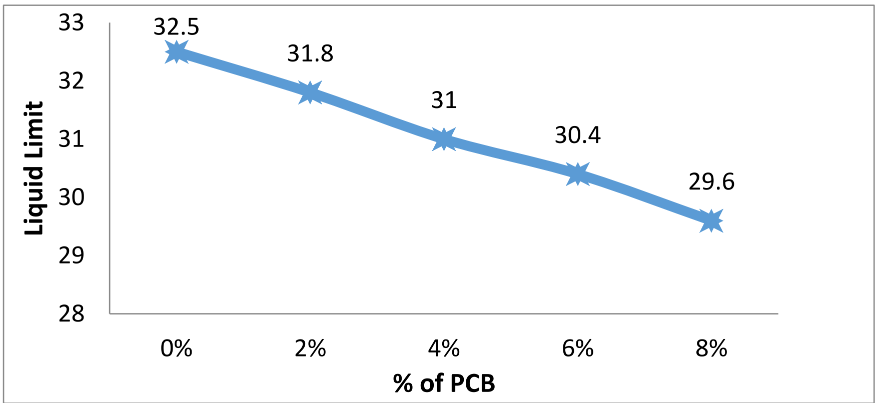

Figure 3. Liquid Limit results for the lateritic soil with mix proportions of PCB

Figure 3 shows the summary of the results of the Liquid Limit test conducted on lateritic soil samples with different mix proportions of pulverized cow bone (PCB). It displays the percentage of PCB added to the soil and the corresponding liquid limit values obtained. As the percentage of PCB added to the soil increases, the liquid limit values decrease. For example, the soil sample with 0% PCB has a liquid limit of 32.5%, while the sample with 8% PCB has a liquid limit of 29.6%. This suggests that the addition of PCB has a stabilizing effect on the soil, making it less susceptible to changes in moisture content.

Figure 4 shows the summary of the results of the Plastic Limit (PL) tests for the Lateritic Soil samples with different mix proportions of Pulverized Cow Bone (PCB). It presents the percentage of PCB used in the mix, ranging from 0% to 8%, and the corresponding Plastic Limit values obtained for each mix. The Plastic Limit is the water content, in percent, at which a soil can no longer be deformed by rolling into 3.2 mm (1/8 in.) diameter threads without disintegrating. The results show that the Plastic Limit values slightly increased with the addition of PCB, from 23.2% for the soil without PCB to 25.1% for the soil with 2% PCB, and then decreased slightly with further additions of PCB, reaching 23.3% for the soil with 8% PCB.

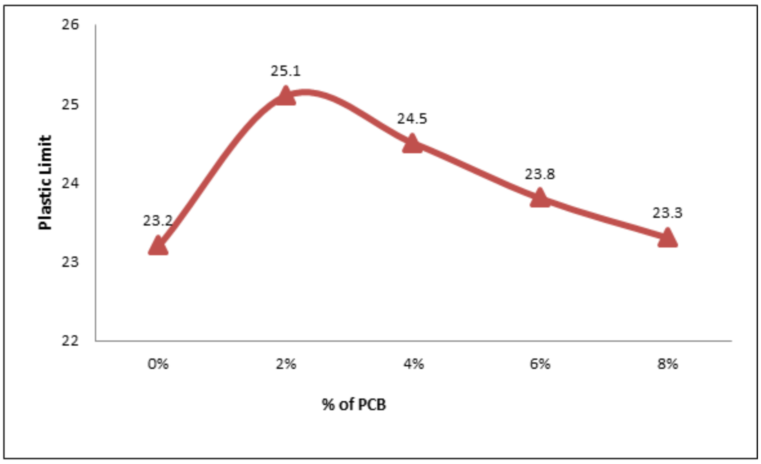

Figure 4. Plastic Limit results for the Lateritic soil with mix proportions of PCB

Figure 5 shows the variation of the liquid limit (LL), plastic limit (PL), and plasticity index (PI) of natural soil and soil mixed with pulverized cow bone (PCB) at different proportions. The liquid limit values ranged from 32.5% for natural soil to 29.6% for soil mixed with 8% PCB. This indicates that the addition of PCB led to a reduction in the liquid limit of the soil. The plastic limit values ranged from 23.2% for natural soil to 25.1% for soil mixed with 2% PCB. This shows that the addition of PCB increased the plastic limit of the soil, except for the sample mixed with 6% PCB, which had a lower plastic limit than the sample mixed with 4% PCB. The plasticity index values ranged from 9.3 for natural soil to 6.3 for soil mixed with 8% PCB. The plasticity index reduced with increasing PCB content, indicating that the soil became less plastic and more brittle.

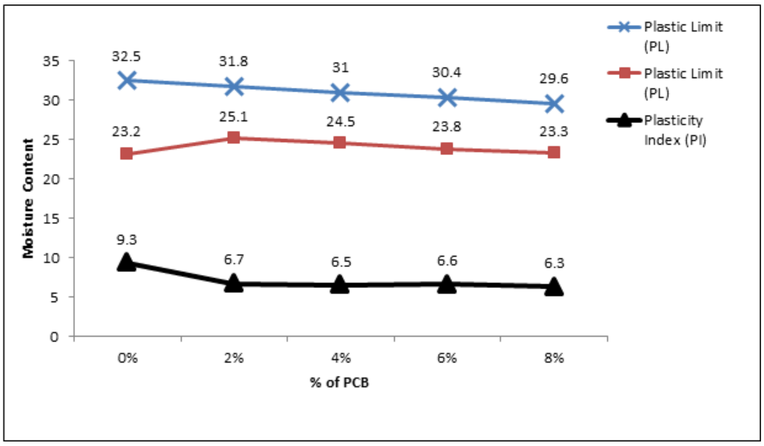

Figure 5. Variation of LL, PL and PI with % of PCB

Overall, the results suggest that the addition of PCB had a significant effect on the Atterberg limits of the soil. The decrease in liquid limit and plasticity index and the increase in plastic limit with the addition of PCB may indicate an improvement in the soil's shear strength and reduced susceptibility to plastic deformation. According to the Federal Ministry of Works and Housing [8], the recommended maximum liquid limit for road works is 50% for sub-base and base materials. All the soil samples studied, both natural and stabilized, fall within this specification, making them suitable for sub-grade, sub-base, and base materials.

4. Conclusion

Based on the results obtained from this study, it can be concluded that the addition of pulverized cow bone (PCB) had a significant effect on the Atterberg limits of the lateritic soil samples. The liquid limit of the soil decreased with the addition of PCB, while the plastic limit increased, except for the sample mixed with 6% PCB, which had a lower plastic limit than the sample mixed with 4% PCB. The plasticity index of the soil also reduced with increasing PCB content.

All the soil samples, both natural and stabilized with different proportions of PCB, fell within the recommended maximum liquid limit of 50% for sub-base and base materials according to the Federal Ministry of Works and Housing. Therefore, the stabilized soil samples can be considered suitable for sub-grade, sub-base, and base materials.

Overall, the results suggest that the addition of PCB may lead to an improvement in the soil's shear strength and reduced susceptibility to plastic deformation. The findings of this study can be useful in the design and construction of roads and other civil engineering structures using lateritic soils in Southern Nigeria.

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