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RESEARCH ARTICLE

THE IMPROVEMENT OF THE CHIKOKO MARINE CLAY USING OYOROKOTO WATER

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ABSTRACT

Engineering properties of an extremely soft marine clay (locally known as Chikoko) were determined using tap water and compared with its properties when Oyorokoto sea water is used. Test results show considerable improvement in its properties when sea water is used. There was a reduction in plasticity index, free swell value, swell pressure and in the maximum dry unit weight, while the unsoaked CBR and optimum moisture content increased. There was however no significant improvement in the unconfined compressive strength (UCS).

INTRODUCTION

The Chikoko soil is an extremely soft marine clay in the Niger Delta area of Nigeria posing numerous problems for foundation engineers. Most near surface Chikoko soils are highly fibrous, organic and consisting mainly of vegetative matter in various states of decomposition (Otoko and Onyekaba 2014; Wong *et al.*, 2006, 2008). According to Adesunloye (1987) the deltaic marine clay presents as dark grey, dark brown to black material with characteristics foul odour.Problematic marine clays exhibit high compressibility, medium to low permeability, low strength and volume instability (Wong et al 2008, Deboucha and Alawi 2007; Hashim and Islam 2008). It fails easily under surcharge load, and it is characterised with low shear strength, low compressibility and high water content (Huat 2007, Kalantari and Haut 2008a, 2008b, 2009).Marine clays are usually stabilized or the marine clays removed and replaced fully or partially with better quality fill before building on it (Huat 2007; Hebib and Farrell 2003).This paper therefore, investigates the improvement of the engineering properties of the Chikoko marine clay using Oyorokoto sea water containing various salts, particularly in view of the economy to be achieved in the planned coasted road passing through Oyorokoto.

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MATERIALS AND METHODS

Sea water was collected from the Oyorokoto sea and tap water from the engineering laboratory of the Rivers State Universityof Science and Technology, Port Harcourt. The Chikoko marine clay was obtained from the Eagle Island (Fig. 1).

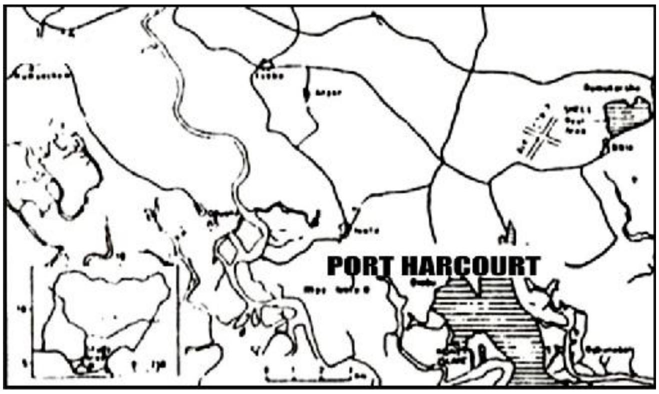

Figure 1. Map of the Niger Delta, Nigeria, showing the location of Port Harcourt City, Nigeria

Tests were conducted with both sea water and tap water as to finding out the effect of sea water on the engineering properties of the Chikoko marine clay. Tests conducted include: Atterberg limits, free swell, swell pressure, compaction, consolidation, CBR and UCS. Results obtained are shown in Table 1, and the particle size distribution shown in Fig. 2

Table 1. Properties of Chikoko

S.No	Property	Results
1	Natural moisture content (%)	90.10
2	Specific gravity	2.45
3	Bulk unit weight (kN/m^3)	14.30
4	Liquid limit (%)	115.0
5	Plastic limit (%)	46.5
6	Plasticity index (%)	68.5
7	Liquidity index (%)	0.64
8	Shrinkage limit (%)	21.36
9	Free swell index (ll/g)	4.23
10	Salinity (g/l)	2.95
12	Activity	1.59
13	Organic matter (%)	6.32
14	PH value	6.75
15	Grain size distribution	
	(i) Clay size (%) (<0.002mm)	43
	(ii) Silt size (%) (>0.002<0.075mm)	40
	(iii) Sand size (%) (>0.075mm)	17

The various salts contained in the Oyorokoto sea water is given in Table 2.

Table 2. Various Salts Contained in the Oyorokoto Sea Water.

S.No	Salt Species	Tap Water	Sea Water
1	Calcium carbonate	0.55	0.82
2	Calcium bicarbonate	0.41	1.23
3	Calcium chloride	No traces	No traces
4	Calcium sulphate	No traces	No traces
5	Sodium carbonate	No traces	No traces
6	Sodium bicarbonate	0.17	0.18
7	Sodium chloride	26.50	435.90
8	Sodium sulphate	No traces	No traces
9	Potassium carbonate	No traces	No traces
10	Potassium bicarbonate	0.11	0.11
11	Potassium chloride	No traces	No traces
12	Potassium sulphate	No traces	No traces
13	Magnesium carbonate	0.25	0.25
14	Magnesium bicarbonate	0.14	0.14
15	Magnesium chloride	10.71	118.75
16	Magnesium sulphate	No traces	No traces

The Atterberg limits and free swell results are shown in Table 3 using tap water and sea water in carrying out the tests.

Table 3. Comparison of Limits, Indices and Free Swell Index

S.No	Parameter	Tap Water	Sea Water
1	Liquid limit	115.0	76.4
2	Plastic limit	46.5	17.1
3	Shrinkage limit	21.36	13.8
4	Plasticity index	68.5	59.3
5	Liquidity index	0.64	0.02
6	Free swell index	4.23	2.34

Test results from standard Proctor Compaction using tap water and using sea water are shown in Fig. 2 and 3 respectively and in Table 4.

Table 4. Proctor Compaction Test Results

S.No	Parameter	OMC (%)	Dry unit weight (kN/m^3)
1	Tap water	14.4	18.2
2	Sea water	16.3	17.5

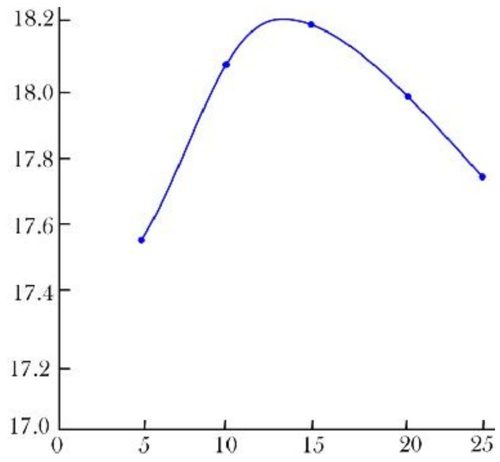

Figure 2. Dry unit weight – Optimummoisture content relationship,using tap water

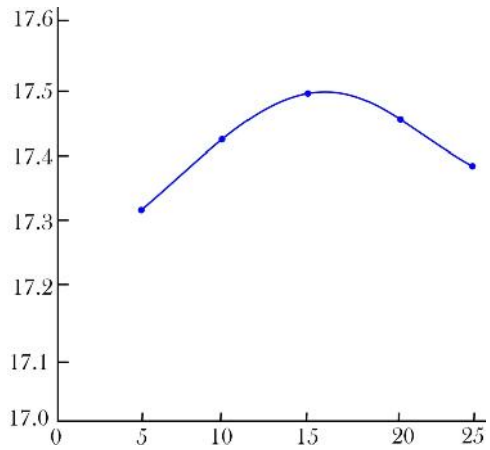

Figure 3. Dry unit weight – Optimummoisture content relationship,using tap water

The stress- strain curves for the unconfined compressive strength test are shown for using tap water and salt water in Fig. 4 and Fig. 5 respectively. Thereafter, three days was allowed for the sea water salts to react with the soil, and the test repeated. The test results obtained after the three days reaction time are shown in Fig. 6 and 7 for using tap water and using the sea water respectively.

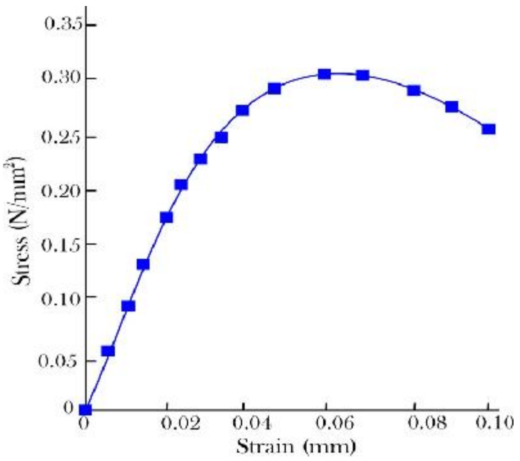

Figure 4. Stress strain relationship ofsoil using tap water

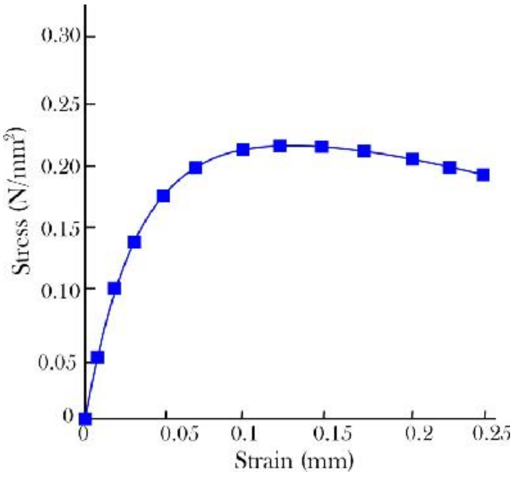

Figure 5. Stress strain relationship ofsoil using sea water

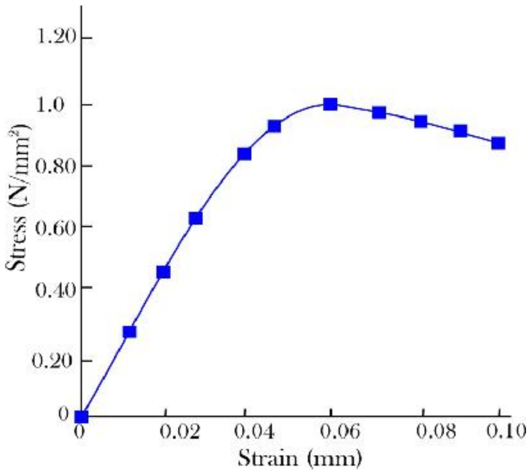

Figure 6. Stress strain relationship ofsoil using tap water after 3 days

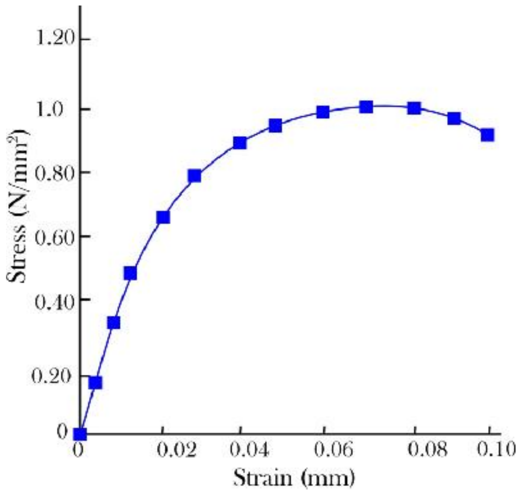

Figure 7. Stress strain relationship ofsoil using sea water after 3 days

The swell pressure, consolidation test using odometer and CBR tests were performed in accordance with BS 1377:1990. Swell pressure and coefficient of consolidation results were in the order of 7.05T/m^2 and 0.0025 for sea water respectively and in the order of 7.44 and 0.0021 for tap water respectively; while the CBR tests show CBR value in the order of 11.2% and 10.3% for sea water and tap water respectively.

Table 4. UCS Test Results

S.No	Parameter	Unconfined compressive strength test N/mm^2	Undrained strength N/mm^2
1	Tap water	0.315	0.158
2	Sea water	0.216	0.108
3	Tap water-soil after 3 days	0.958	0.479
4	Sea water-soil after 3 days	0.975	0.488

RESULTS AND DISCUSSION

Table 1 shows the engineering properties of the sample, while Table 2 shows all the salts contained in the Oyorokoto sea water. From Table 1, there is a drop in the liquid limit and plastic limits, showing less susceptibility to water content changes when sea water is used. There is an increase in the Optimum moisture content by using sea water and decrease in the maximum dry unit weight. Sea water samples, after three days show almost the same values of unconfined compressive strength, probably due to absence of or very small pozzolanic reaction, which usually occurs un lime stabilization due to the presence of calcium which is usually responsible for the strength improvement. The swell pressure decreased, while the coefficient of consolidation and the CBR increased by using sea water. This probably due to the increased size of clay minerals.

Conclusion

While liquid limit, plastic limit, plasticity index, free swell index and swell pressure of clay mineral reduces with use of sea water, the particle size, optimum moisture content, CBR and the coefficient of consolidation increases. Therefore, in view of the planned costa road project, sea water can be used for satisfactory stabilization of the Chikoko marine soil along the preferred route.

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