The Effect of Salt Water on the Physical Properties, Compaction Characteristics and Unconfined Compressive Strength of a Clay, Clayey Sand and Base Course

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ABSTRACT

The Atlantic ocean water (salty water) has been used to mix three soil types and its physical properties, compaction characteristics and unconfined compressive strength compared with the properties of the three soil types mixed with tap water. Results of laboratory investigation are presented to show that plasticity index decreased from 13 using tap water to 5 using salty water for the clay, from 10 using tap water to 4 using salty water for the clayey sand and from 6 using tap to 1 using salty water for the base course. The maximum dry unit weight were in the order of 20.9, 22.5 and 19.5kN/m^3 for the clay, clayey sand and base course respectively when mixed with tap water. Using salty water, decreased the maximum dry unit weight for the clay from 20.9kN/m^3 to 17.5kN/m^3, but increased that of clayey sand and base course from 19.1kN/m^3 to 20.4kN/m^3 and from 22.5kN/m^3 to 23.2kN/m^3 respectively. The unconfined compressive strength increased from 30kN/m^2 to 57kN/m^2, 83kN/m^2 to 130kN/m^2 and 40kN/m^2 to 63kN/m^2 respectively, for the clay, base course and clayey sand when mixed with salty water, in comparison with when mixed with tap water. It is therefore concluded that the Atlantic ocean salty water could be a good stabilizing agent, particularly when construction work is close to the Atlantic shore.

Introduction

Common application of soil stabilization is in the strengthening of soil components of highway and air field pavements. A completely consistent classification of soil stabilization techniques is not available (Chen 1981). It is mostly classified by method of treatment being used e.g dewatering, compaction, thermal or electrical treatment, or by the use of additives as asphalt or cement.

Soils with high clay content have a tendency to swell at high moisture contents (Chen 1981), thus causing cracking and break up of pavements, railways, highways, embankments, roadways, foundations and reservoir linings Erdal Cokca (1999).

Many stabilizing agents have been used, Pyne (1955) used calcium chloride, Lopez and Castano (2001) used calcium oxide, Ghafoori and Cai (1997) and Ghafoori (2000) used coal combustion by-products. Muntohar and Hantoro(2000) and Muntohar (1999) used fly ash and pozzolana. However, more of these studies used a mixture of their compounds as stabilizing agent.

The Atlantic ocean is one of the most prominent geomorphic features in the Niger Delta of Nigeria and its water contains up to 300gm of salt per liter of water. Since calcium chloride, sodium chloride and other salts have been shown from previous studies, to be useful stabilizing agents, it follows that the Atlantic ocean water could be useful stabilizing agent, particularly when considering the Federal Government planned coastal road from Lagos to Calabar along the Atlantic shore.

Experimental Method

The opportunity for this study came where a road construction work was being carried out from Ikuru Town to the Atlantic shore. Three types of soil were investigated viz: a clay, clayey sand and base course. 10kg of each soil type was taken from the construction site, dried at 100^{o}c, sieved to different particle sizes to fulfill the standard requirements (ASTM D421 and ASTM D422) and saved in closed containers at room temperature. Fig. 1 shows the location of Ikuru Town, while Fig 2 show the grain size distribution of the soil types.

Fig 1 Map of part of Niger Delta, Nigeria showing location of Ikuru Town

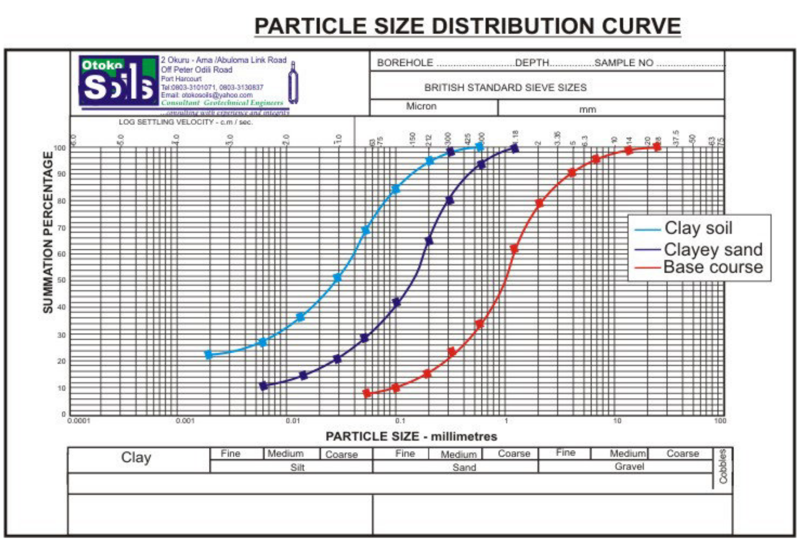

Fig 2 Particle size distribution curves of clay soil, clayey sand and base course.

Compaction Test

Standard/Modified Proctor Compaction Test

Standard Proctor Compaction tests were carried out on 3kg of each soil type passing No. 4 sieve, and mixed with both tap and Atlantic Ocean salty water separately, while the modified proctor compaction tests were carried out on 3kg of each soil type retained on (No. 4 sieve) and mixed with both tap and Atlantic Ocean salty water separately.

The compaction test results gave the optimum moisture content and dry unit weight (ASTM D698 – 78, ASTM and AASHTO T180 – 90) of the compacted soils shown in fig 3, 4 and 5.

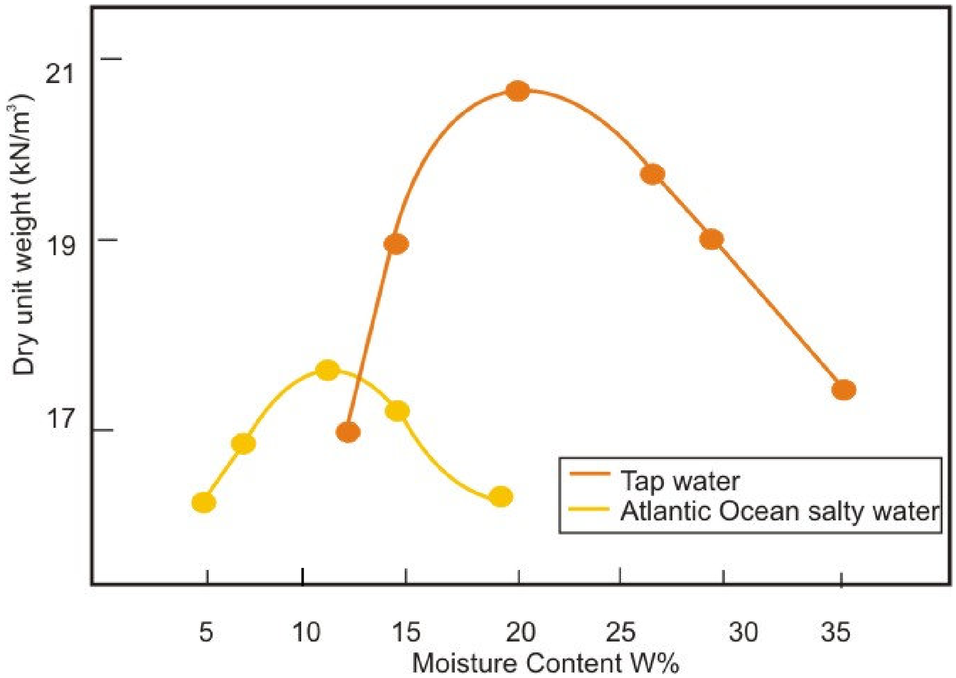

Fig 3. Compaction curves for clay soil using tap water and Atlantic Ocean water

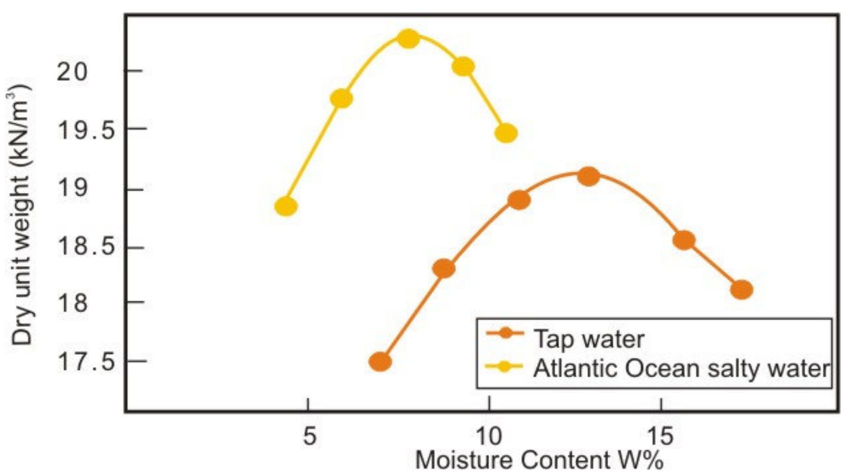

Fig 4. Compaction curves for clayey sand using tap water and Atlantic Ocean water

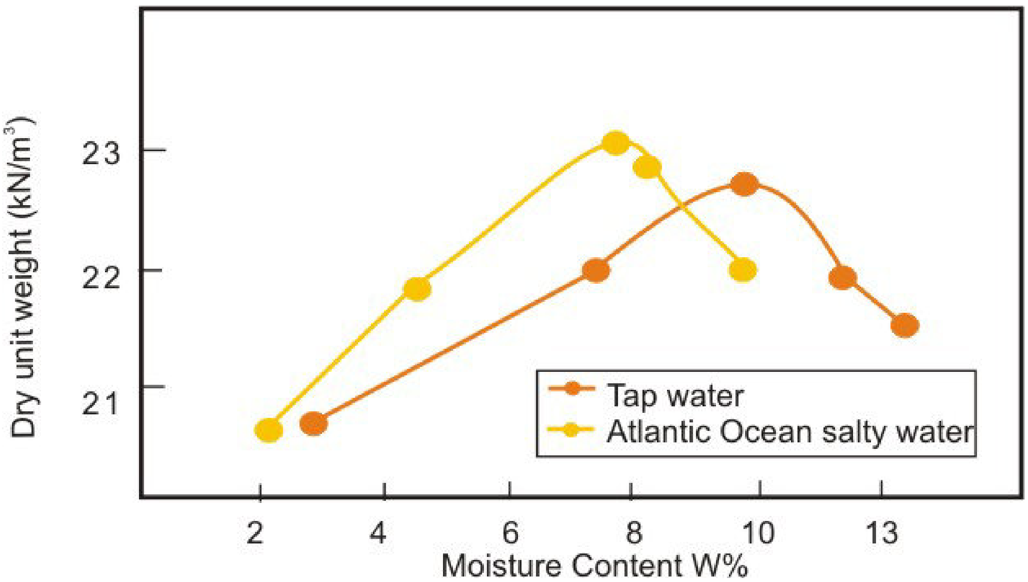

Fig 5. Compaction curves for base course using tap water and Atlantic Ocean water

Atterberg's Limits

About 100g of each of the three soil types were mixed with both tap and Atlantic Ocean salty water separately, to form a uniform paste (ASTMD 4318), with the object of determining the effect of the Atlantic Ocean water on the atterberg limit of the soils. All the soils showed a tendency to stiffen and a drop in the atterberg limits in using the Atlantic Ocean water (see table 1)

Table 1 Effect of salty water on Atterberg limits and compactions

S/N	Soil type	Specific gravity	Water type	Atterberg limits			BS Compaction tests	
				LL	PL	PI	Maximum Dry Unit Weight (kN/m^3)	Optimum Water Content (%)
1	Clay soil	2.75	Tap water	39	26	13	20.9	20.8
			Salty water	29	24	5	17.5	11.0
2	Clayey sand	2.63	Tap water	25	15	10	19.5	12.5
			Salty water	20	16	4	20.5	7.5
3	Base Course	2.50	Tap water	23	17	6	22.5	10.0
			Salty water	18	17	1	23.2	7.5

Unconfined Compression Test

Unconfined compression tests were carried out on the three soil types compacted to optimum water content and there after moulded to a cylindrical shape of dimensions 112.5mm height and 50.0mm diameter in accordance to ASTMD 2166 – 85). The results obtained are shown in fig 6, 7 and 8.

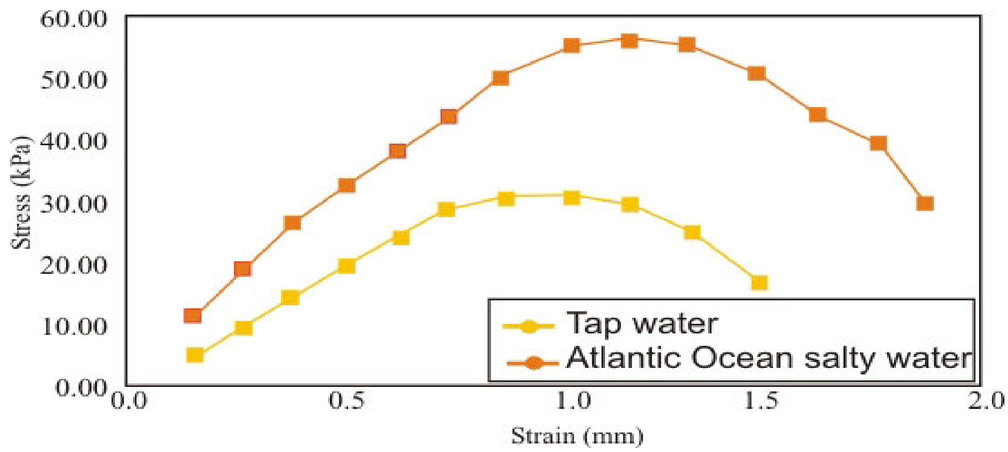

Figure 6. Stress Strain relation for clay soil with tap water and Atlantic salty water.

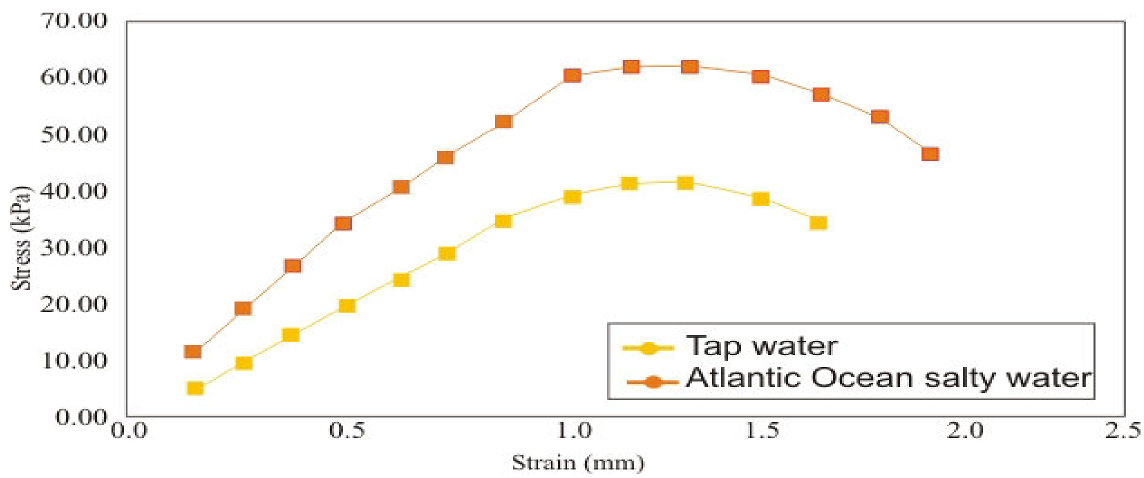

Figure 7. Stress Strain relation for clayey sand with tap water and Atlantic salty water.

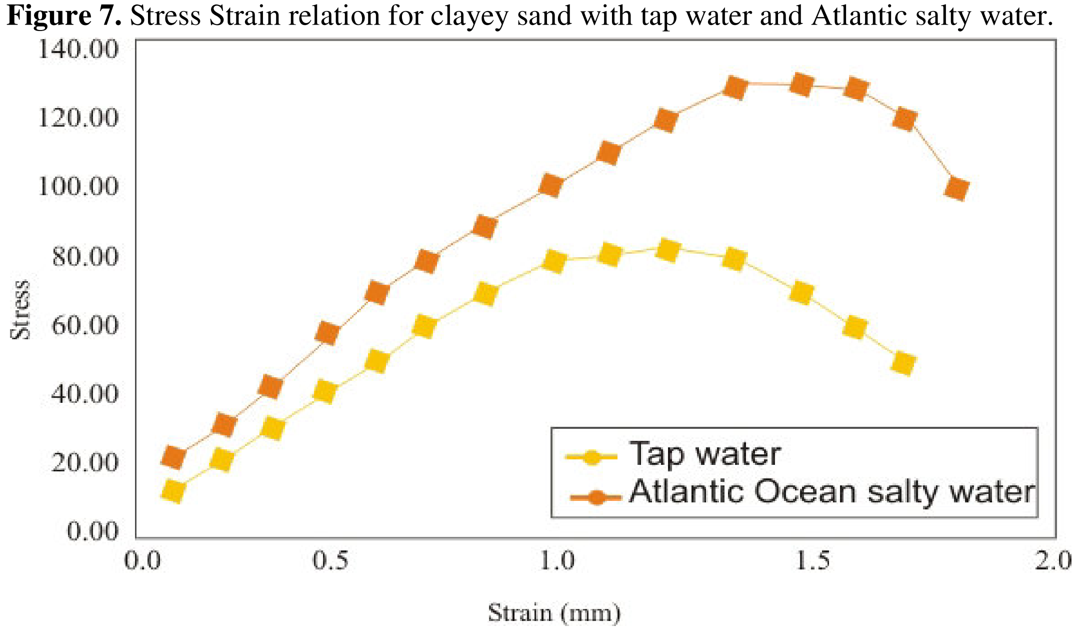

Figure 8. Stress Strain relation for base course with tap water and Atlantic salty water.

Discussion of Results

The physical properties of the soils test showed the specific gravity and compaction characteristic of the clay, clayey sand and base course. The clay gave the highest specific gravity of 2.75, while the base course gave the lowest specific gravity of 2.50. The moisture content ranged from 15% to 29% for the clay soil, 13% to 15% for the clayey sand and 11% to 14% for base course.

The Atterberg's limit, unconfined compressive strength and compaction characteristic of the soils tested, gave the values shown in table1, for both tap and Atlantic ocean water. When mixed with tap water clay gave the highest liquid and plastic limits, while the base course gave the lowest. Plasticity index of the clay soils, clayey sand and base course reduced from 13% to 5%, 10% to 4% and 6% to 1% when mixed with tap water and Atlantic ocean water respectively. This may be attributed to substitution of water molecules by the salts and thereby, decreasing the double layer system, which decreased the water content in the samples to stiffen the samples (Lopez and Castano 2001).

The grain size distribution for the three soil types are presented in fig. 2. The sieve and hydrometer analysis gave the curves shown in the figure.

Fig 3, 4 and 5 shows the compacted characteristic of the soils mixed with tap and salty water. The maximum dry unit weight were in the order of 20.9, 22.5 and 19.5kN/m^3 for the clay, clayey sand and base course respectively when mixed with tap water. Using salty water, decreased the maximum dry unit weight for the clay from 20.9kN/m^3 to 17.5kN/m^3, but increased that of clayey sand and base course from 19.5kN/m^3 to 20.5kN/m^3 and from 22.5kN/m^3 to 23.2kN/m^3 respectively. This may have resulted from the repulsive force between the salt molecules and the clay intermolecular structure, causing an increase in the intermolecular distances and an increase in the void ratios (Emil and William (1990) and Emil (1962). Also, some of the salt ions may have attracted some of the clay particles, which could lead to forming coagulation phenomena that may have affected the fragility of the clay compaction test (Lopez et al 1999); whereas, the increase in the dry unit weight of the base course could be as a result of a chemical reaction between the salt molecules and soil particles, which partially contains lime. Sodium, potassium and magnesium chlorides from salt reacts with calcium oxides and hydroxides from soil to form calcium chloride, which hardens the soil and increases the dry unit weight (Lopez et al 2001, Emil and William 1990 and Emil 1962).

figure 5, 6 and 7 show the relation between the unconfined shear strength and strain from three soil types using tap and salty water respectively. From figs. 5 and 6 the clay soil and the clayey sand have higher unconfined compressive strength using salty water than using tap water respectively, because the clay soil has multi layers of gibbsite and silica sheets with hydrogen bonding linking these sheets (Dunn 1980). Upon axial compression, these sheets become closer to each other and the tendency of these sheets to resist compression is high, which leads to higher shear strength; whereas, the structure of base course has a compacted calcium oxide molecule, which fail more rapidly than clay. Fig.7 shows that salty water enhances the shear strength of the base course. This is due to the change of calcium oxides and hydroxide into calcium chloride, which has more resistance to shear (Lopez et al 2001).

Conclusion

Atterberg limits and compaction characteristics of three soil types were tested mixing with tap and salty water respectively. Test results shows that addition of salty water has great improvement in their atterberg limits, compaction characteristics and unconfined compression strength. Therefore, the Atlantic Ocean salt water could be a great stabilizing agent particularly in such cases where construction is along the Atlantic shore, because of its proximiling, rather than having to input other stabilizing agent to the area.

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