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Effect of Salinity on the Compactness and Bearing Capacity of Gravelly Laterite in the Nuimi Hakalang Area in the Gambia

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Abstract: ***The use of salt water in general earthworks and pavement layers was studied. Six samples (E1, E2, E3, E4, E5 and E6) were prepared and their physical and mechanical characteristics determined. Samples mixed with salt water have γ_d higher than those which are mixed with fresh water ($\gamma_{d\ E2} > \gamma_{d\ E1}$, $\gamma_{d\ E4} > \gamma_{d\ E3}$,..). Regarding the plasticity indices, their evolution shows that the PI are inversely proportional to the salt concentration. CBRs have the same behavior as mdds. However, in the presence of cement and salt water, the CBR increases with little variation. With the addition of sand in the presence of salt water, we observed a strong increase in the CBR (the CBR varied from 52 to 92%, or 40 points). In view of these observations, it appears clear that: the use of salt water makes it possible to increase the performance of the material, Salt has more affinity with sand than with cement, hence it is proposed litho stabilization and not stabilization with cement. Due to the reduction in stiffness and brittle behavior of the material in the optimal water content range for sample E6 [10], we conclude that salt water is used up to the subbase layer and fresh water for the base layer in non-arid areas.***

Keywords: Sample, Salt water, performance, rigidity, litho stabilization

1. Introduction

Studies on the use of salt water in road construction have been initiated since the 1970s in Africa. Research carried out over the last 10 to 20 years has concluded that salts at a certain concentration can improve the physical and mechanical characteristics of lateritic gravel [1]. In the Nuimi Hakalang loop construction project the use of salt water is envisaged for general earthworks. The objective of this study is to evaluate the possibility of its use for pavement layers.

2. Study Area

Figure 1: Location of the study area

In Figure 1 the colored traces show the road corridors under construction. The tributaries of the Gambia intersect the tracks at different points. Under the effect of the tides there are more salt tributaries than fresh water tributaries.

The geology is essentially terminal continental. Discordant on the lower terms, it appears in the form of clayey sandstone and red sandy clays, red variegated clays, “Ile-de-vin”, white with a ferruginous armor (laterite) which develops at its summit. It is in fact a formation of marine origin, "continentalized" that is to say altered late after its establishment [1]. The Continental Terminal covers practically the entire sedimentary basin except the North-West zone. Its power, which on average is 130 m, decreases from the southwest (lower Casamance).

Towards the interior of the basin, but especially from the north of Tambacounda towards the northern coast where it no longer exists. [2].

3. Experimental Program

The planned experimental program is consistent with the needs of the study. It essentially consisted of completely characterizing most of the materials available and resulting from the site investigation carried out. After identifying the laterite samples wetted with fresh water and salt water (Pranulometry, Atterberg limits), the soils are compacted and subjected to mechanical tests using Maximun Dry Density (Mdd) These mechanical tests are essentially CBR, Uni axial Compression Test, los angeles, etc.

The samples tested are listed in Table 1:

Table 1: The different samples of the study

Sample No.	type of material	Casting water
Sample 1	Raw laterite	pure water
Sample 2	Raw laterite	salt water
Sample 3	Laterite+cement	pure water
Sample 4	Laterite+cement	salt water
Sample 5	Laterite + sand	pure water
Sample 6	Laterite + sand	salt water

3.1 Chemical analysis of water sources

The 86 km long project is intersected by four major water sources including one fresh water source and three salt water sources. Samples were collected and sent to the central laboratory in Banjul for analysis. The conditioning was done to produce two samples for analysis: a fresh water sample and a salt water sample. The results obtained are summarized in Table 2.

Table 2: Results of chemical analysis of water samples (HOLICA Energy Water Quality Monitoring Laboratory , Banjul)

Date of analysis:			Weather Conditions:- Sunny
Parameter	Sweet Water	Salty Water	WHO Guideline Values
Temperature (^{o}C)	26.3	26.0	**Acceptable**
Turbidity (NTU)	<5	6	**<5**
pH	6.00	6	**6.5 - 8.5**
pH after aeration (A.pH)	6.15	5.8	**6.5 - 8.5**
Electrical Conductivity (□□□/cm)	26.00	1450	**1300**
Total Dissolved Solids (mg/l)	11.10	1101	**1000**
Salinity (promile)	0.0		**NS**
Color	Normal	Nor0	**Absent**
Odor	Normal	Nor0	**Normal**
Taste	Normal	Nor0	**Normal**
Suspended Solids (mg SS/l)	1.0	15	**NS**
Phosphate (mg PO_4^{3-}/l)	0.10	25	**NS**
Nitrate (mg NO_3^--N/l)	1.5	9	**10**
Nitrite (mg N-NO^-_2/l)	0.009	0.02	**0.03**
Total Iron (mg $Fe^{+2/3}$/l)	0.11	0.41	**0.3**
Chloride (mg Cl^-/l)	2.3	657	**250**
Alkalinity (mg $CaCO_3$/l)	26.5	19	**>20**
Free Carbondioxide (mg CO_2/l)	50		**NS**
Hardness (mg $CaCO_3$/l)	18.0	0.2	**200**
Calcium (mg Ca^{+2}/l)	3.9	420	**200**
Magnesium (mg Mg^{+2}/l)	1.9	1300	**150**
Manganese (mg Mn^{+2}/l)	0.0		**0.5**
Fluoride (mg F^-/l)	0.08	25	**1.5**
Sulphate (mg SO_4^{-2}/l)	1.0	270	**250**
Ammonia (mg NH_4^+/l)	0.11		**0.5**
Total Coliform (No./100ml)	Not Tested	Not0	**Nile**
Faecal Coliform (No./100ml)	Not Tested	Not0	**Nile**
Sanitary Survey	Fairly clean		***Clean, dry with good drainage***

The fresh water sample shows salt concentrations below the World Health Organization (WHO) standard values.

The salt water sample shows high concentrations of : $PO_4^{3,}$ $Fe^{+2/3,}$ $Cl^{-,}$ $Ca^{+2,}$ $Mg^{+2,}$ $F^{-,}$ SO_4^{-2}.

These two water samples will be used for molding the material in the laboratory.

3.2 Particle size analysis

This involves classifying the grains according to the dimensions of standardized sieves. To carry out the test, the sample is soaked in water for 24 hours then washed using an 80 µm sieve to eliminate fine particles, then steamed at 105°C for 24 hours so that it can dry then, put in the sieve column whose meshes decrease from 31.5 mm to 0.08 mm.

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The weight of the rejects is compared to the weight of the washed material then we calculate the proportions of the passers; the results obtained give these particle size curves below:

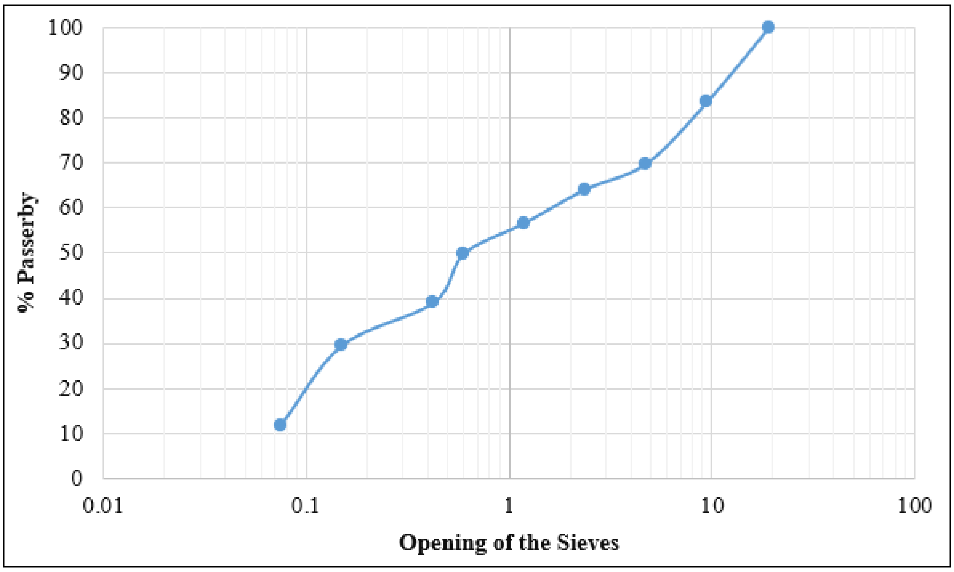

Figure 2: Granulometric analysis of the gravelly laterite from the Bafulato loan

3.3 Atterberg's limits

The Atterberg limits are determined only for the fine elements of the materials (fraction passing through a 0.4 mm sieve), because these are the only elements on which water acts by modifying the consistency of the soil. The test therefore consists of varying the water content of this soil fraction and observing its plasticity [3] [4].

E1, E2, E3, E4, E5, E6 are the materials defined in table 1. The evolution of plasticity is highlighted in figure 3.

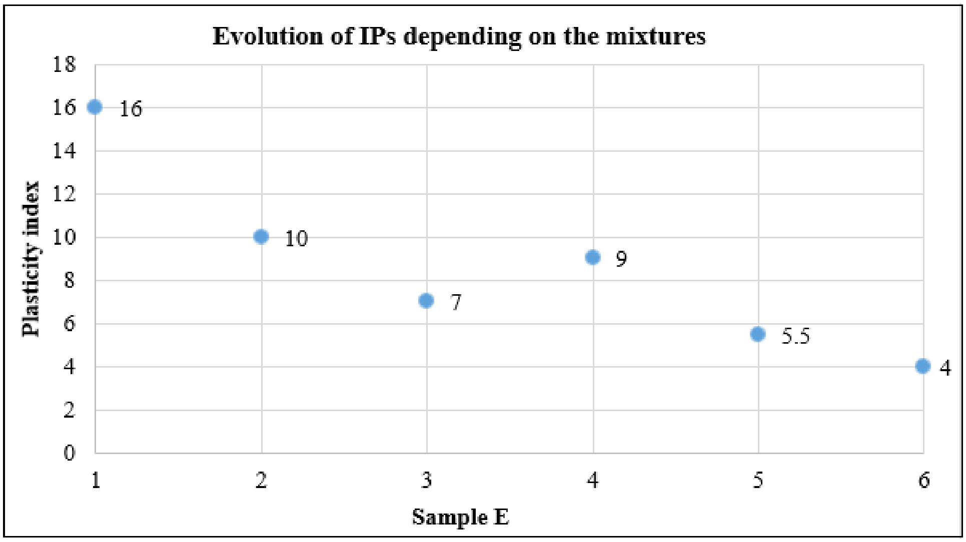

Figure 3: PI values for each mixture

3.4 Mdd test (AASTHO M193)

The aim of the test is to determine the optimal water content for a given material and fixed compaction conditions, which leads to the best possible compaction or maximum load-bearing compactness.

It consists of compacting in a CBR mold, using a modified Proctor ram, according to a well-defined process, the sample of material to be studied and measuring its wet density and its dry density [5].

$$\gamma_h = \frac{m}{V_m} \qquad \text{And} \qquad \gamma_d = \frac{\gamma_h}{1+W}$$

γ_h is the wet density
γ_d the dry density
m the mass of the wetted and compacted sample and W the wetting water content.
We then draw the curve of dry density versus water content called the Proctor curve.

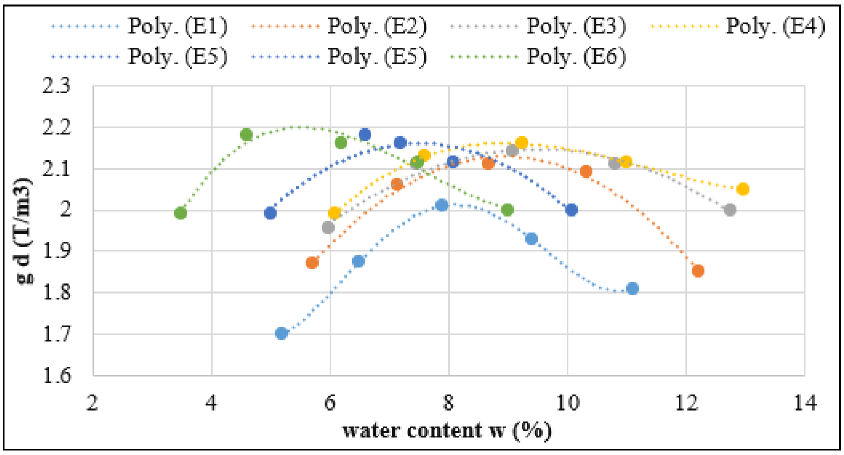

Table 3: Values of γ d and w for each sample

Characteristic	E1	E2	E3	E4	E5	E6
γ d in T/m3	2.01	2.12	2.13	2.15	2.16	2.2
Content in optimal water	8	8.4	8.6	8.5	7.8	5.6

3.5 CBR test

The CBR test is a load-bearing test (ability of materials to support loads) of embankments and compacted layers of road structures. This involves experimentally determining the bearing indices CBR) which allow:

- To establish a soil classification
- Evaluate the trafficability of earth-moving machinery
- Determine the thickness of the pavements (CBR increases ⇒ thickness decreases)

The load brought by the axle on the roadway punches the foundation soil. This phenomenon can be reproduced by compacting the material under the conditions of the Proctor test in a CBR mold then by measuring the forces to be applied to a cylindrical punch to make it penetrate at constant speed into a test piece of this material. We then apply a load close to what the service load will be and we punch the material under determined conditions (constant and determined speed) while measuring the resulting forces (F) and displacements (Δ h): We obtain the test curve [6].

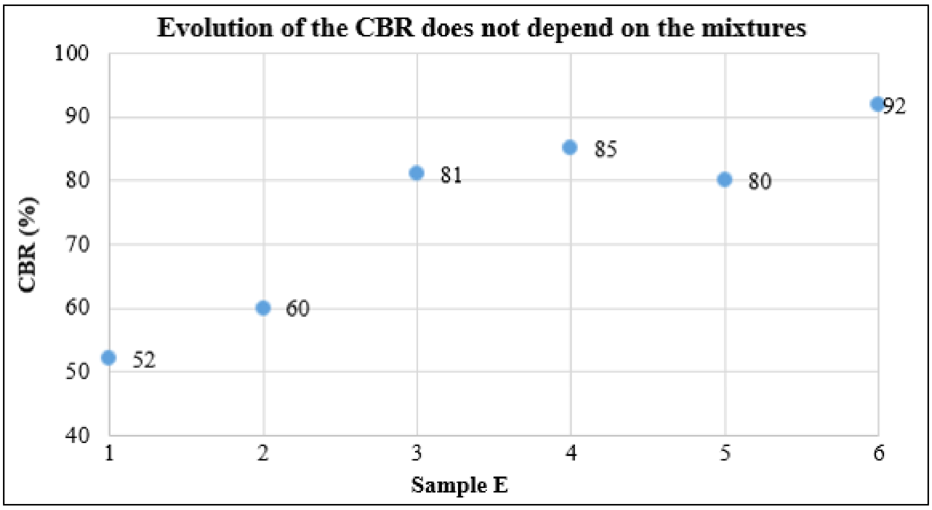

Figure 4: CBR values for each mixture

The uniaxial compression or simple compression test consists of compressing a cylindrical sample between two parallel plates of a rigid press [7]. Tests are generally carried out in batches of 5 samples per homogeneous rock to obtain a good average. During the test, a recorder makes it possible to record the evolution of the axial stress using a force or pressure sensor, as well as that of the deformations either by displacement sensors or by strain gauges. This recording makes it possible to determine different mechanical characteristics according to the need: the resistance to uniaxial compression Rc , the elastic limit Re , the Young's modulus E and the Poisson's ratio ν [8].
The values obtained are recorded in the table below:

Table 4: E-modulus values for each sample

Characteristic	E1	E2	E3	E4	E5	E6
Values of E	400	300	800	600	900	850

4. Results and Discussion

The results obtained are grouped in table 5 below:

Table 5: Summary of study results

Cycles(N)/	E1	E2	E3	E4	E5	E6
$\gamma\delta_{max}$ (T/ ^{m3})	2.01	2.12	2.13	2.15	2.16	2.2
W_l (%)	8	8.4	8.6	8.5	7.8	5.6
I_p (%)	16	10	7	9	5.5	4
95% CBR	52	60	81	85	80	92
E (MPa)	400	300	800	600	900	850

The results show that the optimum Proctor changes vary depending on the type of water used for casting. Samples mixed with salt water have γ_d superior to those which are mixed with fresh water ($\gamma_{d\,E2} > \gamma_{d\,E1}$, $\gamma_{d\,E4} > \gamma_{d\,E3}$, $\gamma_{d\,E6} > \gamma_{d\,E5}$).

Regarding the plasticity indices, their evolution shows that the IPs are inversely proportional to the salt concentration. CBRs have the same behavior as OPMs.

However, in the presence of cement and salt water, the CBR increases with little variation. With the addition of sand in the presence of salt water, we observed a strong increase in the CBR (the CBR varied from 52 to 92%, or 40 points).

Unlike the other parameters the values of E behave differently. We observed that in the presence of salt water, materials lose rigidity.

In view of these observations, it appears clear that:
- The use of salt water increases the performance of the material.
- Salt has more affinity with sand than with cement, hence litho stabilization is proposed and not stabilization with cement.

We suggest the use of salt water for the backfill layers and the foundation layer.

Our reservation for its use in the upper layer comes from two important aspects highlighted by the values of E which decreases in the presence of salt. This leads to brittle behavior of the material under traffic stress [9]. In addition the OPM is obtained in the range 4-6 of optimal water content. This range is low for a base layer in non-arid areas.

5. Conclusion

The Atterberg limits and compaction characteristics of the soil samples were evaluated using both fresh water and salt water. The test results indicate that mixing with salt water significantly enhances the physical and mechanical properties of raw laterite, whether untreated, litho-stabilized, or stabilized with cement. Notably, for sample E6 [10], a reduction in stiffness and brittle behavior was observed within the optimal moisture content range. Based on these results, it is recommended to use salt water up to the foundation layer and to reserve the use of fresh water for the base layer, particularly in non-arid regions.

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