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Research Article

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Studies of the mechanical performance of SH85 and cement-stabilized lateritic aggregates soil

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Abstract The objective of this research is to improve the mechanical characteristics of lateritic soils with calcium silicate (CaSiO3) with the trade name SH-85 as a chemical additive and Portland cement. Laboratory tests have been conducted on natural lateritic gravels (particle size analysis, Atterberg limits, Modified Proctor test and CBR test), but also on SH-85 stabilized lateritic aggregates.

Investigations conducted at the University of Oregon to evaluate the elemental composition of the SH85 stabilizer have confirmed the use of calcium Silicate (CaSiO3), which formula was precisely studied by (Ndiaye et al, 2022). As a chemical additive the percentage of the binder was fixed at 4%.

The results of the tests conducted in Senegal showed that CBR increases by 192% for SH85 enhanced laterite compared to 183% for cement. The compression strength (UCS) gives a value of 2.29 MPa for SH85 treated samples against 2.01 MPa for Portland cement ones. The tensile strength (TS) is 0.29 MPa for SH85 treated samples compared to 0.26 MPa for Portland cement ones.

Keywords stabilized lateritic aggregates, Probase, SH 85, Portland cement

1. Introduction

Senegal, located in the intertropical zone, has several laterite deposits. These laterites have long been the material of reference in road construction and can be gravelly or in continuous or discontinuous blocks (Gning, 2020). The advantage of this material is that it can be mined easily (Fall, 1993). For decades now, we have been witnessing a scarcity of quality laterites due to their excessive exploitation.

(Latifi et al., 2015) conducted a study on tropical laterite soil treated with a calcium powder-based stabilizer (trade name Sh85), which we identified and correlated with Calcium Silicate (CaSiO3). A series of compressive strength tests were carried out to determine the strength of the treated soil. The results of the strength tests showed that the Sh85 stabilized laterite soil was approximately five times stronger than the untreated soil over the seven-day curing period.

At Oregon State University (OSU), it was important to run the same UCS test on samples treated with either cement or calcium silicate under alternating conditions of extreme temperature (heat transferred by a bituminous coating of about 110 degrees Celsius for 24H and relative humidity absorbance by capillary lift at room conditions.

The sections covered by our study comprise a total of 52 kms of rural tracks (Technology of Probase) currently under experimentation (figure 1).

Bambey-Gawane-Thieytou (28 km)
Thiadiaye-Nguénième (17 km)
Poponguine-Ndayane (07 km)

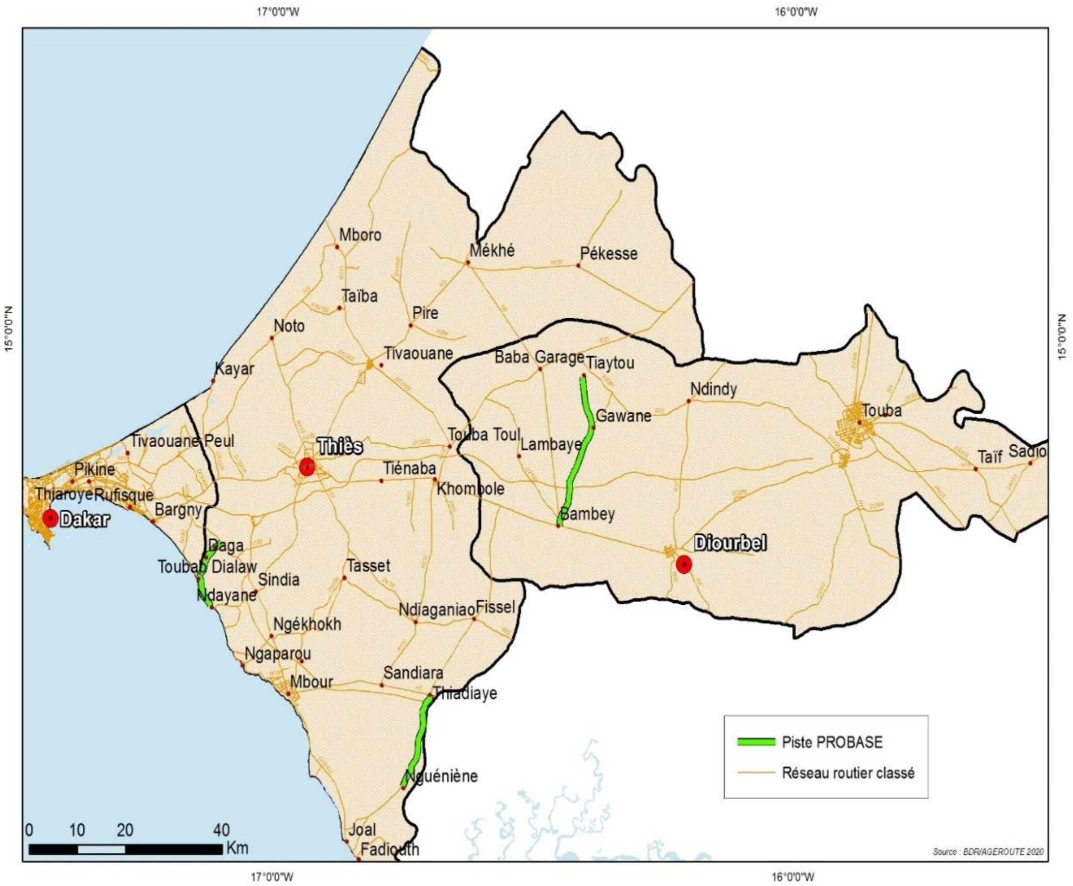

Figure 1: Geographical situation of the various sections Bambey-Gawane-Thieytou, Thiadiaye-Nguénième and Poponguine-Ndayane

Geographic and geological setting

The Ngoundiane quarry (Figure 2) is located in the commune of Ngoundiane, in the Thiès region, 96 km east of Dakar. Its geographical coordinates are approximately 14°42'8"N and 16°44'23"W.

The Ngoundiane lateritic gravel borrow is located in the western part of the Senegal-Mauritania basin. The latter is the largest basin (340,000 km2) on the passive margin of Africa's Atlantic coast. It covers 3/4 of the surface area of Senegal.

The western domain extends west from the 16° 30' W meridian to the slope of the continental slope, as the basement has not yet been reached by drilling. The Meso-Cenozoic sedimentary cover is estimated to be 8,000 m thick in Dakar and 10,000 m thick in Basse Casamance. The oldest known borehole deposits in southern Cape Verde date from the Bathonian to Callovian periods. On the Thiès plateau, the sedimentary series is masked by the fini-Neogene ferruginous cuirass, which extends northwards beneath Quaternary eolian deposits. This cuirass developed on the soils of the Thiès plateau after chemical alteration of the Eocene sediments (Flicoteaux, 1982; Ducasse et al, 1978).

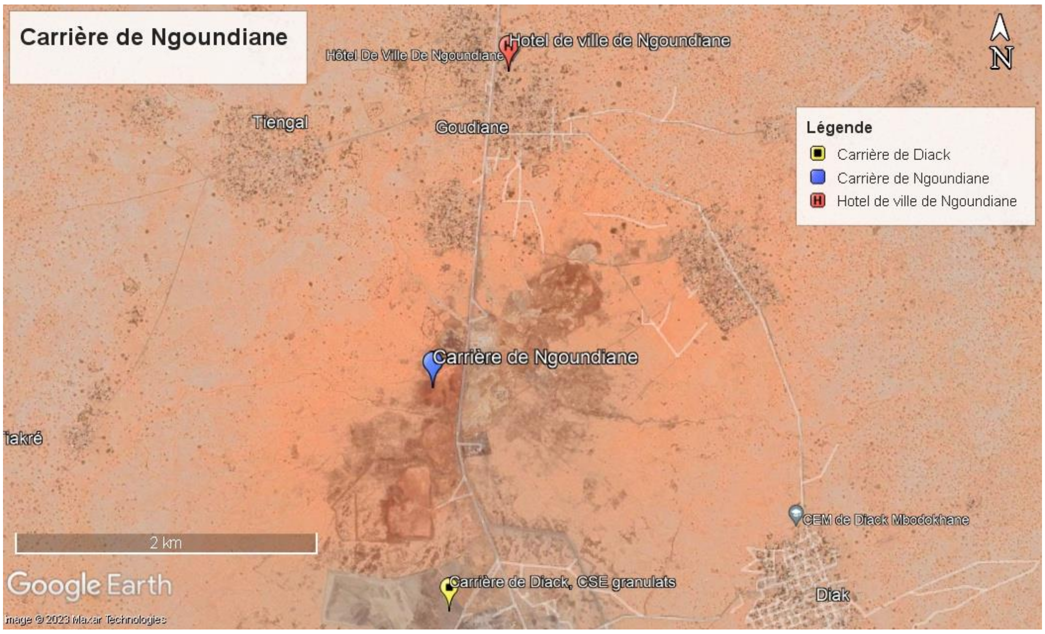

Figure 2: Location of Ngoundiane quarry

2. Materials and Methods

Laterite samples were collected at Ngoudiane and physical and mechanical identification tests were carried out in the raw, cement- and SH85-improved samples.

Physical identification and mechanical tests

The identification tests conducted included: particle size analysis, density measurements, Atterberg limits and the Proctor test in accordance with current standards.

The mechanical tests evaluate CBR, compressive strength and tensile strength. These tests yielded the following results.

3. Results and Discussion

Laboratory tests will be conducted on the particle size distribution of lateritic gravels, their plasticity via Atterberg limits, compaction characteristics and the California Bearing Ratio (ICBR). The results obtained will be shown in Table 1.

Table 1: Physical characteristics of Ngoundiane laterite

Characteristics	**Latérite of Ngoundiane**		**Foundation layer specifications**	**Base layer specifications**
Sieve analysis	% Ø < 0,008 mm	17,33	-	-
	% Ø < 2 mm	30,15	-	-
Limits of Atterberg	W_l (%)	43	< 40	< 35
	I_p (%)	22	< 20	< 15
Modified Proctor	W_{opm} (%)	10,02	-	-
	Rd_{max} (g/cm^3)	2,06	≥ 1,8	≥ 2,1
CBR at 95% of optimum index	23,1		> 30 (GL1) > 60 (GL2 et GLli) > 80 (GLa après amélioration)	
GTR Classification	B6			
USCS Classification	GC			

Studies have shown that granulometric characteristics have a non-negligible influence on the geotechnical properties of lateritic gravels (Odalele et al., 2012; Avwenagha, et al., 2014). However, particle size analysis, conducted in accordance with standard NF P 94-056, enabled us to determine parameters such as the percentage of 80 µm passers which is 17.33% and those of 2 mm 30, 15%. The grading curve for Ngoundiane laterite corresponds to a semi-spread grading soil containing gravel (55.3%) and sand (44.7%).

The limit test was conducted in accordance with standard NF P 94-051 and made it possible to evaluate: the liquidity limit (WL), the plasticity limit (WP) and the plasticity index (IP). These parameters, combined with the granulometric properties, have also contributed to the classification of the soils in the GTR classification systems, giving this laterite the characteristics of class B6. Ngoundiane laterite is plastic, with a liquidity limit of 43 and a plasticity limit of 22, making it unsuitable for use in base layers and foundations. On the other hand, this laterite has good compaction characteristics for use in sub-base courses, with an optimum water content of 10.02% and a dry density of 2.06.

The bearing capacity of Ngoundiane laterite is a low 23.1, making it unsuitable for either sub-base or base courses. Given the inadequate quality of this material, it is important to improve it so that it can be used for base and sub-base. However, cement is the most widely used material for treating these materials. A substitute material such as SH85 could be an alternative to cement for optimal laterite processing. Figure 3 shows the evolution of CBR as a function of cement and SH85.

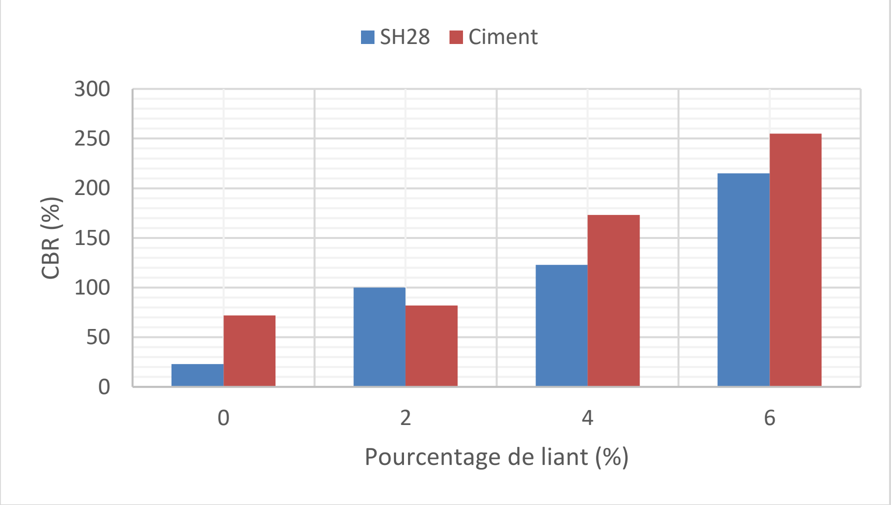

Figure 3: Evolution of the CBR in relation to the percentages of SH85 and cement

Figure 3 shows that the CBR value increases linearly as a function of the HS85 assay and cement. Indeed, the CBR leaves 23 to 215 for percentages of SH85 varying from 0 to 6%, an increase of 192%. For cement there is an increase of 183%. This gives the improvement with the HS85 the best lift. Figures 4 and 5 show the evolution of compression and tensile strength as a function of age of SH85 enhanced laterite.

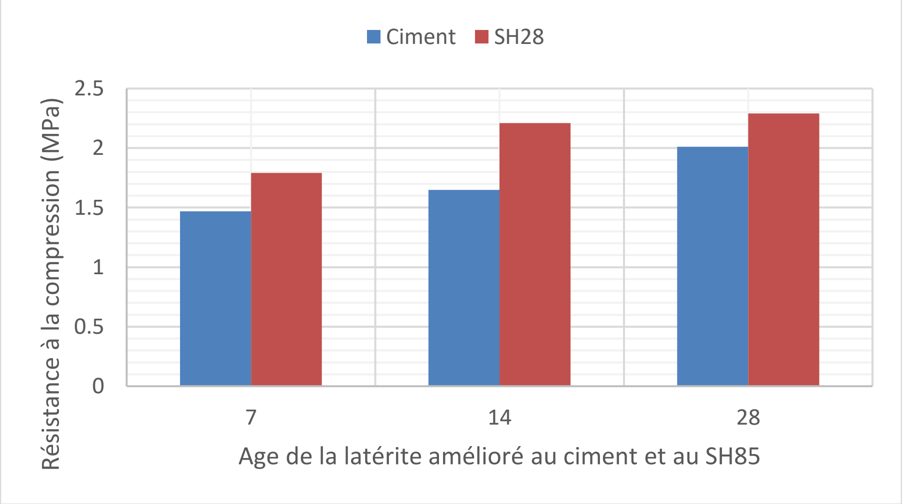

Figure 4: Evolution of compression resistance (UCS) as a function of age

Figure 4 shows an increase in the resistance to regular compression with a more pronounced tendency between 7 and 14 days of treatment and less marked between 14 and 28 days for SH85. Comparatively the cement seems to act more linearly between 7 and 28 with a constant slope. Whereas we note an increasing evolution with SH28 with a considerable increase in tensile strength between 7 and 28 days.

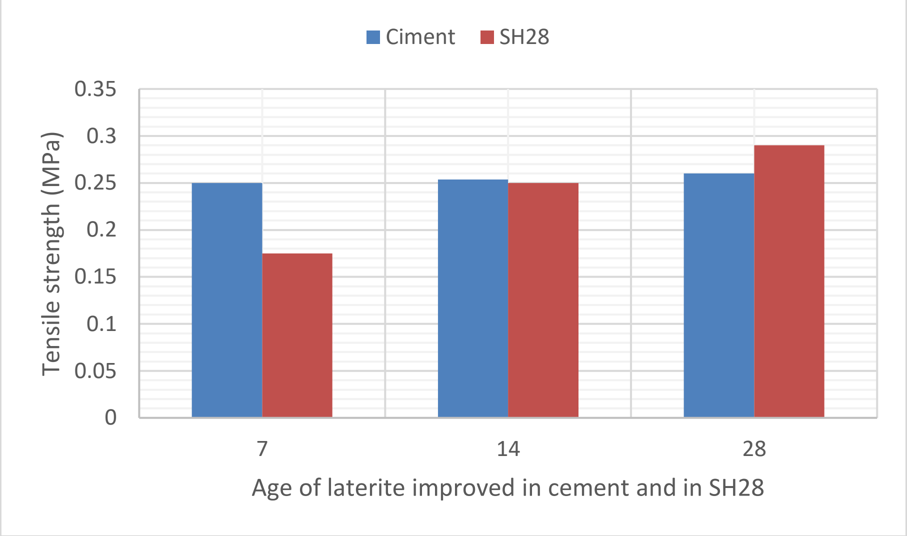

Figure 5: Development of tensile strength as a function of age

At 28 days, the compressive strength of HS85 enhanced laterite is 2.21 MPa higher than the cement value of 2.1 MPa. In traction, the laterite with SH85 gives a value of 0.29 MPa against 0.26 MPa for the cement improved.

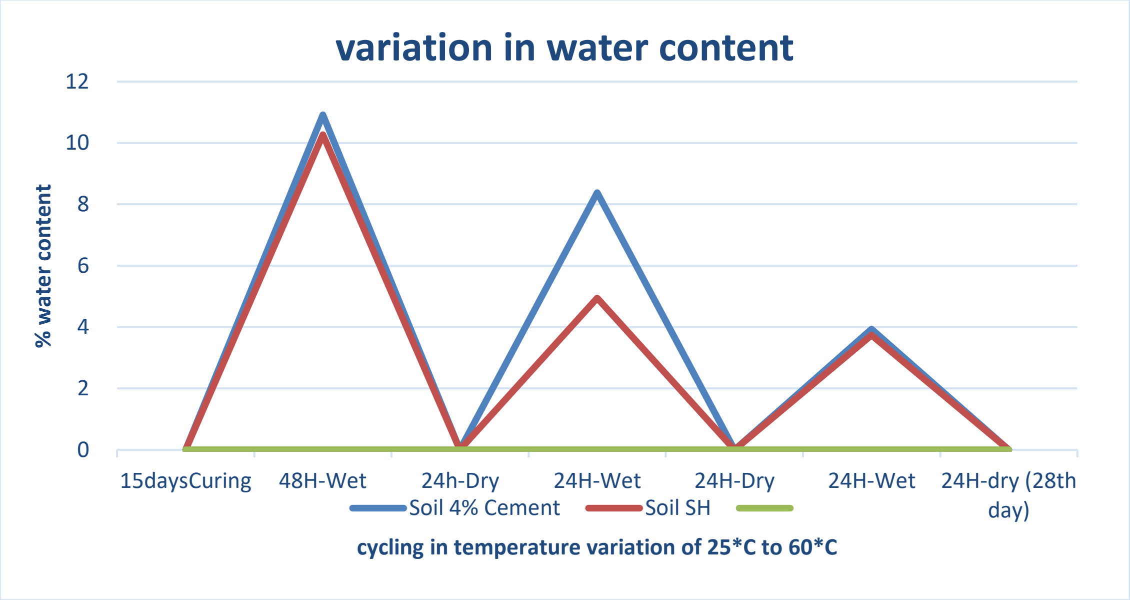

Figure 6: Variation in water content according to cyclic temperature conditions between 15 and 28 days of curing

Alternating temperature between the 25*C humid environment and the 60*C drying oven for 3 cycles showed the tendency of cement-treated laterite samples to absorb more water than calcium silicate-treated samples (Figure 5). But, this does not tell us much about its behavior in the natural environment with 3 to 4 months of precipitation on 12. For this, we examined some samples in conditions alternating extreme heat (110 degrees C) and the coldest temperatures in Senegal (25 degrees C).

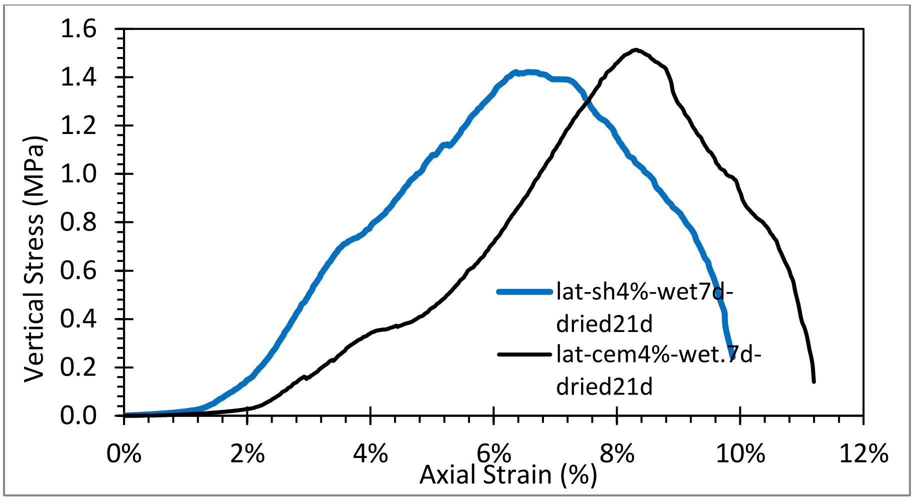

Figure 7: UCS of laterite samples treated at 4% after 28 days of total cure alternating 7 days in wet conditions and 21 days in dry conditions

In the single compressive strength test (UCS), laterite treated with CaSiO3 was found to peak more rapidly with a minimum elongation of about 6% compared to 8.5% for laterite treated with cement, it collapsed well before the cement-treated laterite at about 10% versus 11%.

4. Conclusion

At the end of this study, we can say that figures 3, 4 and 5 show a progressive evolution of the strengths obtained with a progressive dosage of 2 to 6% binders according to the age of the improved laterite.

In the other figures, CBR, compressive strength and tensile strength increase progressively according to whether the laterite is improved with cement or SH85.

However, the compressive strength values obtained on site still do not reflect the reality in the laboratory, especially when the storage conditions of standard specimens are closer to those of their natural environment.

Consequently, it was important to conduct the same test (UCS) on specimens treated with either cement or 4% calcium silicate, alternating extreme temperatures (heat transferred by a bituminous coating of around 110°C for 24 hours) and absorption of relative humidity by capillary action at 25°C for 24 hours.

The cement-treated sample was found to absorb much more water than the calcium silicate-treated sample. This would make it less resistant over time.

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